Project Report

Modelling and Identification of Groundwater Potential Zone and Recharge Sites in the Village Area of Leh District, Ladakh

National Institute of Technology Raipur
(An Institute of National Importance)

G.E. Road, Raipur (Chhattisgarh) - 492010

PREAMBLE

The Leh Nutrition Project (LNP), Leh, Ladakh, sanctioned research project vide letter no. /EYF/2023/07 Dated 29.09.2023 to the National Institute of Technology Raipur for the conduction of a Modelling and Identification of Groundwater Potential Zone and Recharge Sites in the Village Area of Leh District, Ladakh.

Dr. D. C. Jhariya and Dr. Chandan Kumar Singh with their research team carried out a field survey from 08 October 2023 to 21 October 2023 in three villages namely Nang, Muth, Stakmo, and Leh city to collect hydrogeological data. In this survey, 27 electrical resistivity survey data, 101 groundwater level data, and 19 water samples were collected. Detailed data analysis and modelling are undertaken by Dr. Mridu Sahu with her research team.

This interim report is prepared based on a field study in three villages namely Nang, Muth, Stakmo, and Leh City, and is being submitted herewith.

In order to attain the desired objectives of the ongoing research project, there is a strong need to carry out more surveys and data collection of the study area to develop a robust hydrogeological model.

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Certificate

National Institute of Technology Raipur, involved in the conduction of Modelling and Identification of Groundwater Potential Zone and Recharge Sites in the Village Area of Leh District, Ladakh, and preparation of this interim project report.

This work was conducted by Dr. D. C. Jhariya, Associate Professor, Department of Applied Geology, Chandan Kumar Singh, Assistant Professor, Department of Civil Engineering, and Dr. Mridu Sahu, Assistant Professor, Department of Information Technology. The data presented and the interpretations thereof in this report is hereby validated and verified to the best of our knowledge and judgment.

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2024

Modelling and Identification of Groundwater Potential Zone and Recharge Sites in the Village Area of Leh District, Ladakh

Dr. Singh Chandankumar Arvind

CHAPTER –1

INTRODUCTION

1.1 Project description

This project aims to model and identify the groundwater potential and recharge sites in the water scarcity villages of Leh district. With rapid changes in climate and urbanization, many villages in the Leh district are undergoing water shortages, especially in cropping season. The project examined hydrogeological factors in the study sites such as in three villages Nang, Mood, Stakmo and Leh city. This project analyses occurrence, movement, distribution of groundwater in the study sites using geophysical investigation, groundwater monitoring, and groundwater flow modelling. The research will involve a comprehensive field study which includes collection and analysis of groundwater and surface water quality parameters in the study sites. Additionally, the project explores the social and economic conditions in the study that are linked with water scarcity by conducting questionnaire surveys in physical and online mode. Ultimately, the aim of the study is to identify the groundwater potential sites in the study sites which will support to the policy makers, NGOs, and residents to overcome water shortages.

Plain Summary

This project aims to provide safe, sufficient, sustainable water solutions. The project uses popular and advanced scientific techniques that help to achieve the overarching goal of water availability in selected water-scarce villages located in the Union Territory of Ladakh. In long run, this project will be designed to restore spring water and supply sufficient water when needed in the growing/melting season, especially in June and July. At the end of the investigation of this project, the investigators of the National Institute of Technology Raipur, Leh Nutrition Project (LNP) will work with the Ladakhi community to create groundwater potential for domestic and agricultural purpose.

1.2 Background

Ladakh, a union territory in northern India, encompasses a vast expanse of 60,000 square kilometers, divided into two districts: Leh and Kargil. With a population of approximately 3 Lakh. Ladakh's unique topography and remoteness pose significant challenges for confronts distinct challenges concerning water resources attributed to its arid climate and high-altitude terrain. To address the pressing issue of water stress mainly for non-potable use there is an immense scope of using innovative renewable energy-based water harvesting techniques combined with traditional water harvesting techniques of Ladakhi communities.

Leh Nutrition Project (LNP) has been actively involved in water-related initiatives, notably the construction of artificial glaciers and water reservoirs. Recent studies conducted by LNP reveal alarming statistics: 40% of villages in Leh District are facing water scarcity issues, with 12% classified as being at high risk of severe water scarcity. In light of these findings, the LNP and National Institute of Technology Raipur jointly conducted a scientific study focusing on aquifers and hydrogeological analysis in 5 water-scarce villages within Leh District.

Ladakh, situated in the northern part of India, confronts distinct challenges concerning water resources attributed to its arid climate and high-altitude terrain. To address the pressing issue of water stress mainly for non-potable uses, a comprehensive geo-hydrology study is essential. This study is intended to evaluate the water resources of the region and formulate a sustainable water management plan. The primary objective of the proposed study is to furnish essential hydrogeological data and model the movement of water to facilitate well-informed decision-making within this unique context.

1.3 Objectives and scope

The primary **objectives** of this study are as follows:

i Groundwater potential Assessment in 5 villages area

ii Groundwater quality suitability for drinking and irrigation purposes

iii Groundwater recharge zone assessment

iv To identify suitable methods and locations for groundwater recharging

v To identify sustainable solutions to alleviate water scarcity in the study area using combination of field investigation, data collection, hydrogeological modelling, stakeholder survey

Scope of Work

i. Detailed hydrogeological study of the proposed study area.

ii. Geophysical surveys to identify potential borewell locations.

iii. Groundwater quality assessment.

iv. Assessment of groundwater recharging methods and suitable locations.

v. Recommendations for water harvesting measures.

1.4 Study area

Project Locations

The figure 1 shows the location of study area in following five villages within Leh District:

i. Saboo

ii. Leh

iii. Stakmo

iv. Nang

v. Mood

The study sites are located in the district Leh district, Union territory of Ladakh. The study site covers an effective village area of 20 Sq.km approximately. The details of the study area are given in Table 1.1.

Table 1.1: Location details of the project.

S. No.	Particulars	
1.	Name	Modelling and Identification of Groundwater Potential Zone and Recharge Sites in the Village Area of Leh District, Ladakh
2.	Villages	i. Saboo ii. Leh iii. Stakmo iv. Nang V. Mood
5.	District	Leh
6.	Union Territory	Ladakh
7.	Location coordinate	Latitudes 33.193 to 34.210 Longitude 78.701 to 77.606
8.	Area (Approximately)	20.00 Sq. Km
9.	Maximum Elevation (Mined area)	4591 m from MSL
10.	Minimum Elevation (Mined area)	3514 m from MSL
12.	Nearest town	Khardungla at about 71 Km
13.	Nearest City	Kargil
14.	District head quarters	Leh
15	State capital	Leh
16	Nearest Airport	Kushok Bakula Rimpochee Airport, Leh
18	Major River (If any)	Indus Shyok Nubra
19	Other water bodies (Small Drainage/ Lake/Nalla etc.)	Panamic Lake

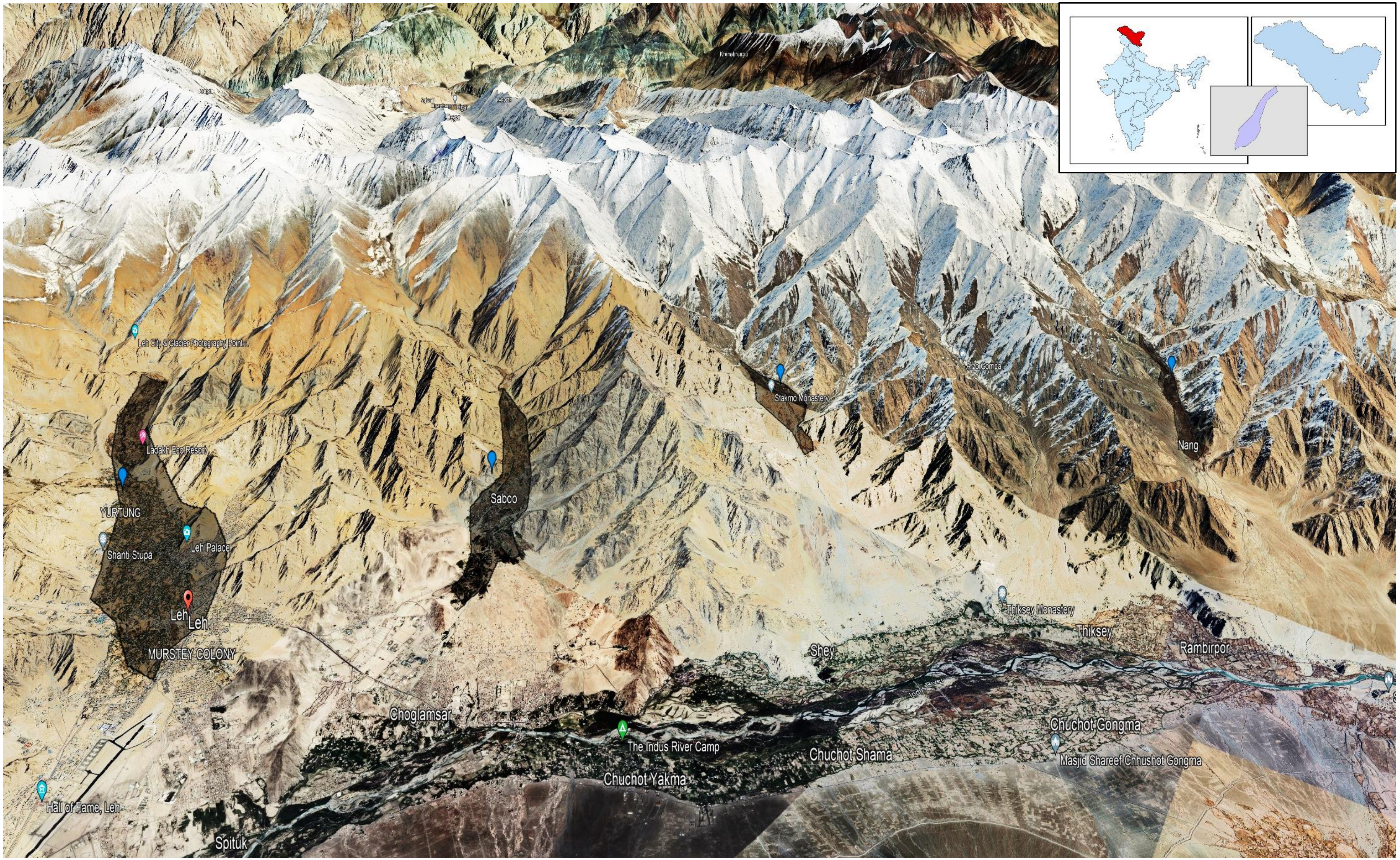

Fig 1: Location map of the study area

1.5 Climate

The climate of the study area experiences a cold desert weather due to very high-altitude ranges between 3514 m and 45921 m above sea level. Summers are from April to July with temperature ranging from 15 °C to 30 °C, winters from October to March with temperature may fall to -20°C (Fig.1.2, 1.3). Monsoons are from July to September with very low Rainfall about 35 mm approximately. The average amount of annual precipitation is 439 mm (Fig 1.4). Leh has dry periods in October, November and December.

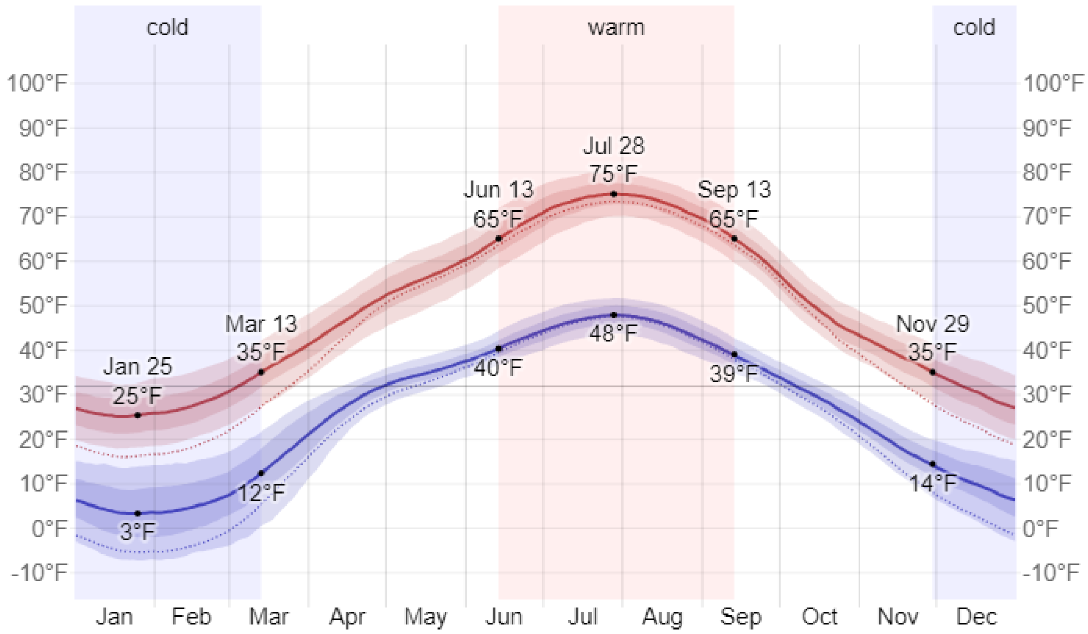

Fig 1.2: The daily average high (red line) and low (blue line) temperature. (Source: https://weatherspark.com/)

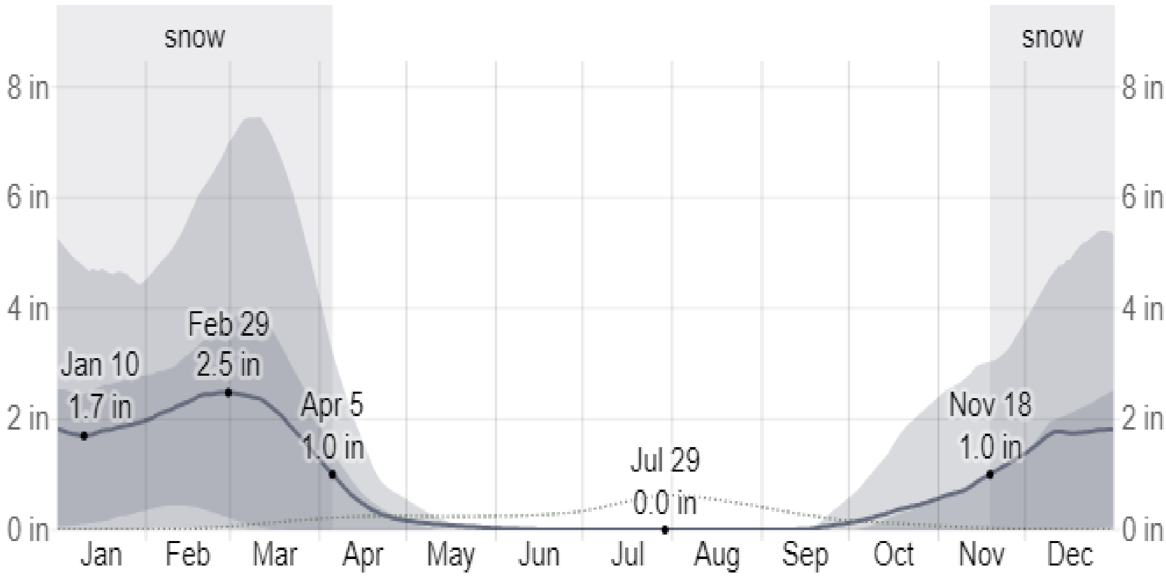

Fig 1.3: The average snowfall (solid line). The thin dotted line is the corresponding average rainfall. (Source: https://weatherspark.com/)

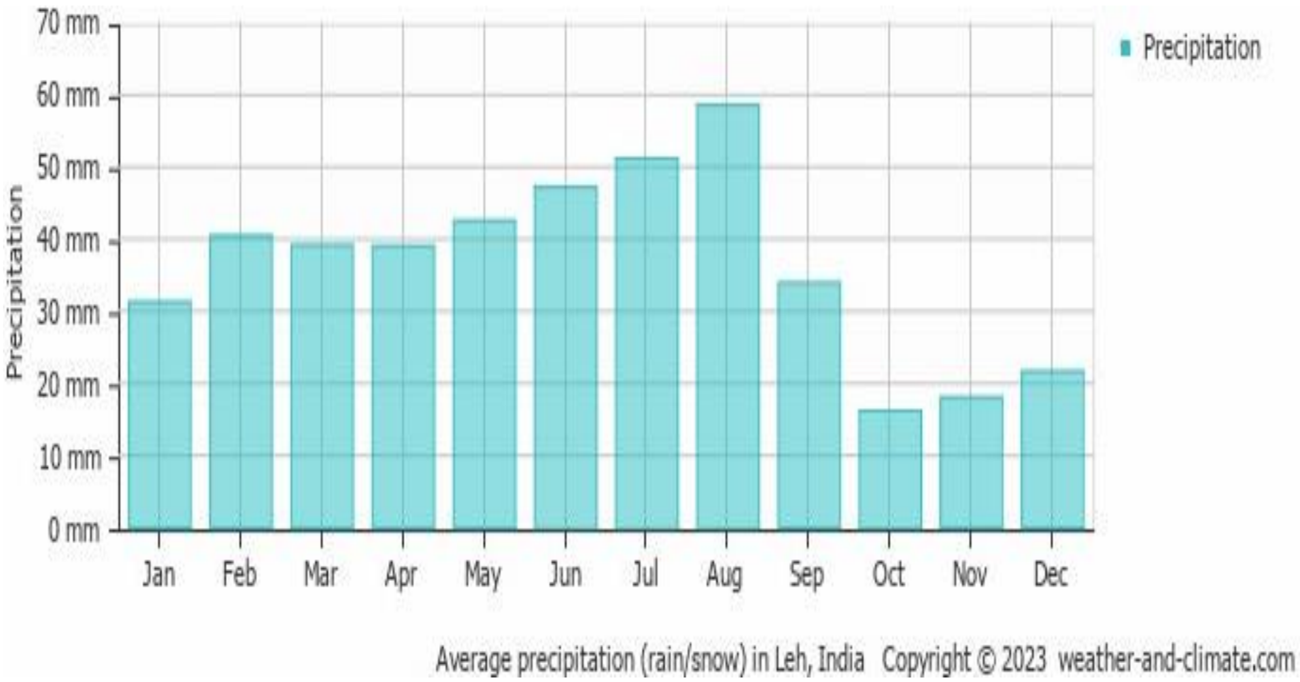

Fig.1.4: Average precipitation of the study area

CHAPTER –2

ELECTRICAL RESISTIVITY SURVEY

2.0 Electrical Resistivity Survey

Geoelectric imaging is one of the most versatile and successful technologies for groundwater prospecting, mineral prospecting, ground resistance measurements, geological mapping, bedrock studies, and civil engineering applications. Electrical imaging is a popular method because of its low cost, simple operation, and efficient ability to distinguish between weathered overburden and compact bedrock by resistivity contrast. Electrical resistivity surveying methods have been widely used to determine layered mediums' thickness and resistivity for groundwater and mineral exploration. Traditionally, vertical electrical

Plain Summary

The electrical resistivity method is an imaging technique which is like X-ray/CT scan. The X-Ray/CT scan examines the parts of the body such as bones, muscles, organs etc. Similarly, electrical resistivity examines the soil and rocks below the ground surface at high depth. It helps you to know where and how much extra water to store below the ground surface. Ultimately, it helps the Ladakhi community to store extra water and use it when needed for agricultural and domestic purpose.

soundings are applied to a horizontally or near to a horizontally layered surface on earth to interpret subsurface geological formation interns of resistivity values such as sedimentary rocks of different lithologies, layered aquifers of different properties, sedimentary rocks overlying igneous, or weathering zone of igneous rocks.

The electrical resistivity method is a useful geophysical tool widely used for groundwater exploration (Olayinka, 1991; Ndlovu et al., 2010; Metwaly et al., 2009). It provides information about the near-surface structures. The Electrical Resistivity method provides reliable information about the subsurface layers. Electrical Profiling (PR) can also be used to determine the aquifer depth, aquifer geometry hydraulic conductivity, the water quality of the aquifer rock, and geological stratigraphy are reported by researchers (Chandra et al., 2008).

In this study, an attempt has been made to infer river bed thickness and subsurface lithology using the GD-10 Multi-Electrode Resistivity.

2.1. Details of Instrumentation and surveying Method

GD-10 is developed based on the latest digital and analogue circuitry technique, making it the world-leading multi-functional direct current (DC) method instrument. GD-10 Multi-Electrode Resistivity Imaging System can conduct 2D/3D cross-section profiling of subsurface lithology. We can predefine survey parameters before field surveys through the array script management in Geomative Studio. GD-10 is equipped with centralized cabling and a distributed cabling system to fulfil any complex field environment (Fig 1).

Fig. 2.1: GD-10-multi-electrode resistivity imaging system.

GD-10 generates a well-regulated current (I) to measure the resulting voltage ΔV between the two potential electrodes. It then calculates the apparent resistivity $R = \Delta V/I$ for the given spacing configuration. The resistivity obtained is the weighted average of all the formations resistivity through which the current is passing. Apparent resistivity is expressed in Ohmmeter(Ω-m). The analysis of apparent resistivity variations as a function of current electrodes' spacing makes it possible to conclude subsurface geological conditions.

In this study handheld GPS (Garmin Make) to take survey location points and altitude.

CHAPTER –3

INVESTIGATION AT NANG VILLAGE

3.0 Nang Village

Nang village mainly comprises granitic rocks which are overlain by unconsolidated sediments. It is observed that the thickness of unconsolidated is increasing towards the southwest. As per the availability of space four numbers of resistivity imaging were carried out in the Nang village (Fig. 2, Fig 2-7; Table 1) and it is found that the thickness of unconsolidated sediments more towards the downstream side.

Plain Summary

This chapter describes the results of electrical resistivity survey similar to the report generated after X-Ray/CT scan. For example, a patient with a foot injury undergoing an X-Ray may find out that the fracture is minor or major in nature and helps to know the severity of injury. So, the chapters from 3 to 6 discuss about cracks in rocks, the depth of rocks that supports to storing water. Ultimately, it helps to know a suitable place inside a village for storing extra glacier water.

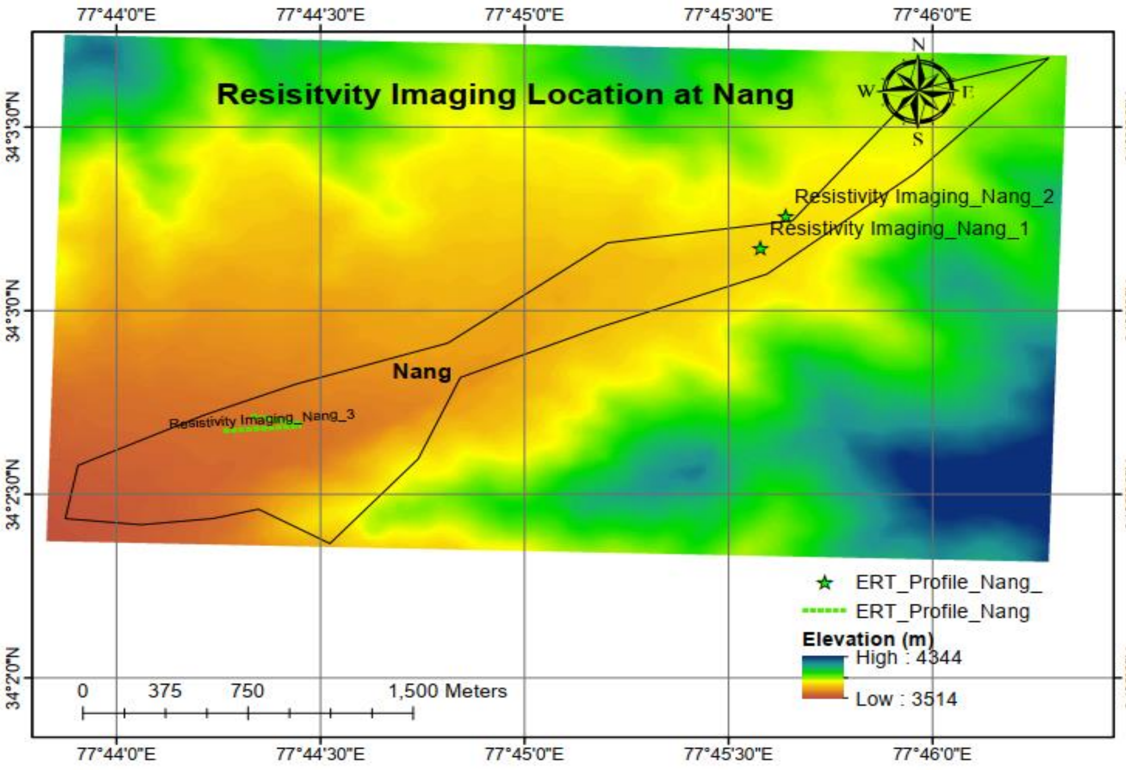

Fig. 3.1 Resistivity Imaging Locations at Nang Village

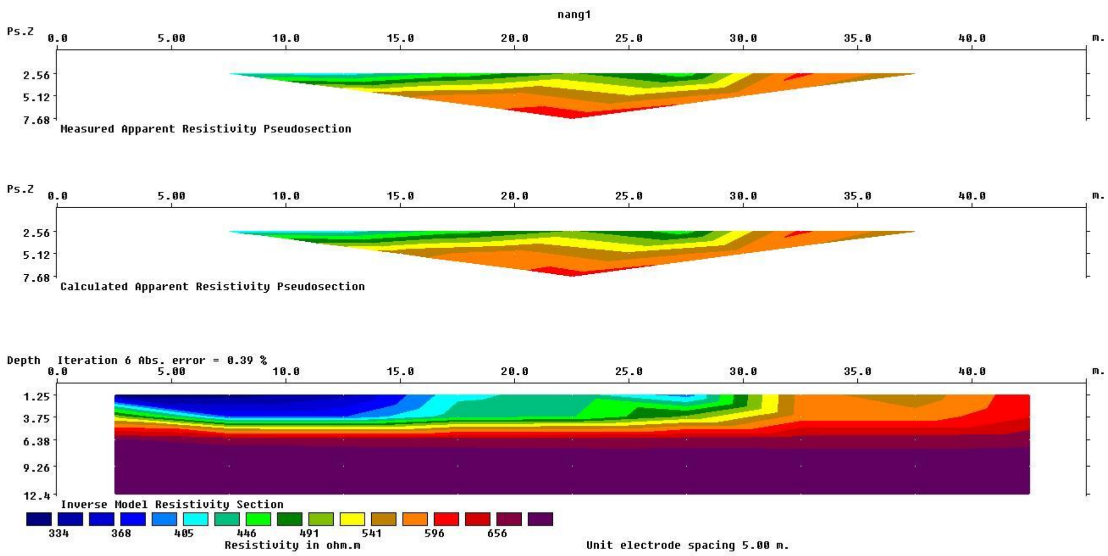

Fig. 3.2. Resistivity Imaging -1

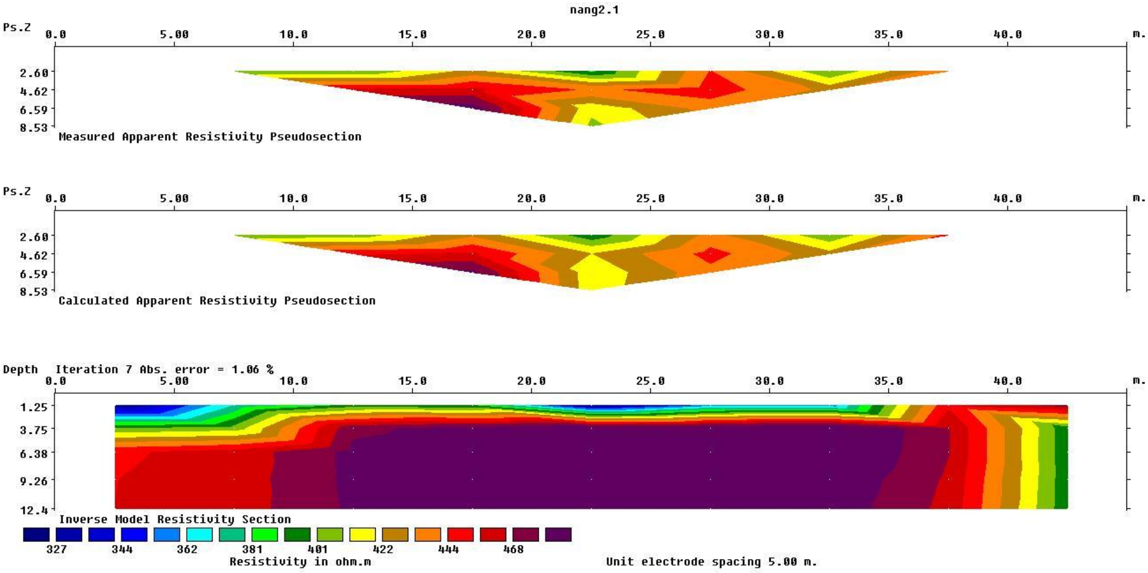

Fig. 3.3. Resistivity Imaging -2

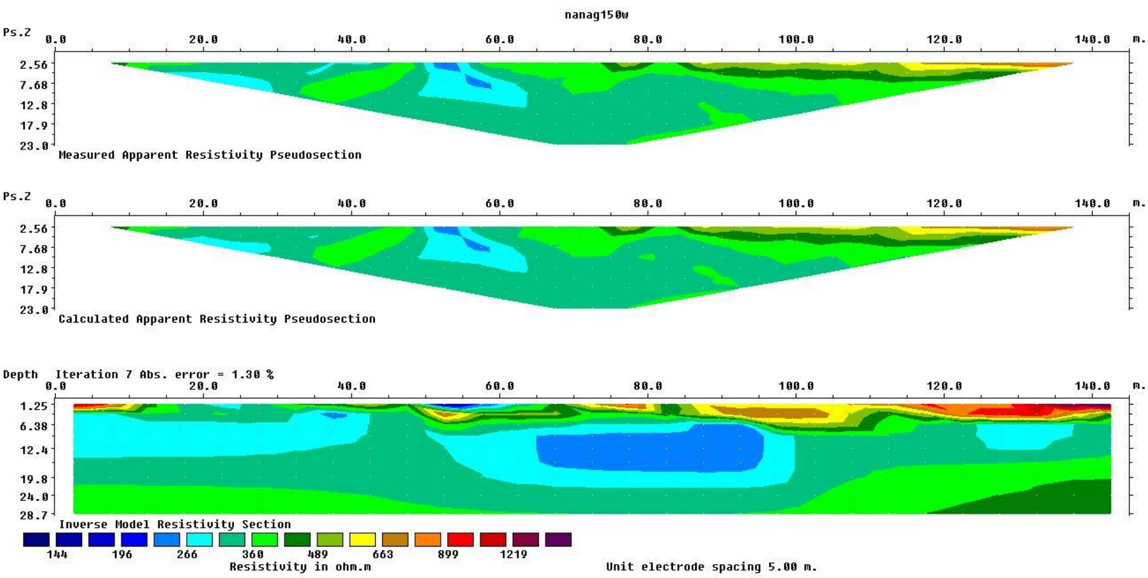

Fig. 3.4. Resistivity Imaging -3

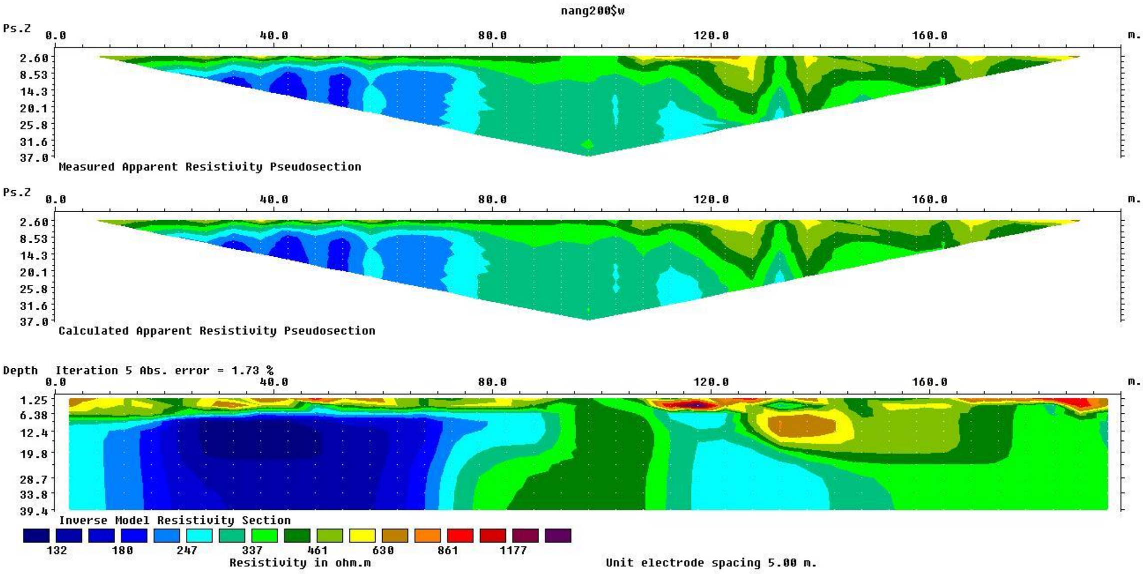

Fig. 3.5. Resistivity Imaging -4

Fig.3.6 Electrical Resistivity Survey in the Nang Village.

Table 3.1. Sounding details VES-1 to VES-**6**

VES No.	Site location	Survey Point Location (Host)		Survey Point Location (End)		Elevation		Direction
		Lat	Long	Lat	Long	Host	End	
1.	NANG	34.052842	77.759671	34.220833	77.740000	3773	3773	307NW
2.	NANG	34.054324	77.760676	34.2313889	77.820000	3795	3795	310NW
3.	NANG	34.2238889	77.85972	34.2208333	77.7433333	3633	3627	83E
4.	NANG	34.2258333	77.74611	34.2313889	77.8250000	3636	3635	91E

3.1 Groundwater Level Monitoring in Nang Village

We have collected groundwater level data from thirteen locations, and it is found that the groundwater level of Nang village ranges from 8.96 bglm to 37.20 mbgl (Table 2; Fig. 8). Groundwater of the study area flowing towards the southwest direction (Fig. 9)

Table 3.2: Groundwater Level of Different Locations

S No.	Symbol	Station	Waypoint	Elevation (m)	Water Level (mbgl)	parapet (m)	Latitude	Longitude
1	BW1	NANG1	920	3799	8.96	0.39	34.055039	77.761266
2	BW2	NANG2	853	3655	37.2	0.48	34.0468	77.73638
3	BW3	NANG3	854	3756	22.2	0.6	34.05232	77.7522
4	BW4	NANG4	856	3691	17.5	0.3	34.04908	77.74708
5	BW5	NANG5	857	3673	28.72	0.51	34.04707	77.7426
6	BW6	NANG6	858	3649	12.89	0.31	34.04568	77.73975
7	BW7	NANG7	859	3612	26.3	0.31	34.0452	77.73392
8	BW8	NANG8	860	3617	29.27	0.47	34.04456	77.73285
9	BW9	NANG9	863	3753	20.3	0.36	34.04224	77.72953
10	BW10	NANG10	864	3556	11.9	0.47	34.04107	77.72921
11	BW11	NANG11	865	3568	13.77	0.46	34.03855	77.72927
12	BW12	NANG12	866	3580	22.66	0.27	34.03974	77.73344
13	BW13	NANG13	867	3602	34	0.58	34.03973	77.7353

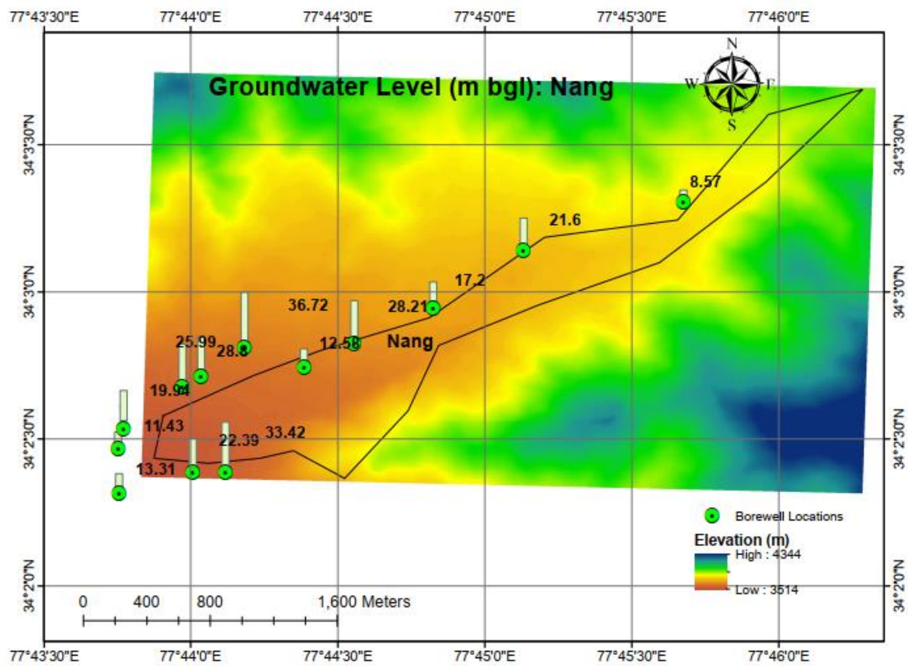

Fig. 3.7. Water level map.

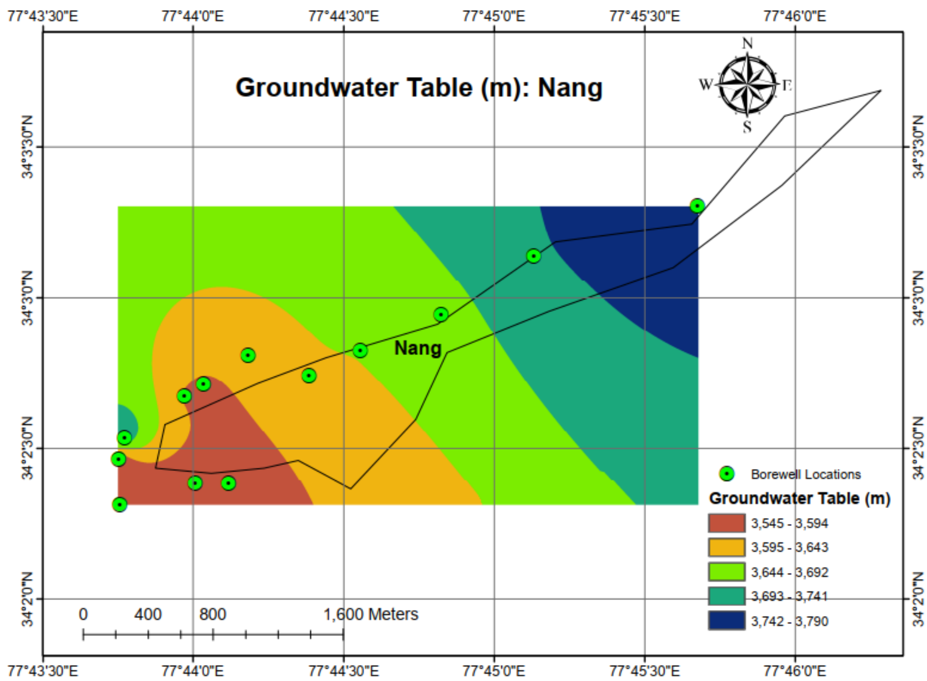

Fig. 3.8. Water Table map.

3.2: Groundwater quality monitoring in Nang Village

Table 3.3: Groundwater Quality of Different Locations

S NO.	VILL.	STATION	TYPE	WAYP	ELEV	LAT	LONG	PH	TEMP ^0C	TDS (PPM)
1	NANG	C1	Canal	918	3809	34.054474	77.760667	8.5	8	80
2	NANG	B1	Borewell	920	3799	34.055039	77.761266	4.5	7.3	220
3	NANG	B2	Borewell	853	3655	34.0468	77.73638	5	12.2	190
4	NANG	B3	Borewell	868	3643	34.04627	77.73806	4.49	9.6	240

Three groundwater and one surface water sample for water quality analysis were collected. Some parameters like TDS, pH and Temperature were measured in the field (Table 3).

CHAPTER –4

INVESTIGATION AT MOOD VILLAGE

4.0 Mood Village

Mood village mainly comprises unconsolidated sediments and the basement rock is granite. Resistivity imaging was carried out in three sites across the drainage to understand the function of check dem (Fig 10, Fig 11 and Fig 12, Fig. 13; Fig. 14, Table 4).

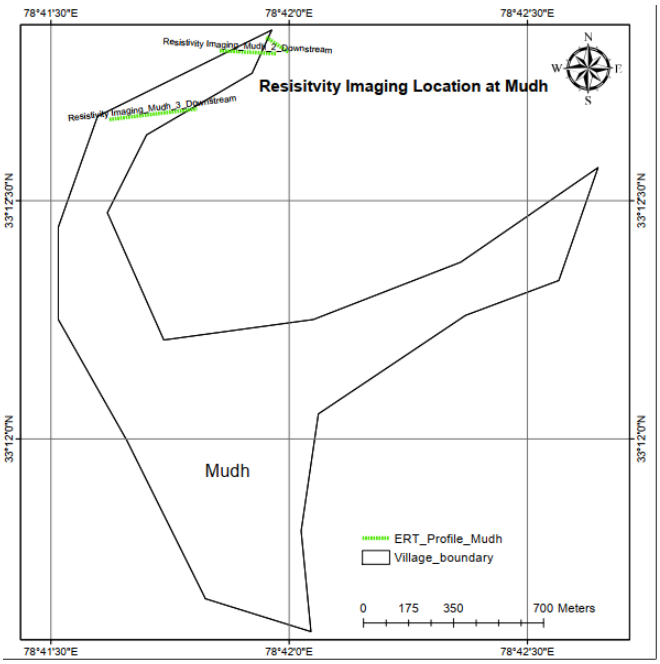

Fig. 4.1. Resistivity Imaging Locations at Muth Village.

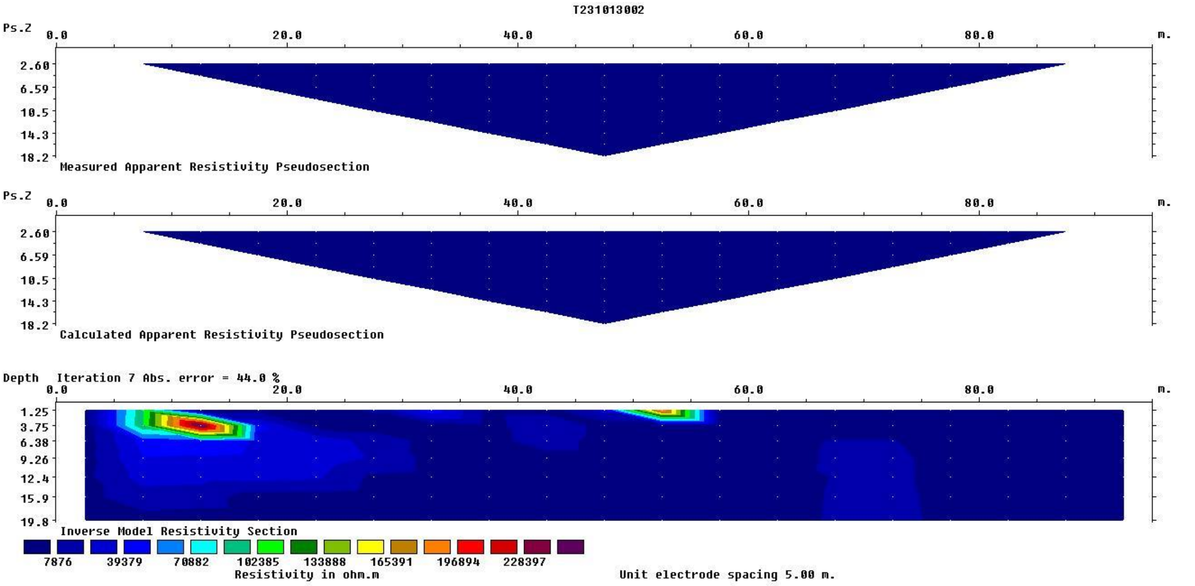

Fig. 4.2. Resistivity Imaging at Upstream

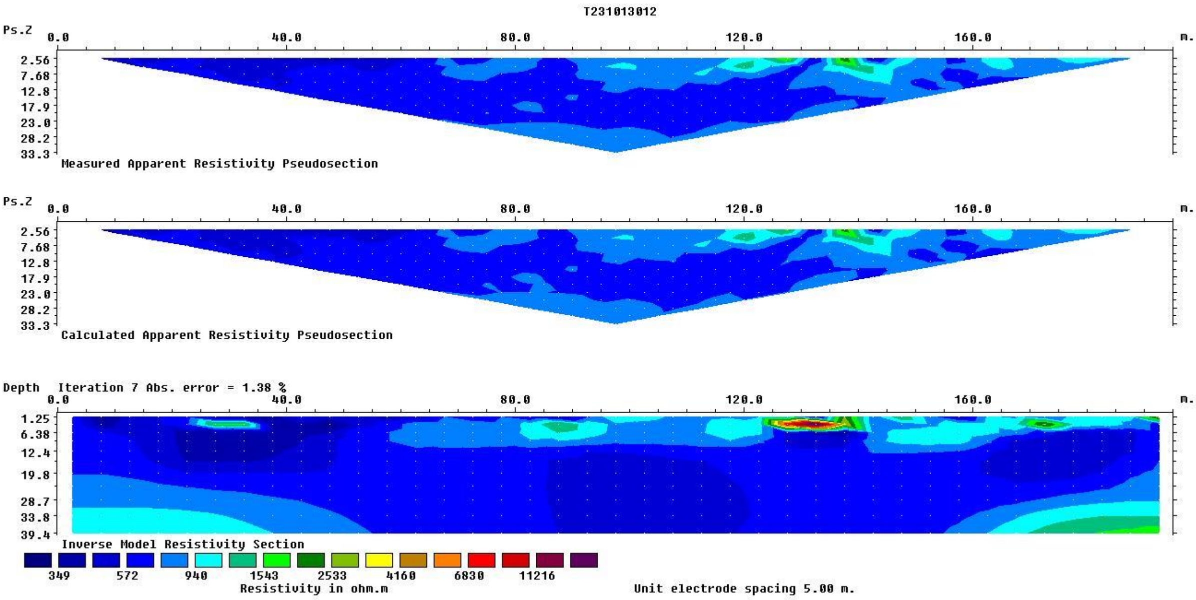

Fig. 4.3. Resistivity Imaging at downstream.

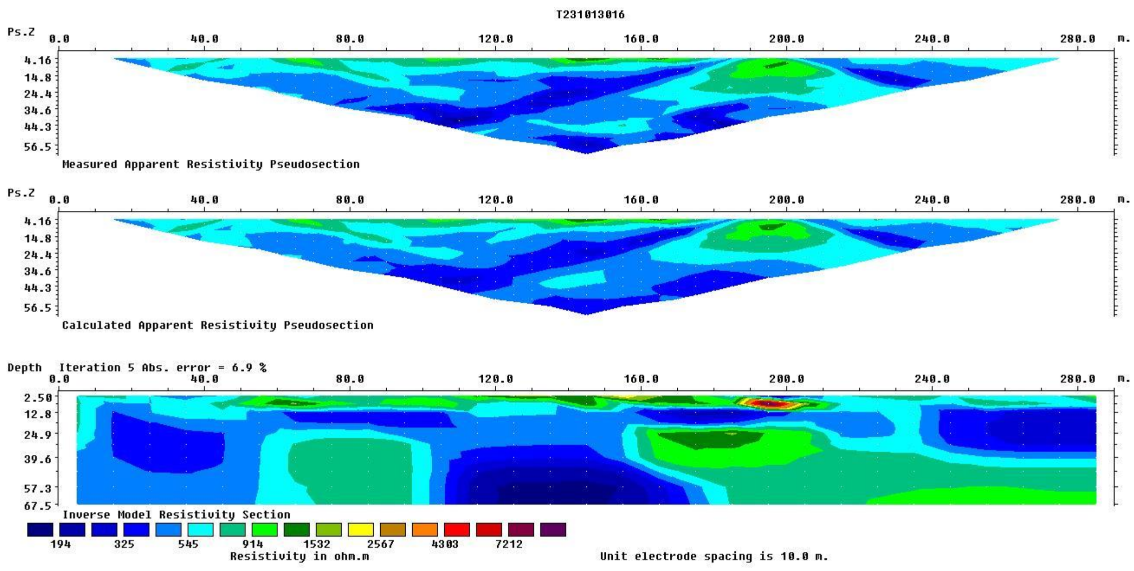

Fig. 4.4. Resistivity Imaging at downstream.

It is found that there is the occurrence of more than 15 meters thick unconsolidated sediments in upstream of the check dam which allows groundwater base flow. The thickness of unconsolidated sediments is more than 50 meters on the downstream side. It is observed that the thickness of unconsolidated is increasing towards the south.

Fig. 4.5. Electrical Resistivity Survey in the Muth Village.

In this study, 03 numbers of Vertical Electrical Sounding (VES) have been carried out at suitable places in the study area. Sounding location details are given in Table 4.

Table 4.1 Sounding Location details

VES No.	Site	Survey Point Location	Survey Point Location (End)	Elevation	Direction

	location	(Host)						
		Lat	Long	Lat	Long	Host	End	
1	MUTH	33.213526	78.699972	33.21405	78.699202	4353	4350	304NW
2	MUTH	33.213481	78.699544	33.213586	78.697537	4358	4349	259W
3	MUTH	33.211547	78.696768	33.211177	78.693696	4322	4305	66NE

4.1. Groundwater Level Monitoring in Muth Village

Groundwater level data from six locations were collected, and it is found that groundwater level of Muth village ranging from 10.20 mbgl to 30.11 mbgl (Fig 15). The groundwater flow of the study area is towards the south as per the water table study (Fig 16)

Table 4.2: Groundwater Level of Different Locations

S No.	Symbol	Station	Waypoint	Elevation (m)	Water Level (mbgl)	parapet (m)	Latitude	Longitude
1	BW14	MUTH1	873	4238	30.71	0.6	33.20008	78.6953
2	BW15	MUTH2	874	4214	10.84	0.64	33.19871	78.6961
3	BW16	MUTH3	875	4193	17.3	0.53	33.1954	78.69827
4	BW17	MUTH4	876	4167	16	0.5	33.19033	78.7033
5	BW18	MUTH5	877	4194	26.63	0.63	33.1939	78.69798
6	BW19	MUTH6	878	4233	20.63	0.68	33.20232	78.69688

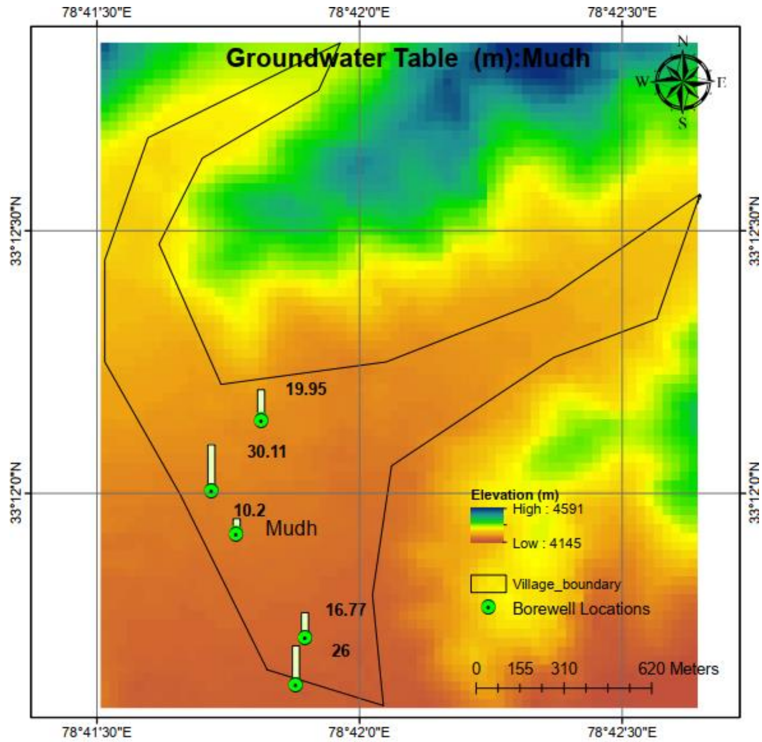

Fig. 4.6. Water level map.

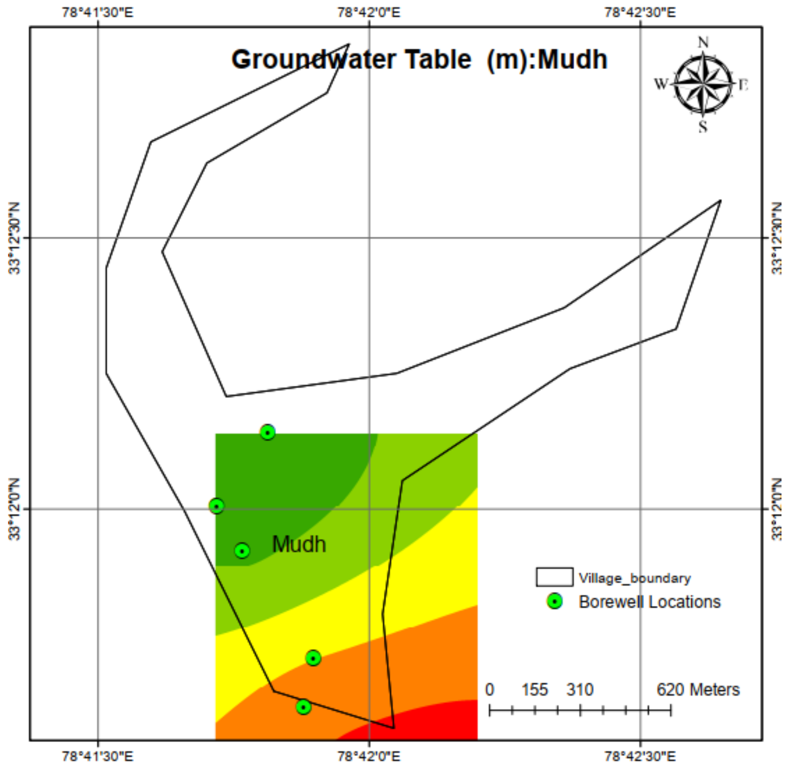

Fig. 4.7. Water table map.

4.2: Groundwater Quality Monitoring in Mood Village

Two groundwater and one surface water sample for water quality analysis were collected. Some parameters like TDS, pH, and temperature were measured in the field (Table 6).

Table 4.3: Groundwater Quality of Different Locations

S NO.	VILL.	STATION	TYPE	WAYP	ELEV	LAT	LONG	PH	TEMP ^{0}C	TDS (PPM)
1	MUTH	R1	Stream	870	4347	33.21341	78.69888	5.15	5.3	30
2	MUTH	B4	Borewell	873	4238	33.20008	78.6953	5.3	9.4	60
3	MUTH	B5	Borewell	876	4167	33.19033	78.7033	5.23	10.2	40

CHAPTER –5

INVESTIGATION AT STAKMO VILLAGE

5.0 Stakmo Village

Stakmo village comprises granitic rocks which are overlain by unconsolidated sediments. It is observed that the thickness of unconsolidated is increasing towards the southwest. As per the availability of space four numbers of resistivity imaging were carried out in the Stakmo village (Fig. 17-22, Table 7).

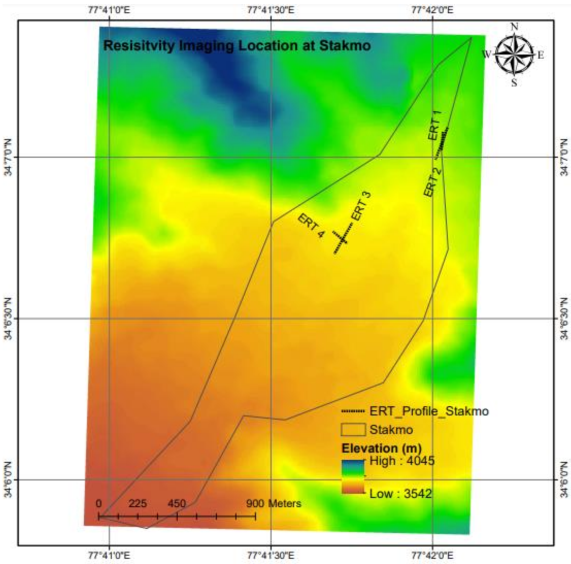

Fig. 17. Resistivity Imaging Locations at Stakmo Village.

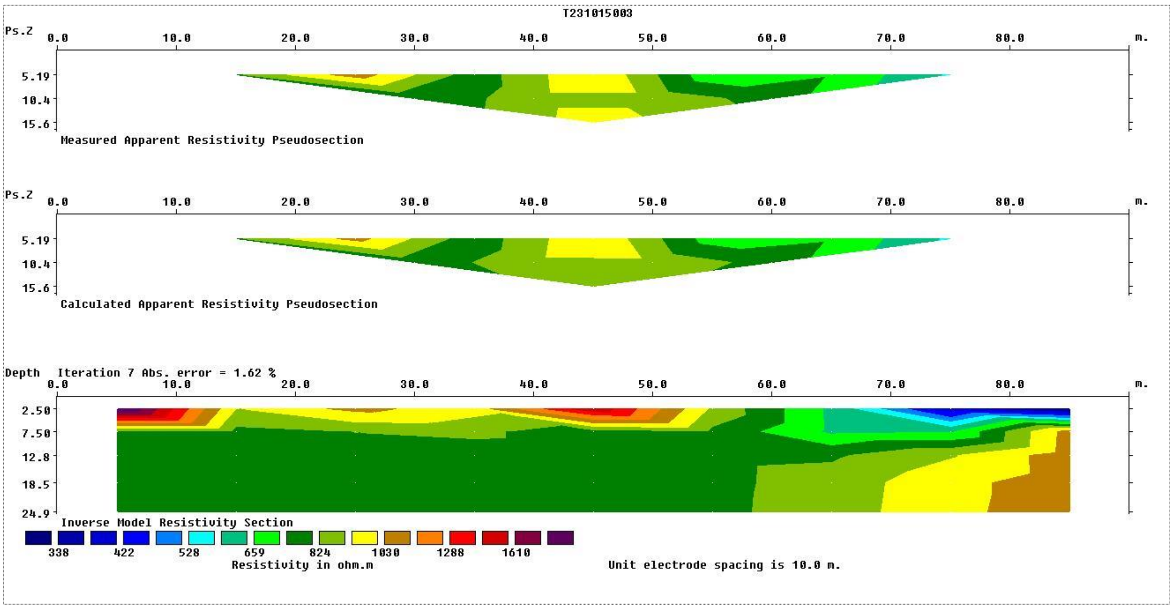

Fig. 18. Resistivity Imaging-1 at Zing

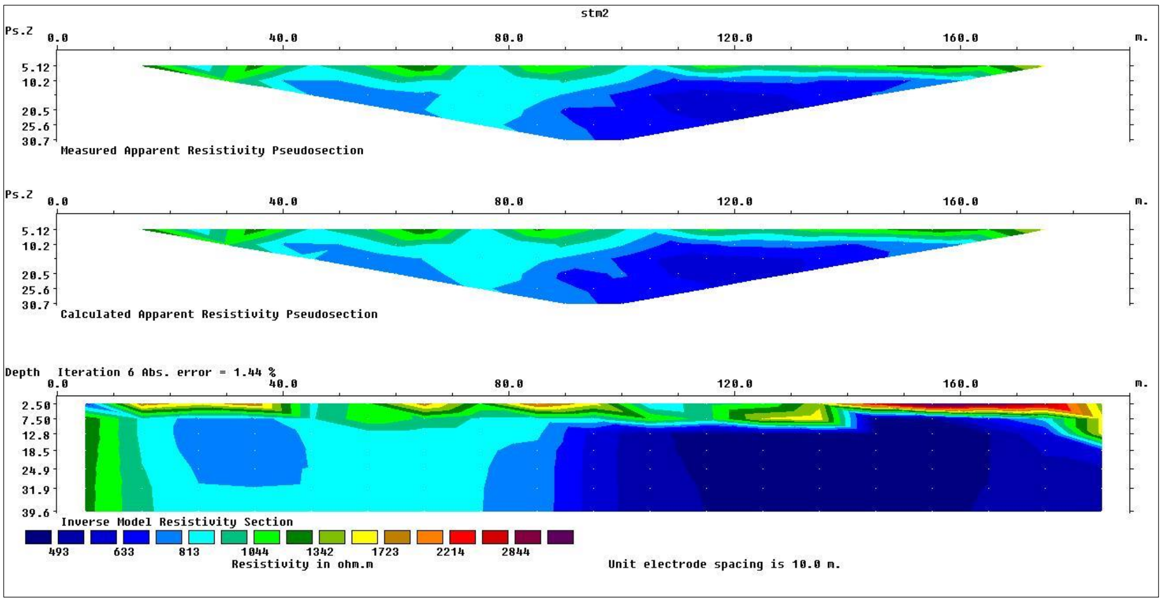

Fig. 19. Resistivity Imaging-2 at Road

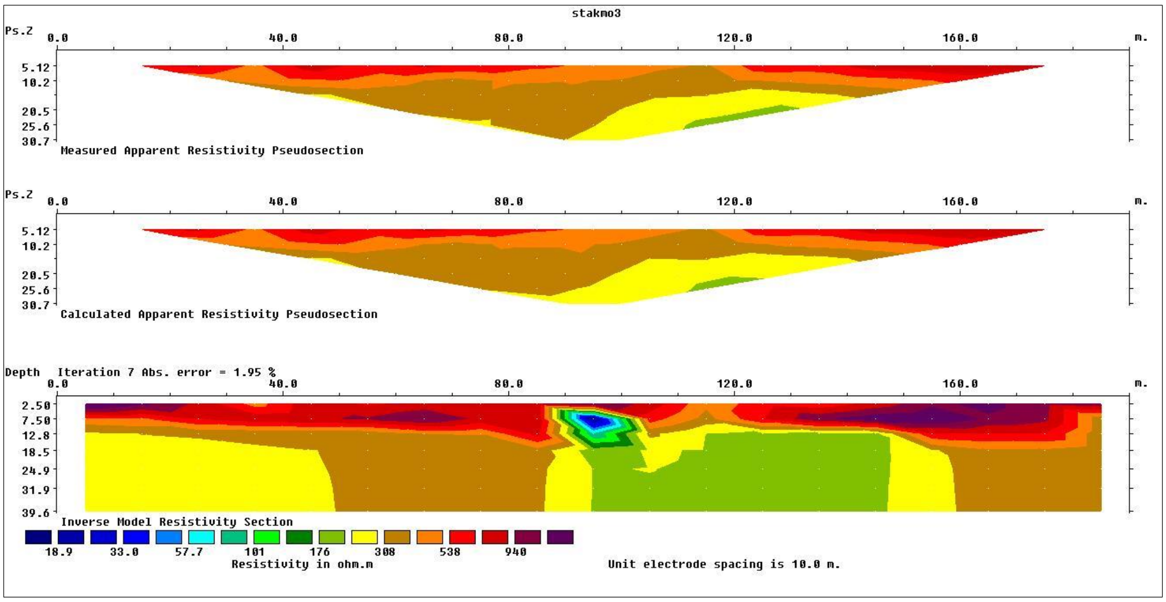

Fig. 20. Resistivity Imaging-3 at Gampa Temple (200 m)

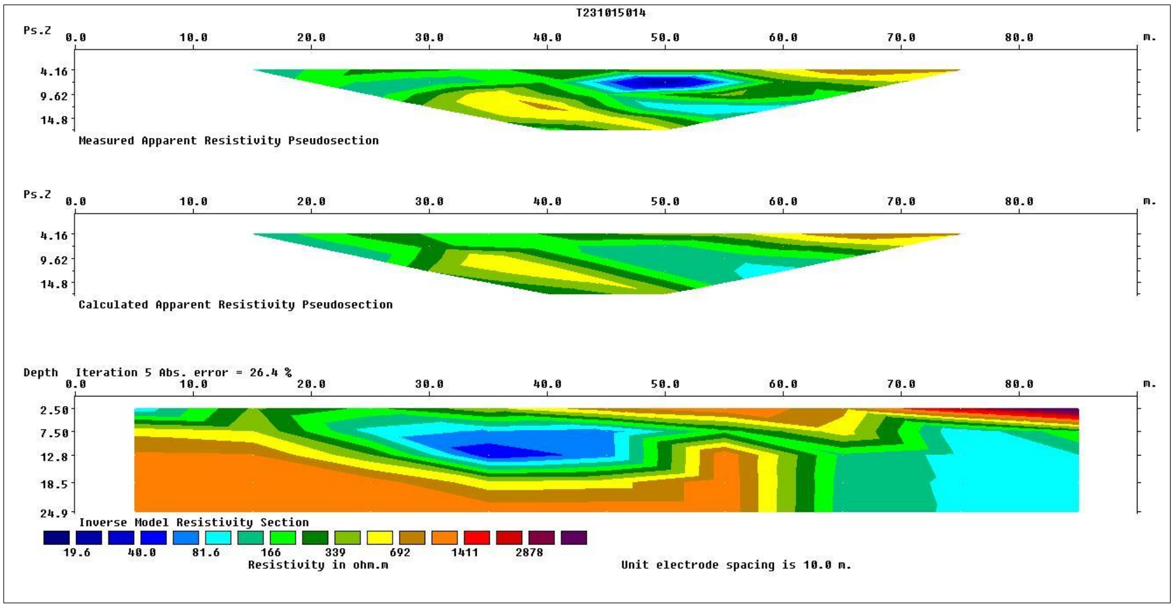

Fig. 21. Resistivity Imaging-4 at Gampa Temple (100 m)

Fig.22. Electrical Resistivity Survey in the Stakmo Village.

Table 5.1. Sounding Location details.

VES No.	Site location	Survey Point Location (Host)		Survey Point Location (End)		Elevation		Direction
		Lat	Long	Lat	Long	Host	End	
1	STAKMO 1	34.11708	77.70047	34.11797	77.70053	3813	3821	5N
2	STAKMO 2	34.11657	77.70016	34.11825	77.70079	3803	3826	8N
3	STAKMO 3	34.11171	77.69496	34.11331	77.69589	3753	3774	20N
4	STAKMO 4	34.1122	77.6956	34.11283	77.69486	3764	3767	308N

5.1 Groundwater Level Monitoring in Stakmo Village

Six locations of groundwater level data were collected from different locations of the Stakmo village, and it is found that groundwater level of Stakmo village ranging from 8.00 mbgl to 19.50 mbgl (Table 8; Fig. 23). Groundwater is flowing towards the southwest direction in the study area (Table 9; Fig. 24).

Table 5.2: Groundwater Level of Different Locations of Stakmo

S No.	Symbol	Station	Waypoint	Elevation (m)	Water Level (mbgl)	parapet (m)	Latitude	Longitude
1	BW20	STAKMO_1	882	3760	8	0.3	34.112622	77.695454
2	BW21	STAKMO_2	883	3761	8.77	0.1	34.112616	77.695492
3	BW22	STAKMO_3	884	3757	14	0.25	34.111962	77.695944
4	BW23	STAKMO_4	886	3826	11.3	0.49	34.118103	77.699023
5	BW24	STAKMO_5	887	3804	9.6	0.47	34.116613	77.700378
6	BW25	STAKMO_6	890	3685	19.5	0.41	34.116748	77.70014

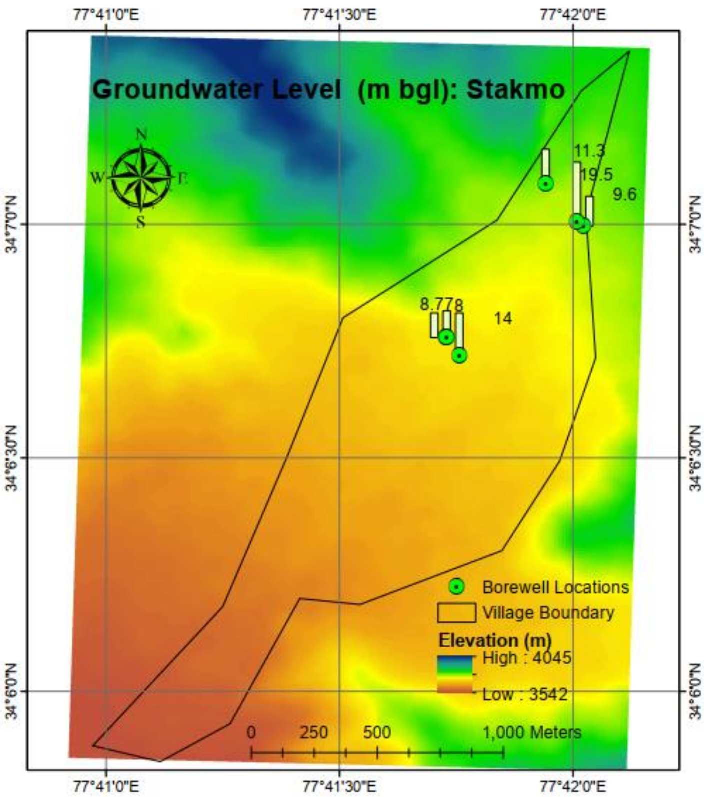

Fig. 23. Water level map.

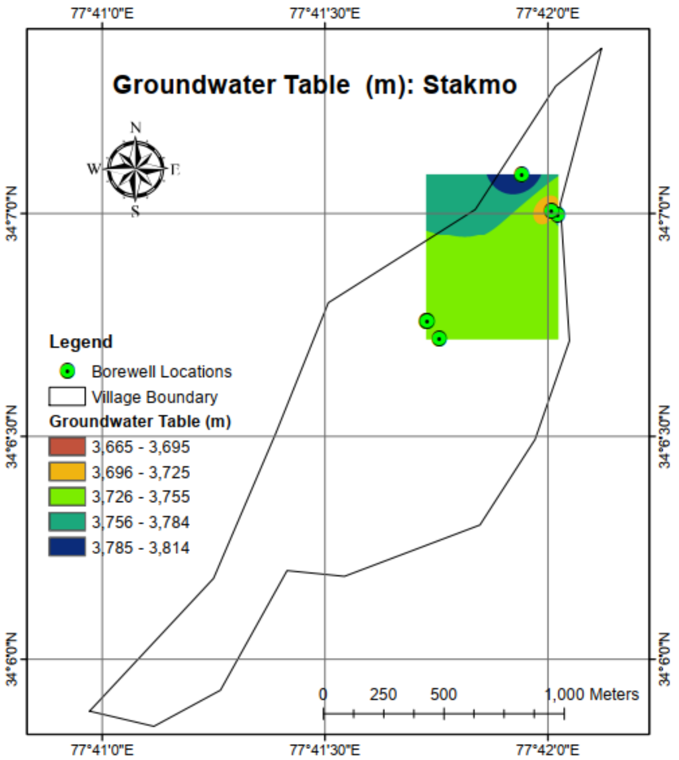

Fig. 24. Water Table map.

5.2: Groundwater Quality Monitoring in Stakmo Village

One groundwater, one surface water, and one spring water sample were collected for water quality analysis. Some parameters like TDS, pH, andQuality Monitoring temperature were measured in the field (Table 9).

Table 5.3: Groundwater Quality of Different Locations in Stakmo

S NO.	VILL.	STATION	TYPE	WAYP	ELEV	LAT	LONG	PH	TEMP ^{0}C	TDS (PPM)
1	STAKMO	B6	BOREWELL	886	3826	34.118103	77.699023	4.27	8.3	140
2	STAKMO	R2	GLACIAL RIVER STREAM	889	3796	34.105181	77.691012	4.51	8.1	70
3	STAKMO	S1	SPRING	891	3666	34.103385	77.691951	3.96	8.9	160

CHAPTER –6

INVESTIGATION AT LEH CITY

6.0 Leh City

Leh City mainly comprises granitic rocks which is overlain by unconsolidated sediments. It is observed that the thickness of unconsolidated is increasing towards the southeast. sediments increasing towards the downstream side.

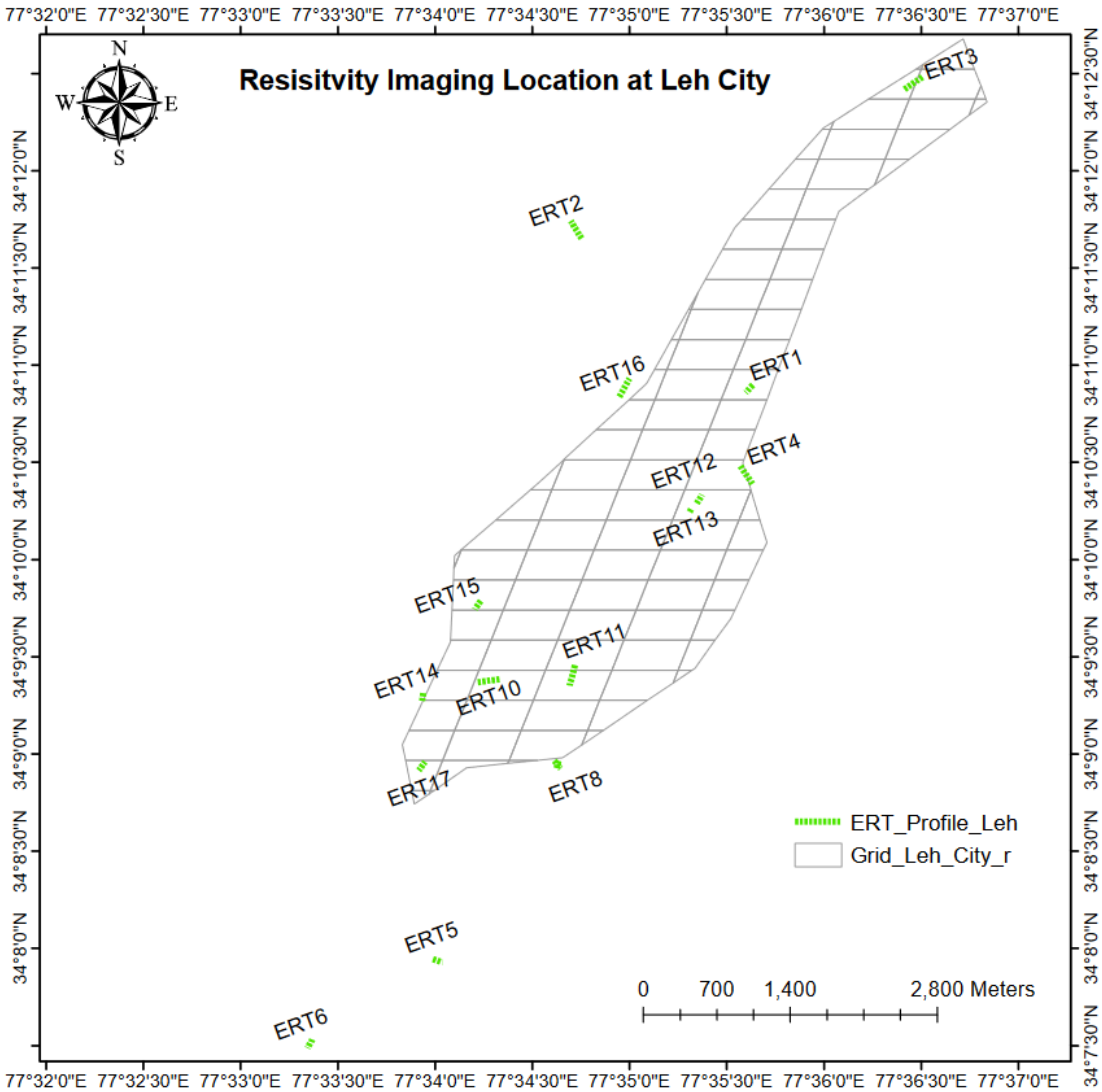

Fig. 25. Resistivity Imaging Locations at Leh City.

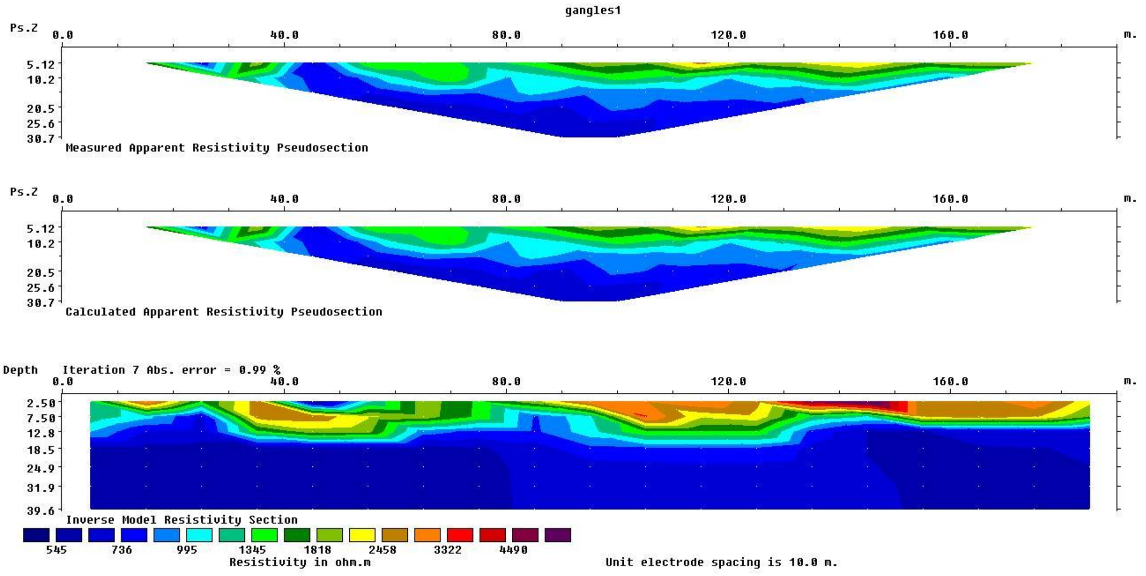

Fig. 26. Resistivity Imaging -1

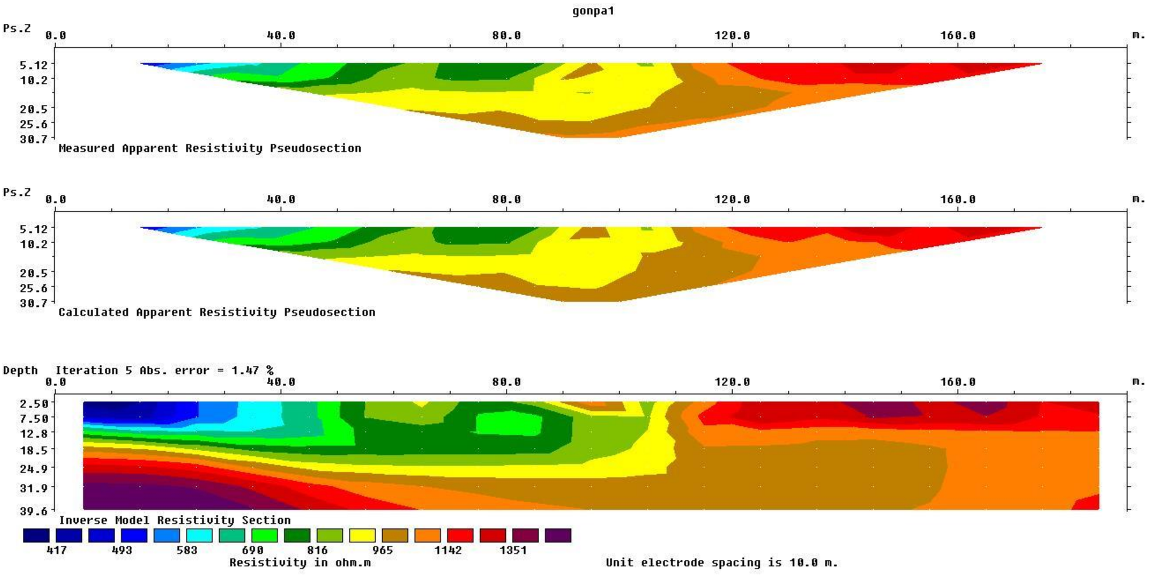

Fig. 27. Resistivity Imaging -2

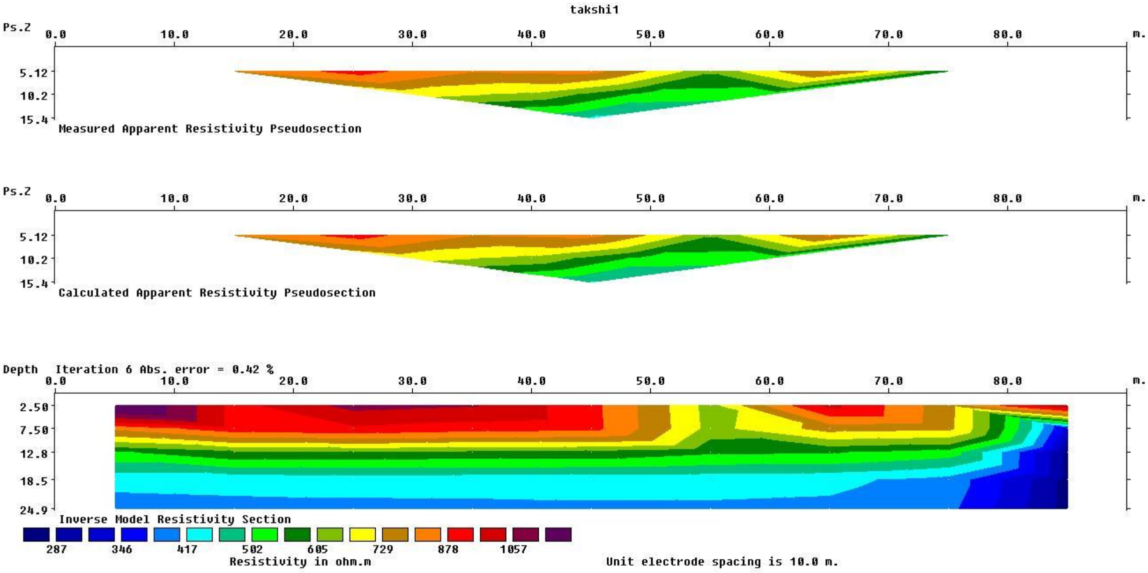

Fig. 28. Resistivity Imaging -3

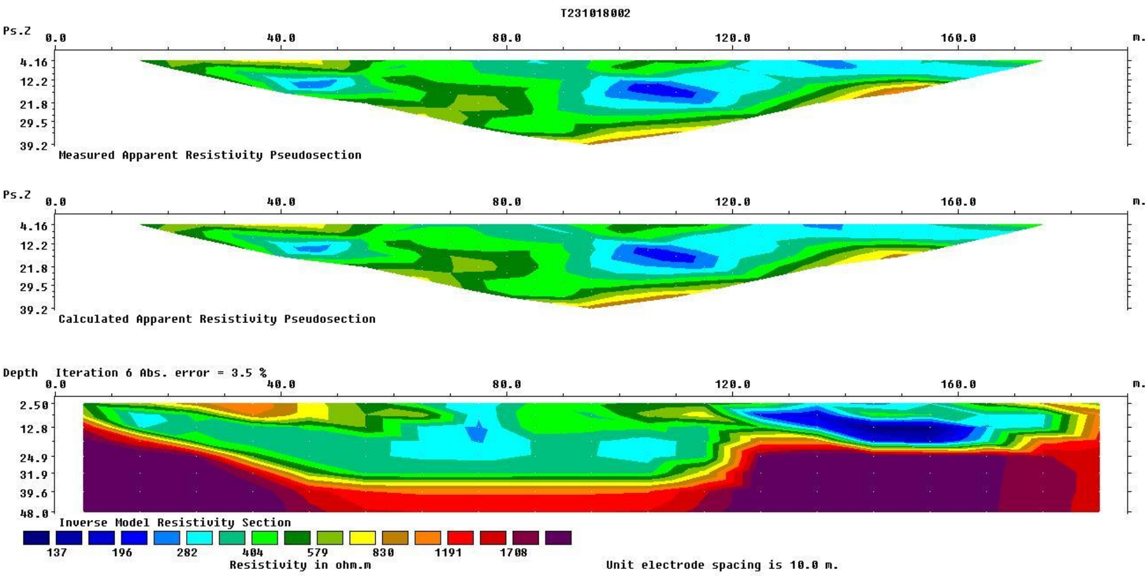

Fig. 29. Resistivity Imaging -4

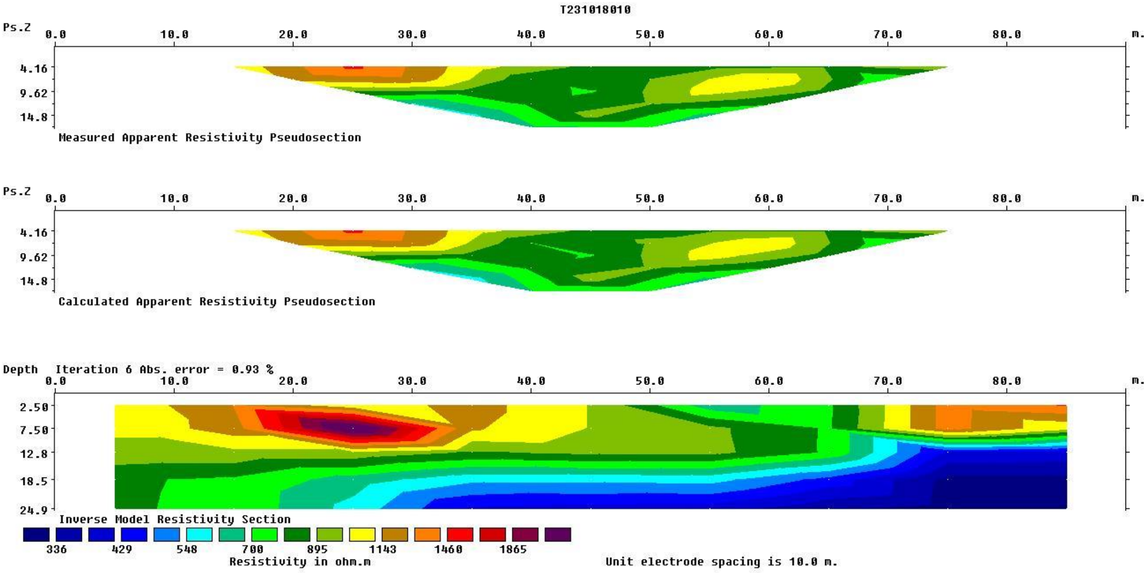

Fig. 30. Resistivity Imaging -5

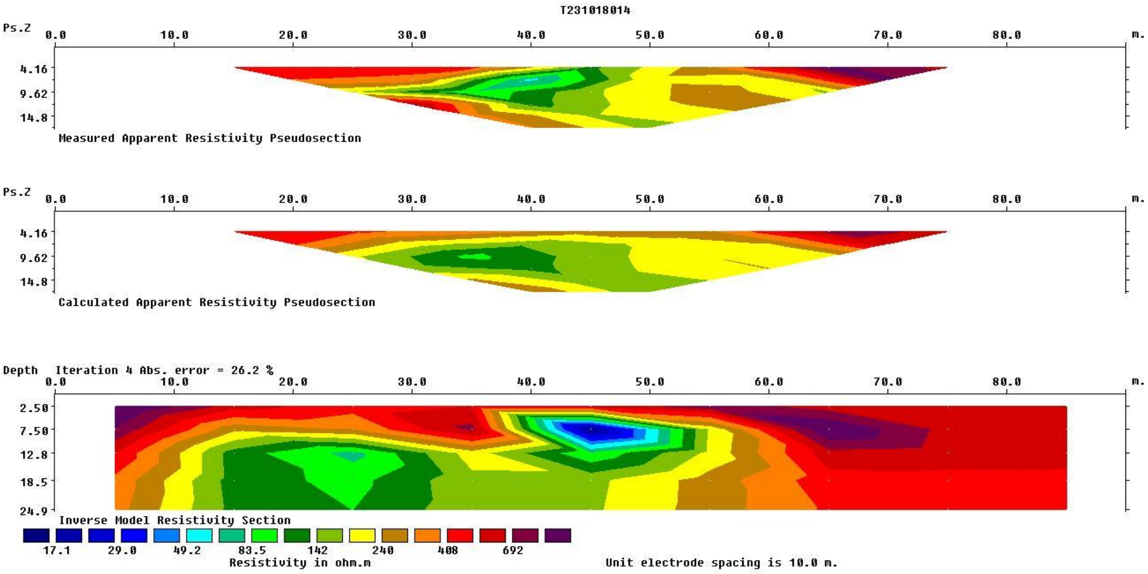

Fig. 31. Resistivity Imaging -6

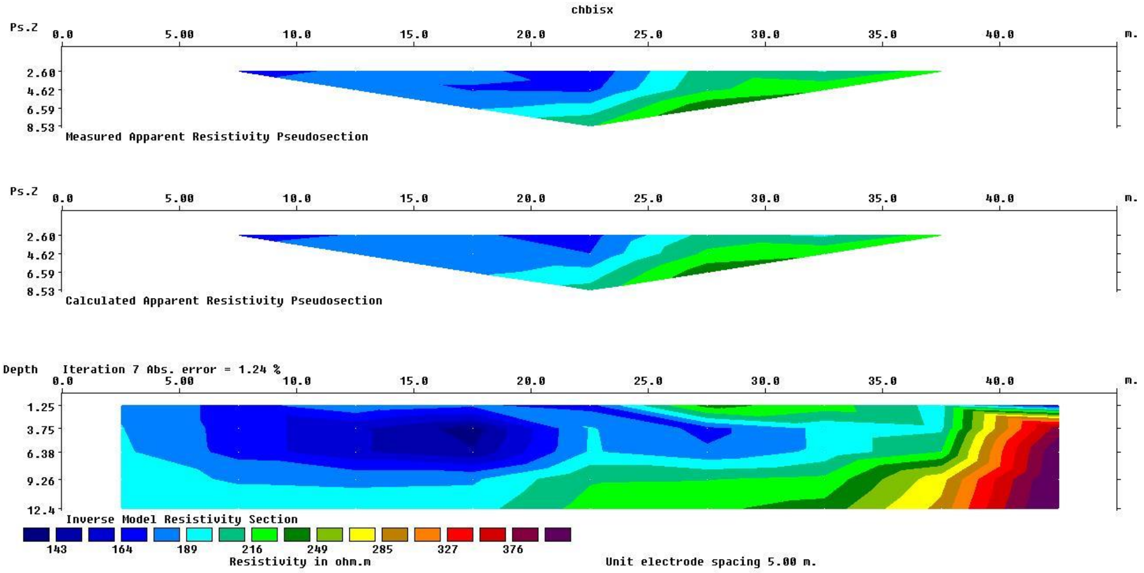

Fig. 32. Resistivity Imaging -7

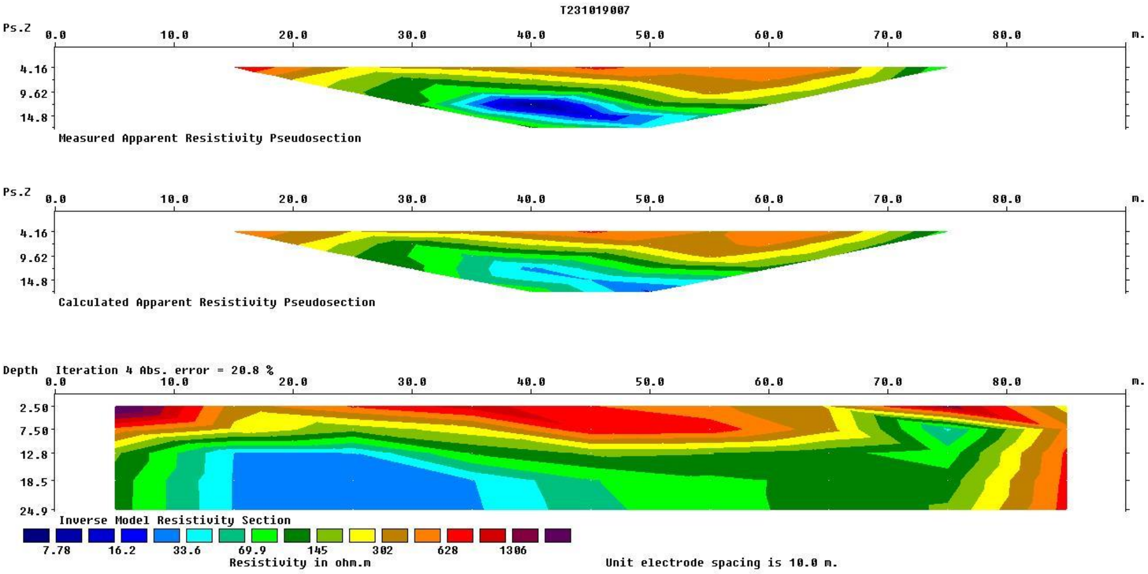

Fig. 33. Resistivity Imaging -8

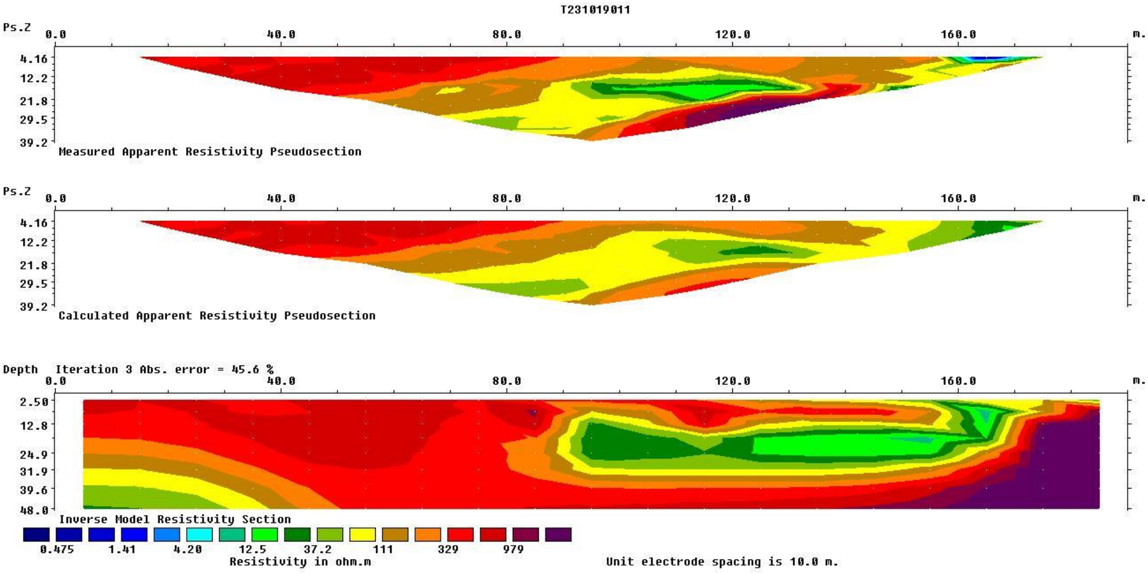

Fig. 34. Resistivity Imaging -9

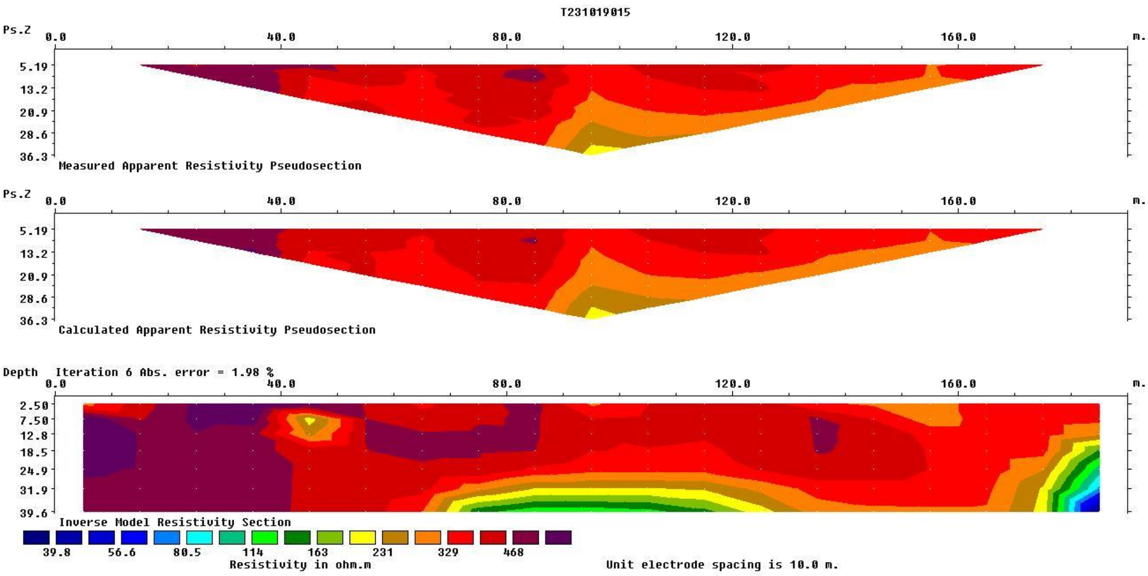

Fig. 35. Resistivity Imaging -10

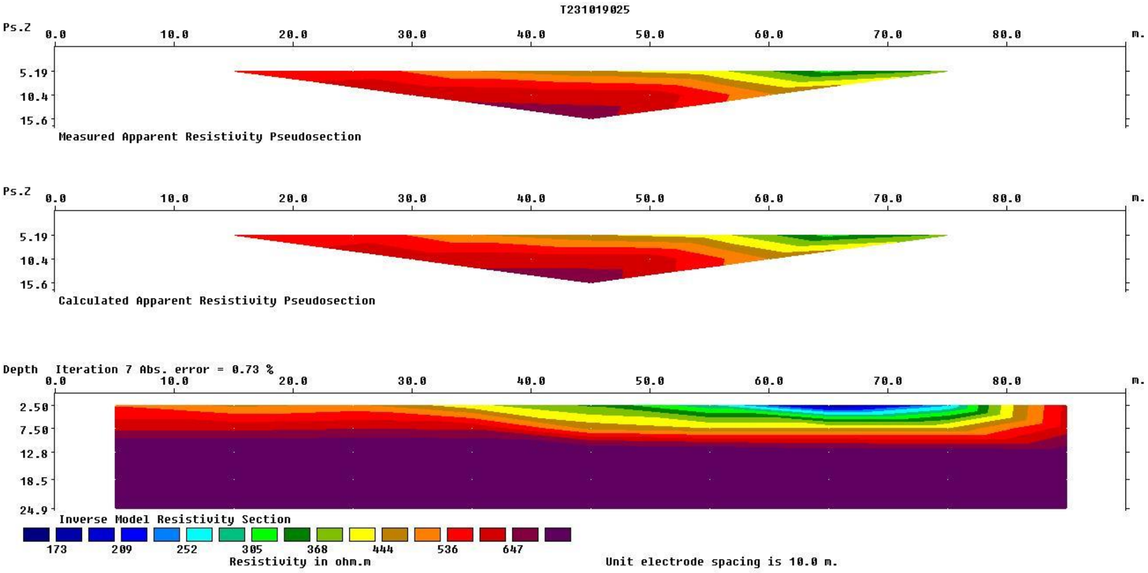

Fig. 36. Resistivity Imaging -11

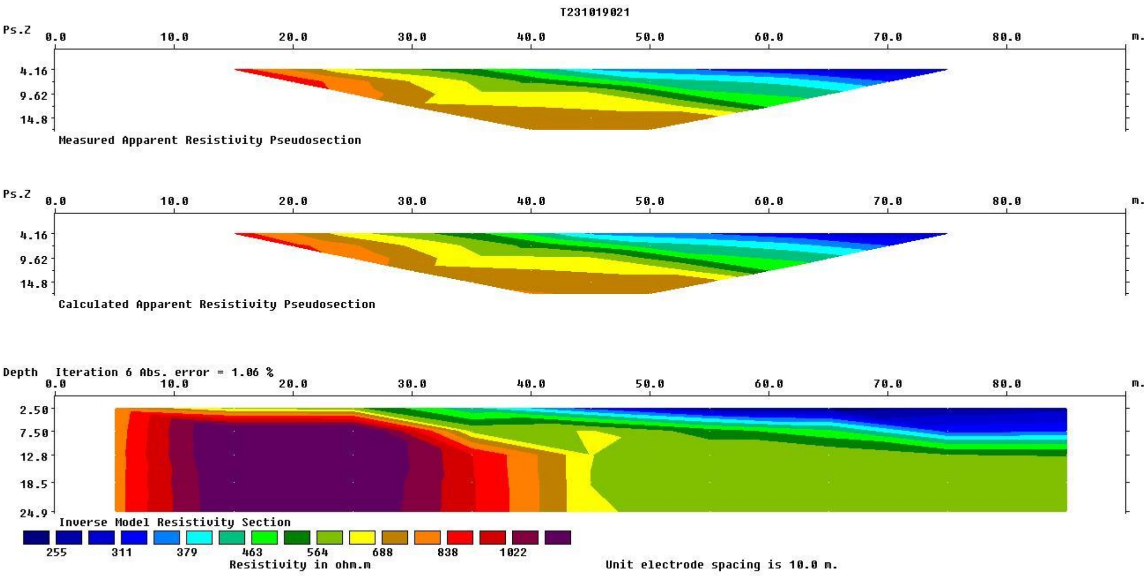

Fig. 37. Resistivity Imaging -12

Fig. 38. Electrical Resistivity Survey in Leh City.

In this study, 16 Electrical Resistivity tomography have been carried out at suitable places (Fig 26-37) in the study area (Fig 38). Sounding location details are given in Fig 25 and Table 10.

Table 6.1. Sounding location details

VES No.	Site location	Survey Point Location (Host)		Survey Point Location (End)		Elevation		Direction
		Lat	Long	Lat	Long	Host	End	
1	GANGLES LEH	34.208077	77.608463	34.206911	77.606808	3889	3875	N40
2	TAKSHI LEH 1	34.194125	77.579254	34.195705	77.578289	3787	3800	N340
3	TAKSHI LEH 2	34.180962	77.593305	34.181641	77.593882	3667	3678	N45
4	TISURU LEH	34.182179	77.583315	34.180503	77.582386	3599	3560	N212
5	TUKCHA LEH	34.163154	77.570602	34.1624	77.570063	3478	3473	N221
6	SKARA LEH	34.155313	77.565668	34.154455	77.565515	3422	3418	N185
7	CHHUBI LEH	34.163154	77.570602	34.1624	77.570063	3478	3473	N221
8	KATPA LEH	34.171475	77.589102	34.172211	77.589538	3574	3580	N24
9	SHEYNAM LEH	34.15761	77.578662	34.155869	77.578204	3469	3458	N9

10	SKARA 2 LEH	34.15642	77.572292	34.156132	77.570232	3431	3438	N70
11	NSD STADIUM LEH_1	34.148745	77.577425	34.149437	77.576861	3409	3409	N140
12	NSD STADIUM LEH_2	34.148726	77.577088	34.149526	77.577261	3408	3409	N10
13	KALON BAGH	34.14932	77.565789	34.148572	77.565276	3380	3380	N312
14	ANGLING	34.12551	77.556141	34.124767	77.55571	3259	3257	N324
15	HEART F.	34.132136	77.567265	34.132462	77.566354	3301	3301	N111
16	LAMDON SC.	34.174706	77.592817	34.173141	77.593864	3620	3623	N154

6.1 Groundwater Level Monitoring in Leh City

Seventy-six locations of groundwater level data were collected from different locations of the Stakmo village, and it is found that the groundwater level of Leh City ranges from 0.72 mbgl to 50.3 mbgl (Fig. 25). Groundwater is flowing towards the southwest direction in the study area (Fig. 26).

Table 6.2: Groundwater Level of Different Locations of Leh City

S No.	Symbol	Station	Waypoint	Elevation	Water Level (mbgl)	parapet (m)	Lat	Long
1	BW26	Gonpa, Ganglez	896	3925	34.68	0.45	34.209242	77.610706
2	BW27 (B7)	Angchuk, Ganglez	897	3871	10.2	0.3	34.206506	77.605589
3	BW28	Rinchin, Ganglez	898	3905	16.9	0.47	34.207134	77.610827
4	BW29	Namgyal, Ganglez	899	3904	5	0.31	34.205731	77.611968
5	BW30(B8)	Stanzin Spoon, Ganglez	900	3957	25.8	0.25	34.209087	77.615147
6	BW31	Rinchen (Dunghu), Ganglez	901	3970	23.91	0.22	34.209792	77.615393
7	BW32	Near Golboz house, Ganglez	902	3898	12.76	0.45	34.205495	77.607977
8	BW33	Hakim , Horzey	903	3853	15.55	0.12	34.202073	77.603471
9	BW34	Horzey	904	3831	9.44	0.45	34.200116	77.602183
10	BW35	Masjid Horzey	905	3819	12.86	0.12	34.198655	77.601483

11	BW36	Cheaang Dumting, Horzey	906	3810	5.65	0.44	34.199658	77.599759
12	BW37	Skal zing dumting, Ginglez	907	3852	0.72	0.66	34.203718	77.603311
13	BW38	Wangchuk Zingual, Gonpa Village	908	3691	8	0.36	34.188747	77.587948
14	BW39	Gonpa School	909	3746	10.43	0.22	34.192086	77.58581
15	BW40	UTUP (Parcha), Gonpa Village	910	3716	19.82	0.34	34.189816	77.58839
16	BW41	Sonam, Gonpa (Doktuk)	911	3749	33.44	0.3	34.191626	77.588811
17	BW42	Public PHP, Gonpa	912	3723	11.22	0	34.190872	77.591906
18	BW43	Spurka	913	3755	9.93	0.75	34.192624	77.595706
19	BW44	Stanzin Namgyal	914	3623	26.43	0.36	34.180356	77.583718
20	BW45(B9)	Tsewang Dorzey	915	3577	14.19	0	34.174002	77.577565
21	BW46	Goba Guest House, Chanspa	916	3526	17.5	0.24	34.170027	77.574937
22	BW47	Tsering Motup House	917	3525	6.9	0.2	34.168613	77.579639
23	BW48 (B10)	Upper Tukcha, Kushu Agyal	919	3508	10.23	0	34.165201	77.57551
24	BW49	Upper Tukcha, Sangto	920	3498	28.53	0.22	34.167366	77.573233
25	BW50	Zingyok, Upper Tukcha	921	3503	8.23	0.42	34.165411	77.579837
26	BW51	malpak, Upper tukcha	922	3525	6.08	0	34.165584	77.582616
27	BW52(B11)	community hall, shenam	923	3440	4.38	0.34	34.156849	77.572079
28	BW53	kawoo,shenam	924	3443	13.71	0.22	34.155812	77.574784
29	BW54	mikza, shenam	925	3472	14.72	0.27	34.158317	77.578802
30	BW55	chamba, shenam	926	3500	10.23	0.22	34.162029	77.582532
31	BW56	wangyal, shenam	927	3842	21.1	0.14	34.159491	77.580991
32	BW57	Tharpaling shenam	928	3423	33.82	0.71	34.149677	77.575918
33	BW58	Digur, Horzey	930	3763	9.33	0.26	34.196511	77.595005
34	BW59	Tsewang Dorjey, Digur, Horzey	931	3764	5.8	0.21	34.196085	77.593246
35	BW60	Khursida bano, Horzey	932	3800	7.77	0.71	34.198434	77.600066

36	BW61	Masjid-e-sharif, Horzey	933	3810	5.84	3.3	34.199673	77.600489
37	BW62(B12)	Nawang Tsering (Goba)	934	3580	8.65	0.61	34.172696	77.588934
38	BW63	Lamdon School	935	3596	28.28	0.37	34.173846	77.591109
39	BW64	Sonam Durzey, Khaksal, Bell	936	3635	6.7	0	34.179723	77.588737
40	BW65	Phunchok, Angchok Shuma, Shankar	937	3618	5.29	0.36	34.178537	77.587391
41	BW66	Sankar, Dongoz	938	3600	7.13	0.78	34.177002	77.587131
42	BW67	Yangchan, Dumbing, Katpa	939	3855	11.05	0	34.173811	77.588322
43	BW68	HP Petrol pump, Chubi, Leh	940	3567	0.95	0.5	34.169573	77.589323
44	BW69(B13)	Monastry, Skara	941	3444	11.37	0.41	34.158341	77.564716
45	BW70	Community Hall, Skara	942	3428	7.09	0.27	34.155617	77.572466
46	BW71	Chunka House, Scara,(Ladakh imperial hotel)	947	3417	12.51	0.31	34.153366	77.572675
47	BW72 (B14)	Tsunba House,Skara, Yokma	951	3378	41.52	0	34.146128	77.562158
48	BW73	Rinchen Kartsepa ,Skara ,Yokma	952	3368	50.3	0.29	34.147829	77.559712
49	BW74	Khaksal, Abagon, (Near to hotel charu palace)	953	3665	27	0	34.182109	77.592009
50	BW75	Hotel Khaksal, Chubi	954	3643	13.2	0	34.179494	77.591104
51	BW76	Near Avalok home stay, tinton	955	3700	6.5	0	34.187796	77.591269
52	BW77	Near Ladakh Cerenity House	956	3643	10.44	0.44	34.181974	77.588235
53	BW78	Near morning sky guest house	957	3613	12.04	0.15	34.176423	77.590233
54	BW79	Hotel Casa galwan	958	3579	13.34	0	34.17584	77.580907
55	BW80	Hotel Lyon, Chanspa	959	3542	22.05	0	34.170641	77.576485

56	BW81	Leadakh Ecological development group etsd.office	960	3536	2.84	0	34.167957	77.584052
57	BW82	Lachumir House, Upper Karzu	961	3547	6.65	0	34.169887	77.583619
58	BW83	commercial park, Leh main market, Skes Sovenir shop	962	3507	20.22	0	34.163941	77.584134
59	BW84	Gurudwara Singh sahab, Below leh palace	963	3527	27.57	0.43	34.163679	77.586624
60	BW85(B15)	LNP Office	964	3419	45.24	0.28	34.149604	77.579872
61	BW86	P Namgyal, Ex-Mp house, Near Hotel Abduz	965	3446	28.9	0.3	34.155291	77.578265
62	BW87	Nabir, Lower Tukcha	966	3503	8.8	0.29	34.163583	77.580178
63	BW88	Front of Khan Manzil	967	3528	4.38	0.42	34.16568	77.584853
64	BW89	Near Shenam Committee hall, Skara	968	3417	4.64	0.14	34.157391	77.571812
65	BW90	Hostel Khastang, Skara	969	3451	5.54	0.12	34.160429	77.570137
66	BW91	Behind Zorawar Fort, Skara, Yokma	970	3439	4.3	0.44	34.156742	77.569412
67	BW92	Hotel Zombday, Skara Yokma	971	3416	21.94	0.42	34.152842	77.566657
68	BW93	GHE impact Venture PVT Limited, Tiyapa, Skara Yokma	972	3405	20.5	0.59	34.15099	77.56502
69	BW94	Near L.H.I School, Skara Yokma (Phuluchan)	973	3379	34.26	0.49	34.148851	77.562165
70	BW95	Near Degree College, Murtesey Colony	976	3399	39.47	0.41	34.147184	77.579255
71	BW96	Behind SNM hospital, Near municipal meat shop	978	3470	44.9	0.26	34.155941	77.581575

72	BW97	Behind new bus stand	979	3485	29.2	0.28	34.157549	77.582581
73	BW98	Under Construction site, Near DC office	980	3541	42.6	0.5	34.161541	77.58897
74	BW99	Angling, Camp No.9	981	3250	33.54	0.14	34.124301	77.554034
75	BW100	Angling Camp No.9	982	3257	39.8	0.19	34.125918	77.554623
76	BW101	Camp No.8, Near Kiran Cargo	983	3256	36.38	0.2	34.123204	77.557688

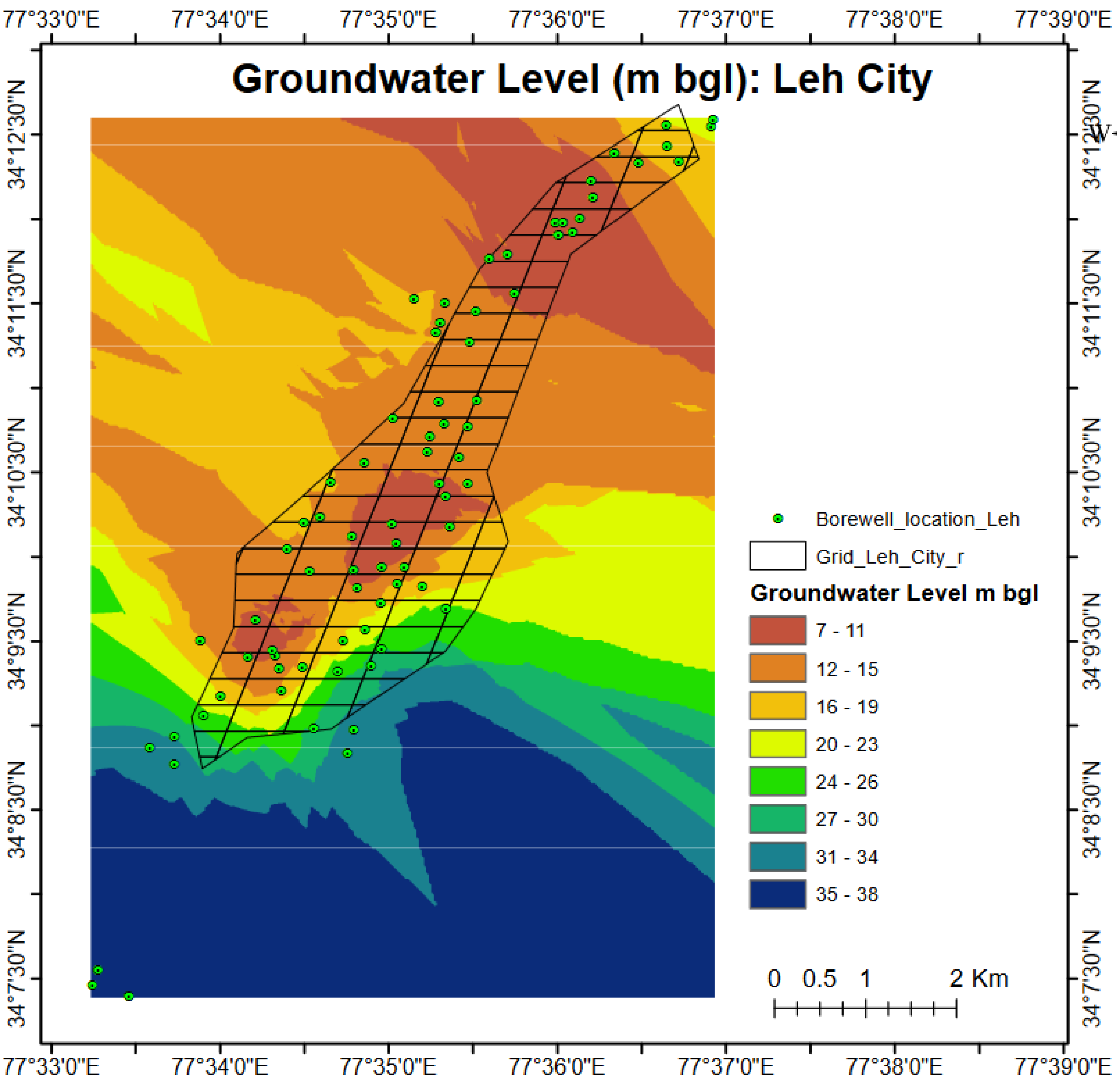

Fig. 39. Water level map.

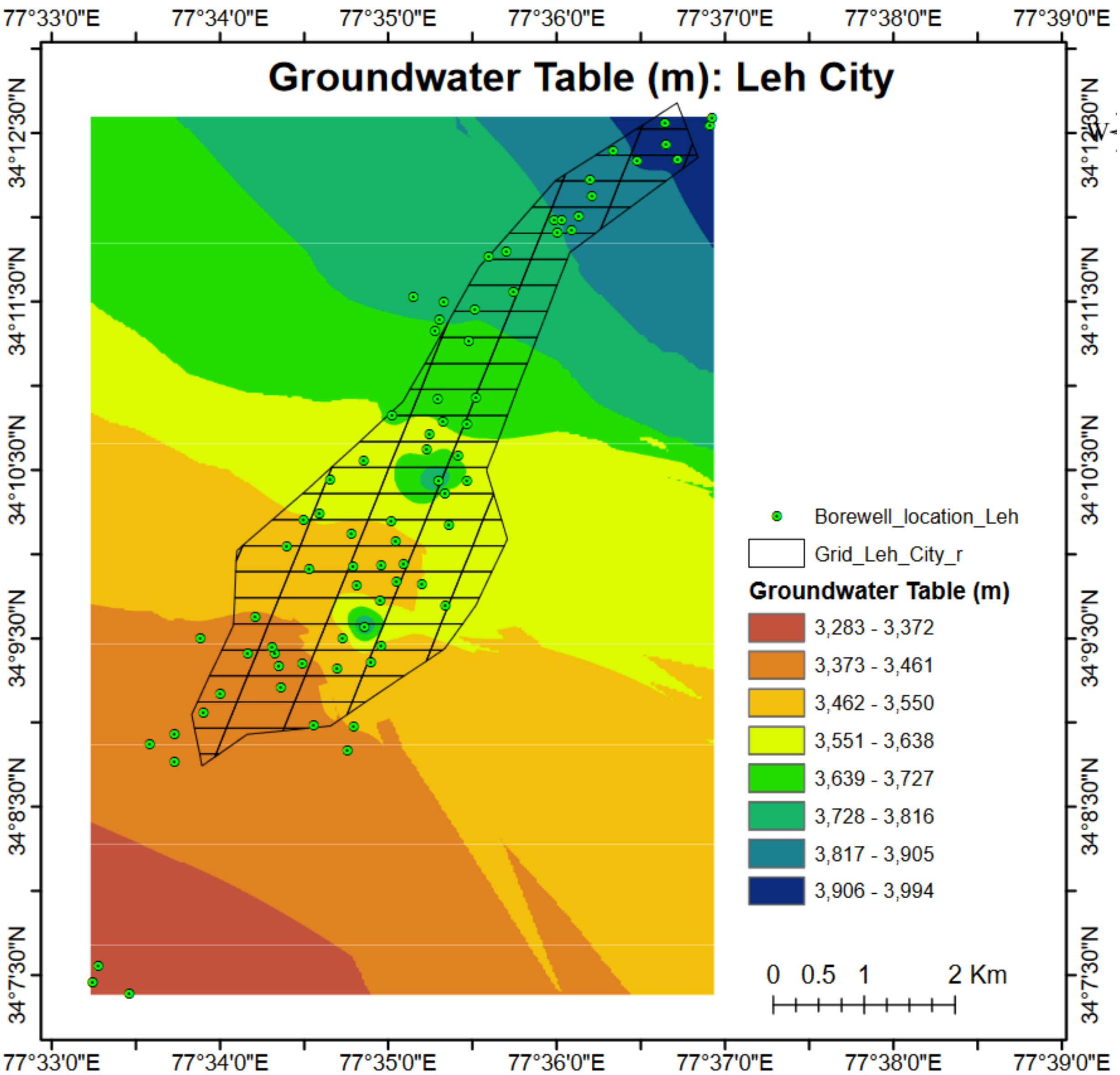

Fig. 40. Water Table map.

6.2 Groundwater Quality Monitoring in Leh City

Nine groundwater water samples were collected for water quality analysis. Some parameters like TDS, pH, and temperature were measured in the field.

Table 6.3: Groundwater Quality of Different Locations in Leh City

S NO.	CITY	STATION	TYPE	ELEV	LAT	LONG	PH	TEMP ^0C	TDS (PPM)

1	Angchuk, Ganglez	B7	BOREWELL	3871	34.206506	77.605589	4.35	7.8	80
2	Stanzin Spoon, Ganglez	B8	BOREWELL	3957	34.209087	77.615147	4.25	8.3	60
3	Tsewang Dorzey	B9	BOREWELL	3577	34.174002	77.577565	3.88	10.8	460
4	Upper Tukcha, Kushu Agyal	B10	BOREWELL	3508	34.165201	77.57551	3.88	10.1	120
5	community hall, shenam	B11	BOREWELL	3440	34.156849	77.572079	3.58	9.4	120
6	Nawang Tsering (Goba)	B12	BOREWELL	3580	34.172696	77.588934	4.09	9	130
7	Monastry, Skara	B13	BOREWELL	3444	34.158341	77.564716	3.04	10.5	690
8	Tsunba House,Skara, Yokma	B14	BOREWELL	3378	34.146128	77.562158	4.12	7.7	140
9	LNP Office	B15	BOREWELL	3419	34.149604	77.579872	3.61	9.7	450

CHAPTER –7

STAKEHOLDER SURVEY

7.1 Introduction

The stakeholder questionnaire for Survey on Geo-Hydrogeological Study in the Villages of the Leh (2023) was conducted in both online and offline mode. The main objectives of conduction the stakeholder survey include “understanding the needs of farmers in the study area located in the Leh district”, “identify key issues and concern related to water availability for drinking and irrigation purposes”. The investigators have asked the questions with the following details.

Plain Summary

This chapter provides information collected from the Ladakhi community through personal interviews and online surveys through Google Forms. The purpose of the interview was to know the opinion of farmers, local government bodies, and other local people on water-related problems in selected villages such as Nang, Stakmo, Leh, Mood, and Saboo. Several questions related to agricultural practices, uses of water, key problems faced by farmers for drinking and agricultural purposes were asked. We received overwhelming responses from individuals and groups. We asked questions to Nambardars, farmers, ward members, sarpanches, officials of Leh municipality, public health and water supply divisions, hotel owners, students etc. All the responses were digitally recorded and presented in this chapter.

“Juley ! Namaste!

*We belong to **Leh Nutrition Project (LNP)** and **National Institute of Technology Raipur**. In this online survey, we are collecting the data related to Surface water and Groundwater consumption, water availability for farmers and stakeholders in the Villages of Leh. We will use this data for study and research purpose only and will not publish any of your personal information.*

Therefore, we request to fill the questionnaire. We would be grateful for your response and participation.

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About LNP: https://lnp.org.in/engage/

About NIT Raipur: http://www.nitrr.ac.in/"

The questions were asked to the residents of the Saboo, Leh, Stakmo, Nang, and Mood. The respondents were having ages of all group ranging from younger age group to older age.

7.2 STAKEHOLDER SURVEY FRAMEWORK

This section gives information about the overall process of stakeholder survey from framing the questions to receiving the responses.

1. **Questions preparation:** We have prepared several survey questionnaires in 4 section 1. General information, 2. Social and economic, 3. Agricultural, and 4. Water related issues and concern. We asked around 20 Questions to an individual and group of farmers in the study sites.

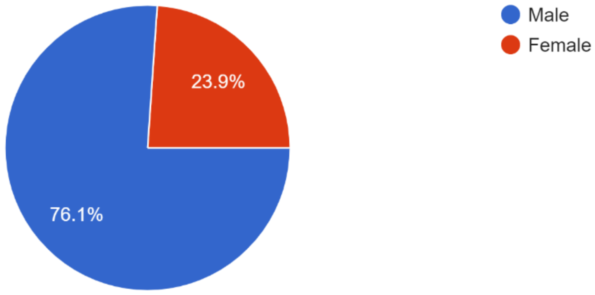
- Framework of the questions were easy and simple, we asked questions in English language and in offline mode we asked questions in English, Hindi and local vernacular language.
- Most of the questions were of Multiple-choice questions and two of them were subjective questions. The questions were framed in such a way that a stakeholder can answer question within 10 minutes.
- 1st section contains general information about stakeholders which includes name, address, profession, age, gender, education, annual income, household members, etc.
- 2nd section contains social questions which is targeted to find social conditions of stakeholders.
- 3rd Economical condition is targeted to find Economical condition of stakeholders as we have seen currently farmers are in the most vulnerable condition, so we have tried to relate the economic conditions and their living standards with geographic and climatic condition.
- 4th Agricultural and water related questions have been asked so we can study how the natural and human activities affect the water availability for domestic and agricultural purposes.

2. **Distribution:** To distribute the survey questions among all the stakeholders, we circulated GOOGLE FORM in online mode. The questions were also taken in hard copy and circulated among individual or groups of farmers.
3. **Trail:** We have run a trial survey questions among our teams of investigators and other project associates to know refine the questions and observe the time taken for response. According to their suggestions, we have modified the questions.
4. **Distribution:**
    - **Stakeholders:**
        1. Farmers
        2. NGOs
        2. Students
        3. Local government bodies
        4. Residents in study area

7.3 RESPONSES:

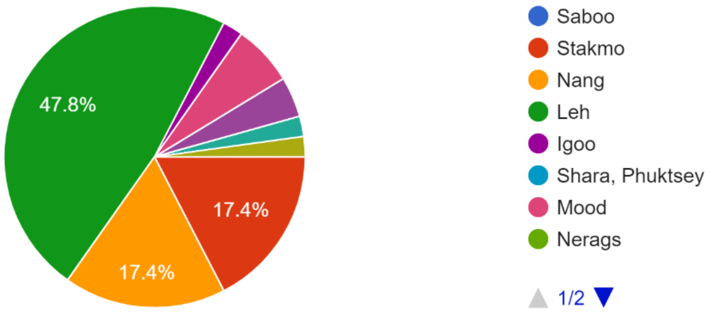
The subsequent sections indicate responses received from the key stakeholders. Based on the responses received, following are the key issues and recommendation suggested by the key stakeholders.

46 responses



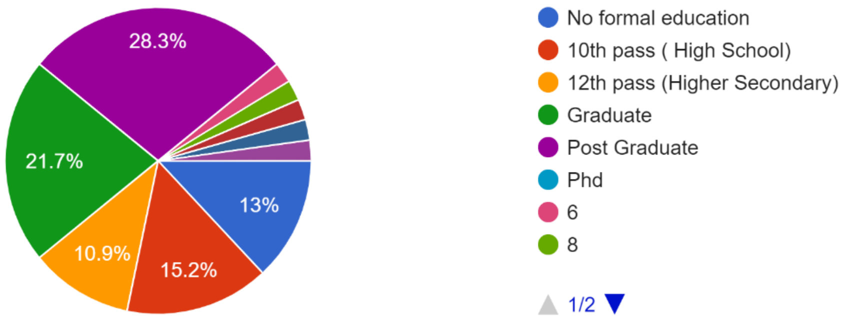
Village/Taluka/Tehsil/Block

46 responses



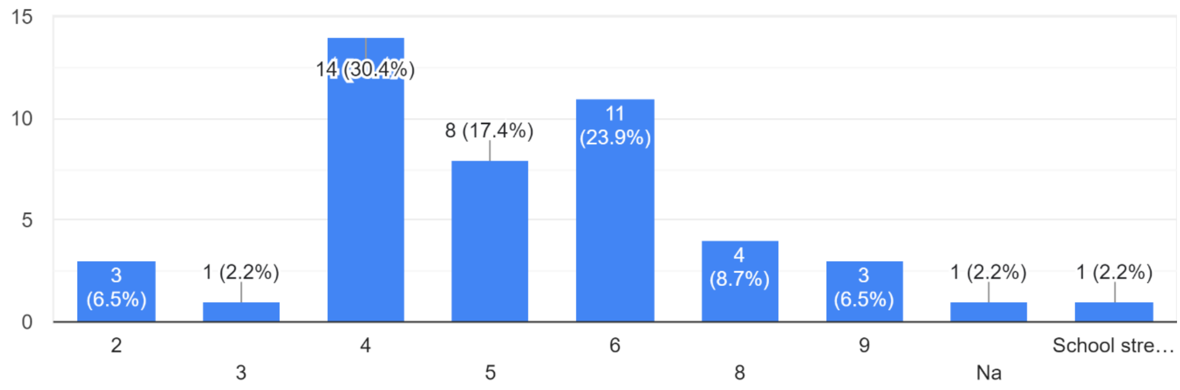
Educational Level:

46 responses



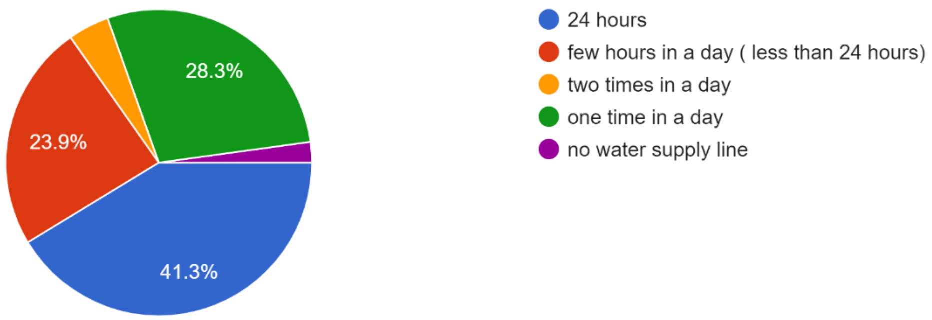
Family Size (number):

46 responses



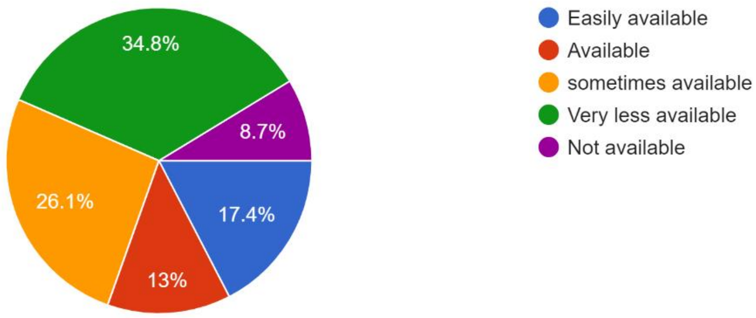
1. How much drinking water supply is available in a day for your village/city?

46 responses



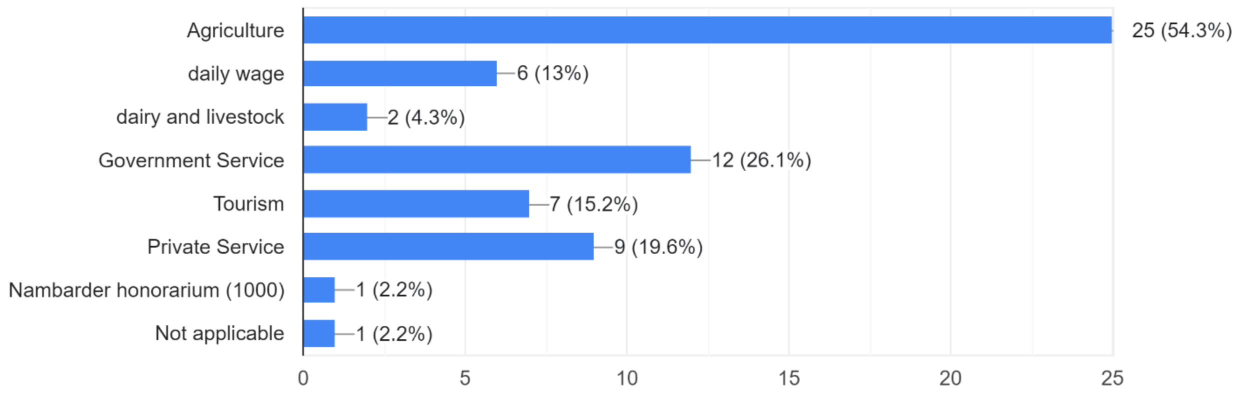
2. What is the availability of local daily wages-labor?

46 responses



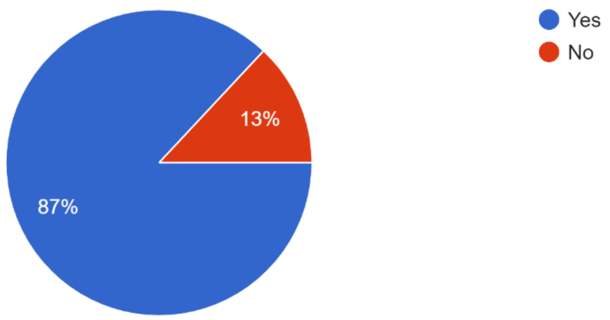
3. Source of income per house? (Agriculture, daily wage, dairy and livestock, Service, other)

46 responses



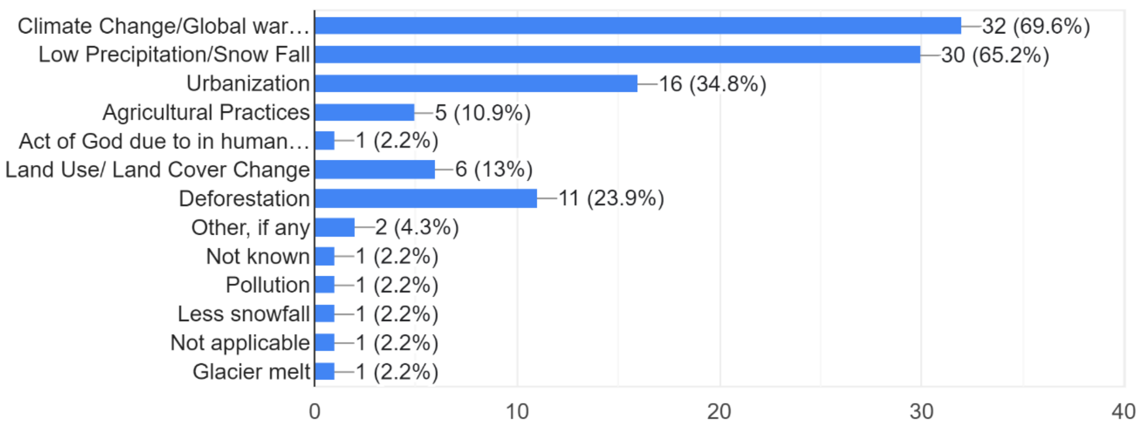
4. Are you facing any water scarcity problem in your village?

46 responses



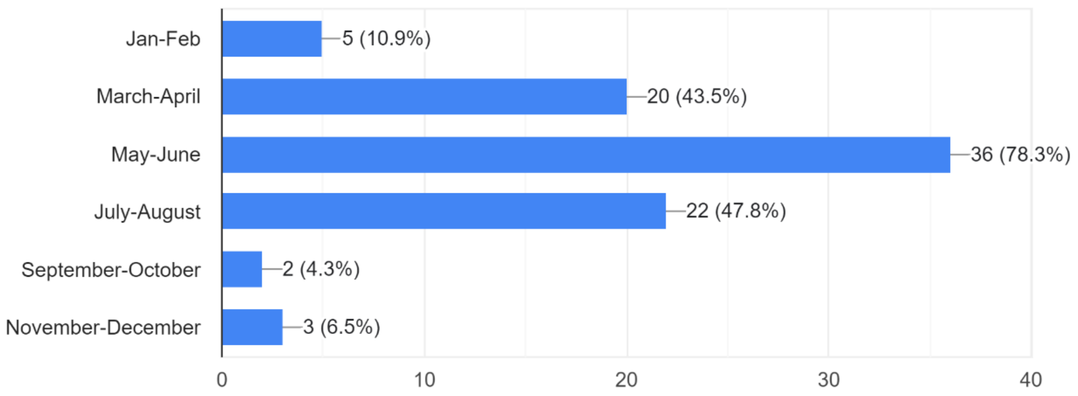
5. In your opinion, what are the primary reasons of water scarcity in your village?

46 responses

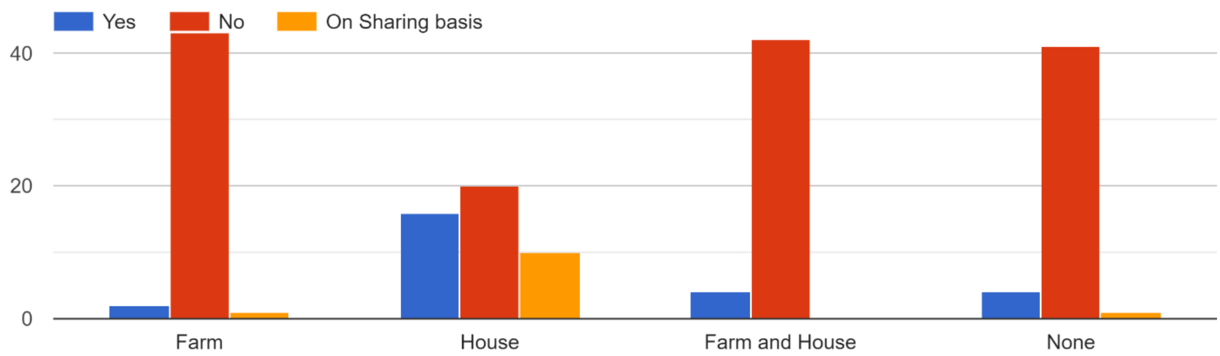


6. In which month you face more water scarcity problem ?

46 responses

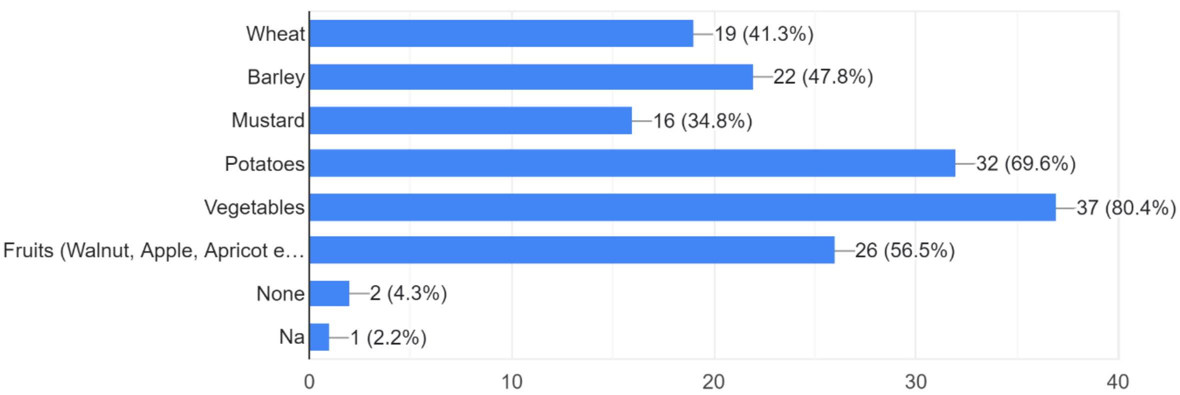


7. Do you have a borewell facility at your farm and Home?

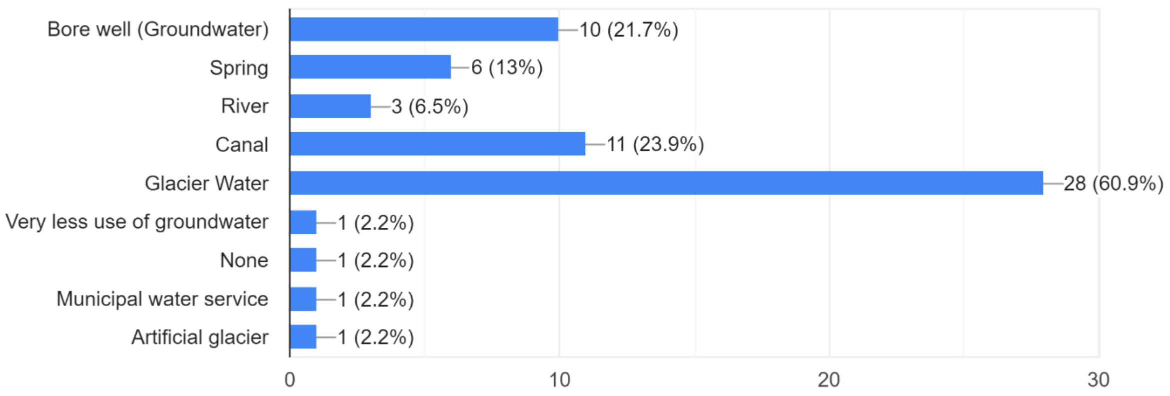


8. What kind of crop do you produce?

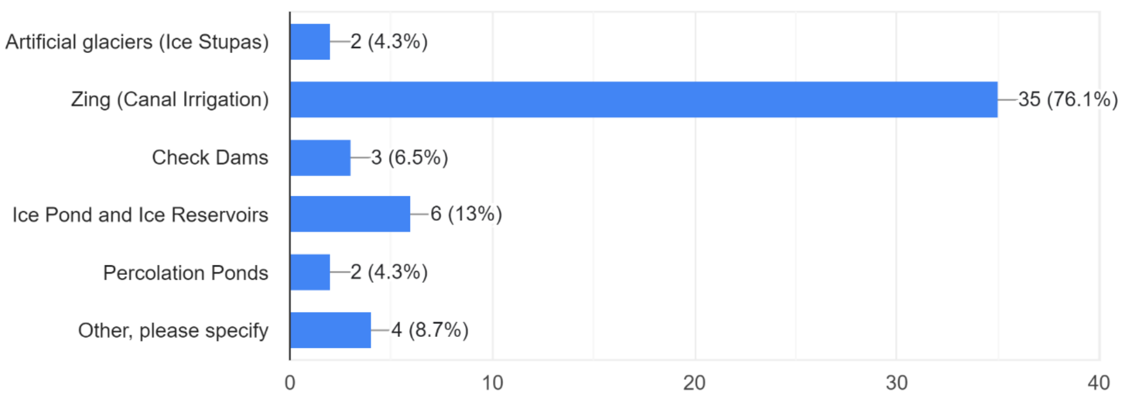
46 responses



9. What are the sources of irrigation
46 responses



10. What are the methods of water conservation structures in your village ?
46 responses



11. Based on your experience at village, write any two disadvantages of the water conservation structure. (Selected responses)

- Non availability of enough water during sowing season
- Water conservation works will help in the month of June and July
- Borwell near highway is measured threat to the village because the existing Spring in village disappear which lead to reduction in the capacity of chasma.
- 1. Due to increase in use of water conservation structure and borewell, water flow through pipes has decreased. 2. Excessive water flow observed in summer which usage may lead to water scarcity in other subsequent months.
- 1. Local have to migrates to other places which affect their livelihood. 2. Disturb the natural flow of river and canals.
- Not useful at needed time.
- Nothing
- No disadvantages.
- Leakage increases the size of zing

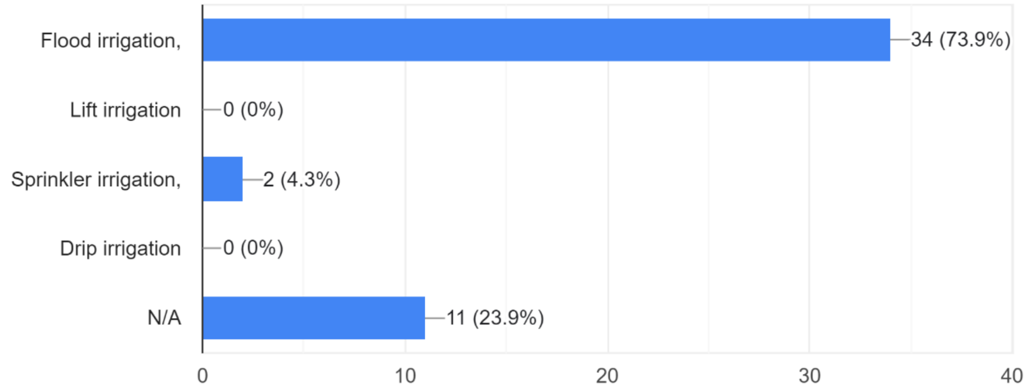
- Scarcity of water
- No comments
- Need more conservation structure.
- Damage of the land after the construction
- Satisfied.
- Water scarcity is more due to more digging of borewell.
- Capacity of water retention structure is less.

12. Based on your experience at village, write any two advantages of the water conservation structure. (Selected responses)

- It is advantageous only in june and July. Chasma or Spring helps during other months.
- Agriculture
- Environmental benefits. Reduces greenhouse gas emission.
- 1st :- Glacers and streams water are very good quality for our daily uses . 2nd :- minimizes water pollution and health risks
- None
- Agriculture
- Saves crops and fruits.
- It helped during scarcity of water.
- To check the scarcity of water needed at the right time. To solve the problem faced by agriculture sector in Ladakh due to shortage of water.
- Easy availability of water
- Water for planting and other domestic use
- No comments
- Useful for Agriculture
- Not dependent on natural water or rain Easy distribution
- Proper use of water whenever needed.
- Water availability Reduces water purchase cost.
- Water conservation structure provides easy availability of water when in need.
- Easy access to water when in need good quality water for vegetation
- Water distribution among the villagers. Easy availability of water for irrigation
- Recharge of ground water. Individual water service
- Improve the water recharging.
- It recharges the underground water level. Every individual can use the water for their agriculture fields.
- Water recharge. Improve crop yield.
- No need for extra work on canal.

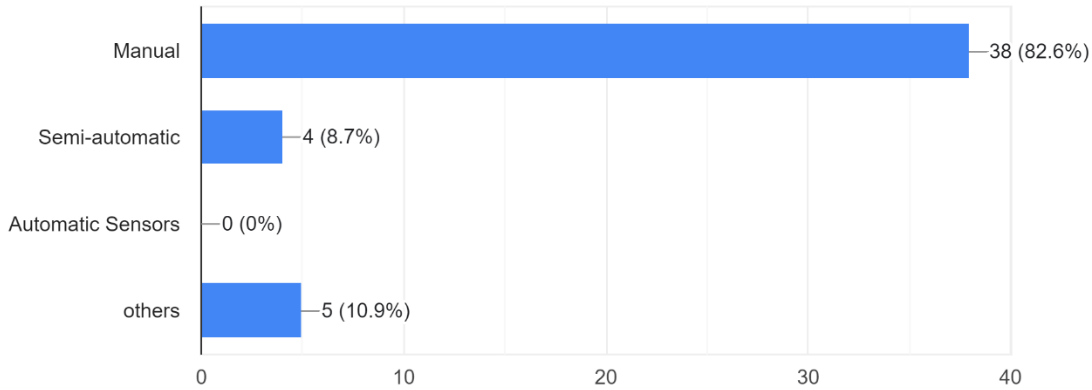
13. Which method of irrigation do you use in the field?

46 responses

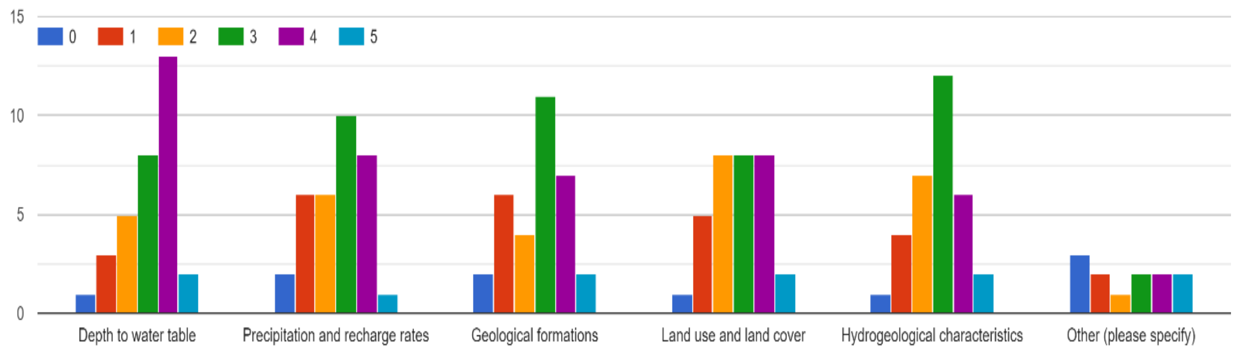


14. Which mode or technology of irrigation do you use on your agriculture land?

46 responses

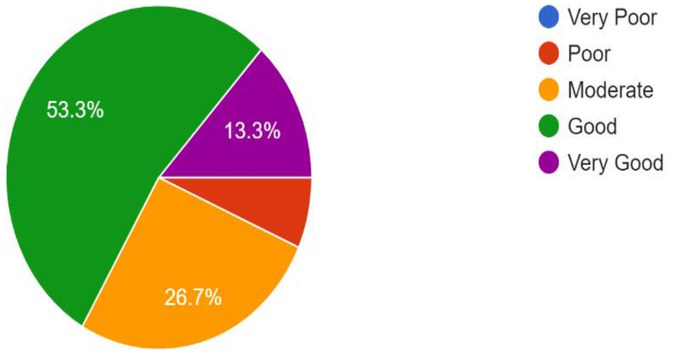


15.Considering the significance of various factors, please rank the following criteria for groundwater potential by assigning a score from 0 to 5 for each

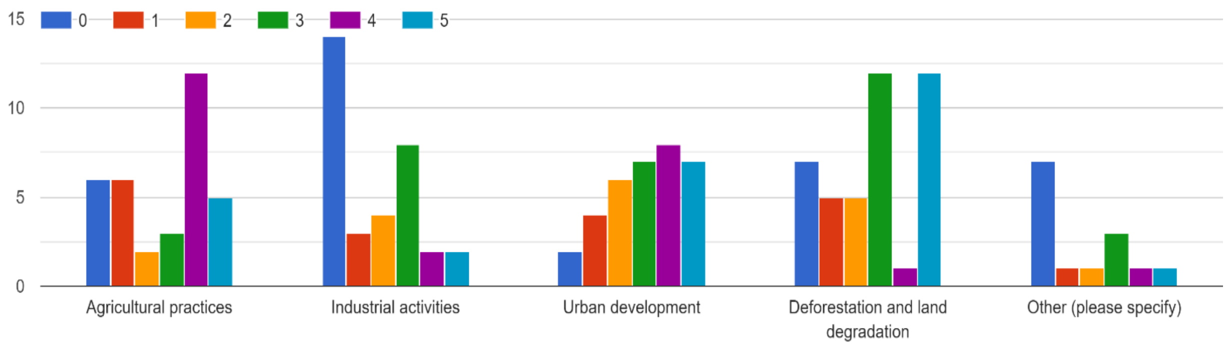


16.In your opinion, how would you rate the current state of groundwater quality in our village on a scale of 0 to 5 (Very Poor to Very Good) ?

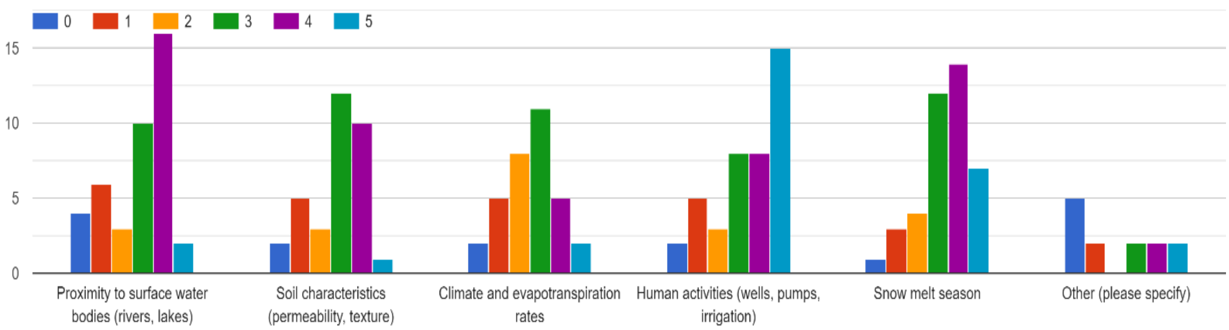
45 responses



17.Please assign scores from 0 to 5 to the following criteria based on their impact on groundwater availability and quality in your village (optional) :



18.Considering the following factors, please allocate scores from 0 to 5 to indicate their influence on groundwater potential in your village (optional):



19. Any other comments/suggestions: (Selected responses)

- Less snow means less Underground water, I guess. Need to implement some sustainable initiative for climate change.
- Save water save future.
- Drinking water should be available for 24 hours.
- Submersible pump is need during winter as the hand pump is inconvenience for elderly people.

- Need to construct water conservative structures at the hill side region. Avoid the use of chemical fertilizers.
- To get sufficient water for the community, borewell with high power motor required.
- Ladakh is facing water scarcity issues because of global warming. It is essential to take the basic necessities to conserve water which will need for sustainable livelihood.
- Conservation of water is necessary for our life.
- Health condition can be improved by supplying stream that has soft water (better quality) as compare with borewell water (Groundwater).
- GW Potential will be increase in the village.
- Borewell must be install on U/S of new structure.
- No comments
- Water shortage in winter for local farming in greenhouse.
- None
- Need water supply (efficient) service during sowing season.
- Renovation of the existing canals so that the reservoir water can be used by every household efficiently.
- Borewell facilities by the government within the community for public use
- Need to repair the water channels.
- Global warming is the cause of water depletion in the region.
- Khardongla tunnel (diversion structure may help to improve water issue)
- No comments
- Due to global warming, Ladakh is facing water shortage.

Fig.7.1 (a): Survey response collected by the investigators in offline mode. Photographs taken while conducting stakeholder responses at different locations in the study area of Leh district.

Fig.7.1 (b): Survey response collected by the investigators in offline mode

CHAPTER –8

WATER QUALITY ANALYSIS

8.1 Introduction

The term "water quality" encompasses the chemical, physical, biological, and radiological properties of water,which determine its suitability for specific applications and the preservation of ecosystem health. Various parameters and conditions can have a significant influence on water quality, affecting its potability, ecological balance, and suitability for industrial, agricultural, and recreational purposes.

Plain Summary

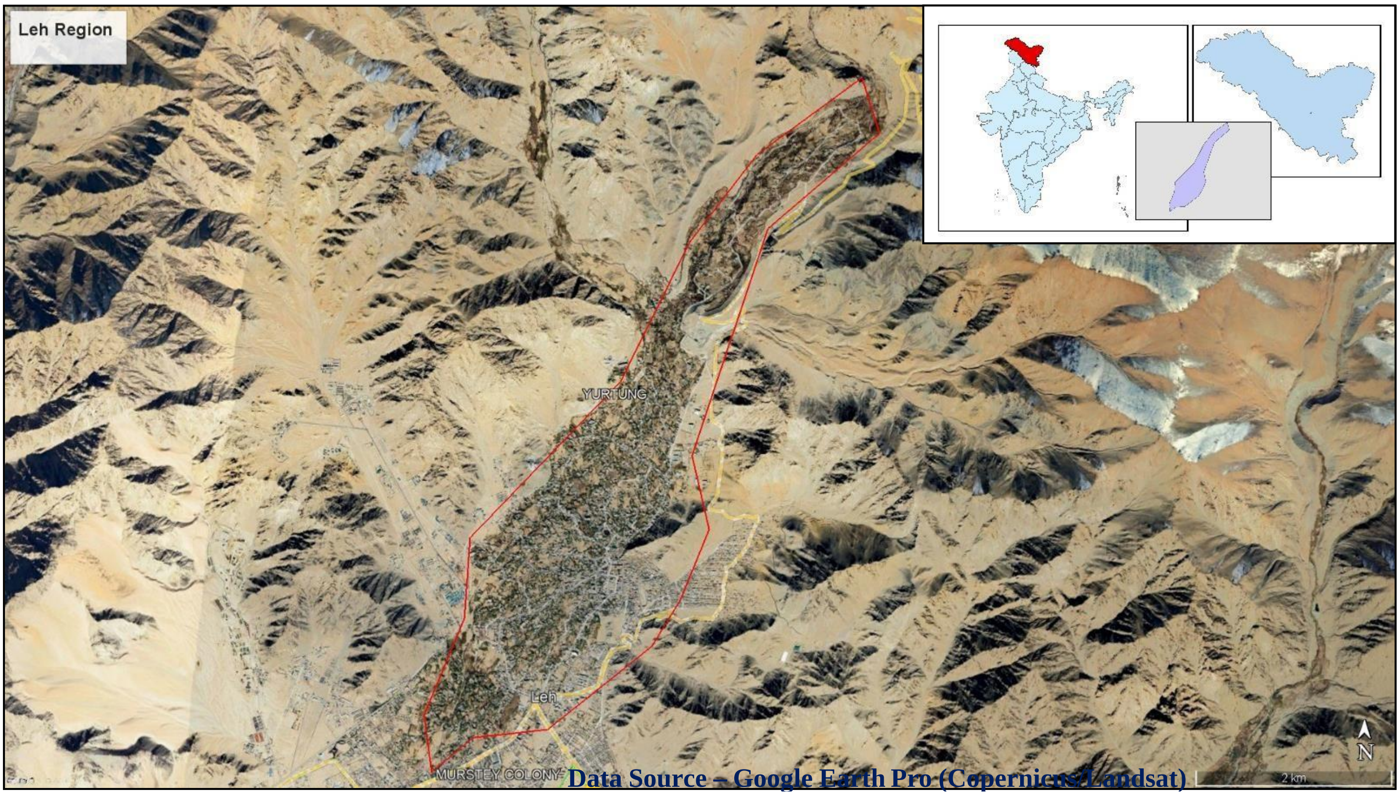
To provide safe drinking water and ensure safe addition of surface water to groundwater, water must be free from impurities for domestic and agricultural uses. There are several water quality parameters used by scientific studies such as temperature, total dissolved solids, turbidity, hardness, alkalinity, chloride etc. Investigators from the National Institute of Technology Raipur with LNP collected water sample from borewells, spring water, and surface water in the study area. Further, these samples were sent to laboratory of National Institute of Technology Raipur for analysis and preparation of water quality report of the study sites. This chapter gives a detailed report on water quality parameters based on collected water samples.

When assessing water quality, it is essential to consider chemical parameters such as pH, dissolved oxygen (DO), nutrients (nitrogen and phosphorus), heavy metals, and organic compounds. Temperature, turbidity, andsedimentation are physical parameters that have a direct impact on water clarity, habitat suitability, and chemical reactions. On the other hand, biological parameters, such as the presence of pathogens, algae, and aquatic organisms, provide insights into the overall health of the ecosystem and the safety of the water. The presence of radioactive elements such as radon, radium, and uranium in water sources is assessed through radiological parameters. These elements can enter water sources naturally or as a result of human activities. Anthropogenic activities, including industrial discharge, agricultural runoff, urban development, and improperwaste disposal, have a substantial impact on water quality. They introduce pollutants, alter hydrological processes, and disrupt ecological functions.

8.2 Method of Chemical Analysis

Sampling was done in the month of October and November 2023 to test the various physiological parametersof the water of the regions. Total 19 sampling points were selected and their water sample was collected in polyethylene bottles, after rinsing them with the same sample water. All the sampling norms are according to American Public Health Association (APHA, 1995) guidelines. Sampling points lies in region, Leh (9 samplepoints), Stakmo Village (3 sample Points), Muth village (3 sample points), Nang village (4 sample points). Various type of water bodies chosen for sampling, Borewell (15 sample points), Stream (2 sample points), Canal (1 sample Point), Spring (1 sample point).

The sample were tested for the physical parameter such as PH, TDS, and temperature in the field itself, immediately after the sampling. After the completion of sampling the samples were transported to the laboratory to perform the chemical analysis to find out the major ion chemistry, including the Ca^{2+}, Mg^{2+}, Na^{+},K^{+}, Cl^{-}, SO_4^{2-}, F^{-}, NO_3^{-}, and Si^{4+}. The major ions including Ca^{2+}, Mg^{2+}, HCO_3^{-}, Cl^{-} were analysed with the titration method while Na^{+} and K^{+} were analysed by the flame photometric method. The rest of the parametersinclude the SO_4^{2-}, F^{-}, NO_3^{-}, and Si^{4+}, were analysed with the help of the spectrophotometric method. All chemical and physical analyses are conducted according to the standard analytical method APHA, 1995.



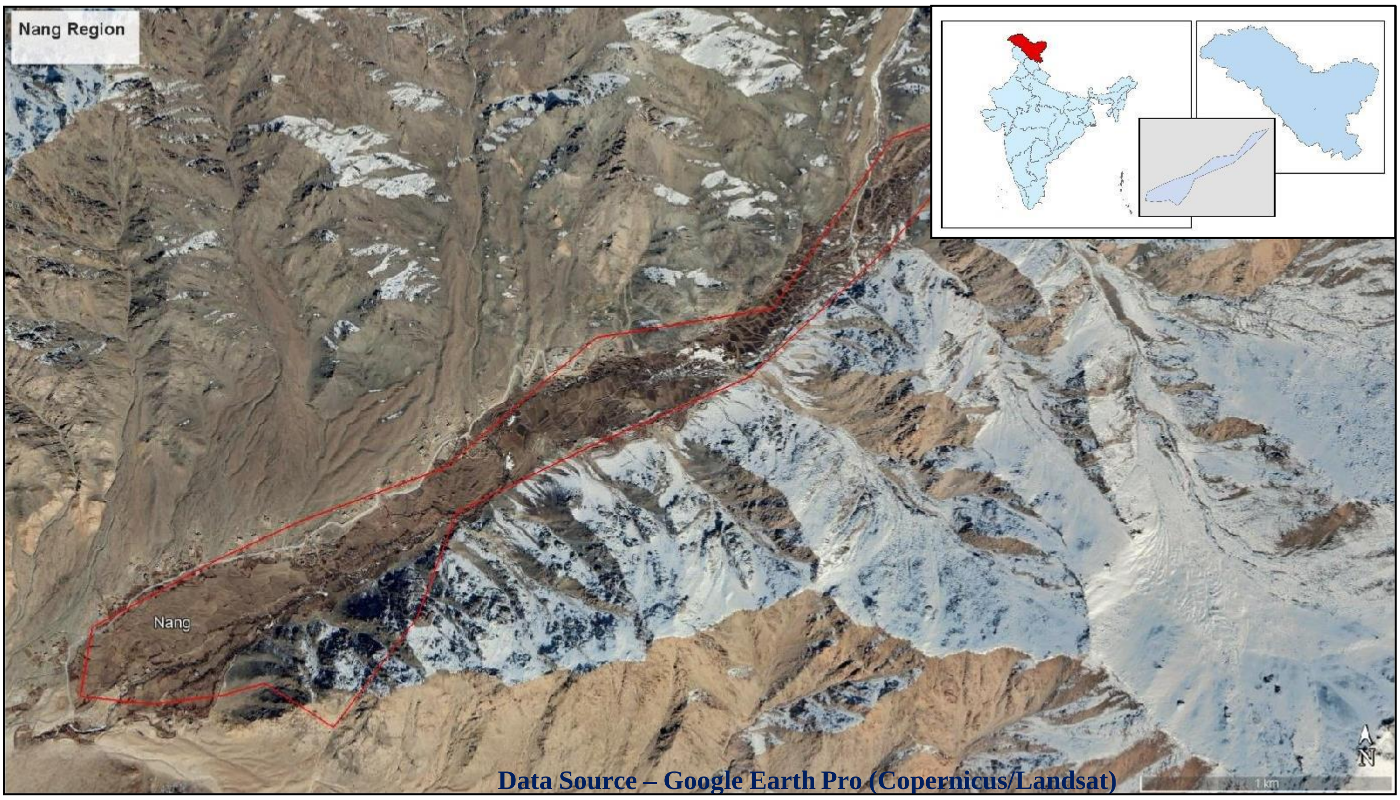


Fig 8.2 *- Nang Region Satellite Image with Study Area Boundary acquired from Google Earth Pro*

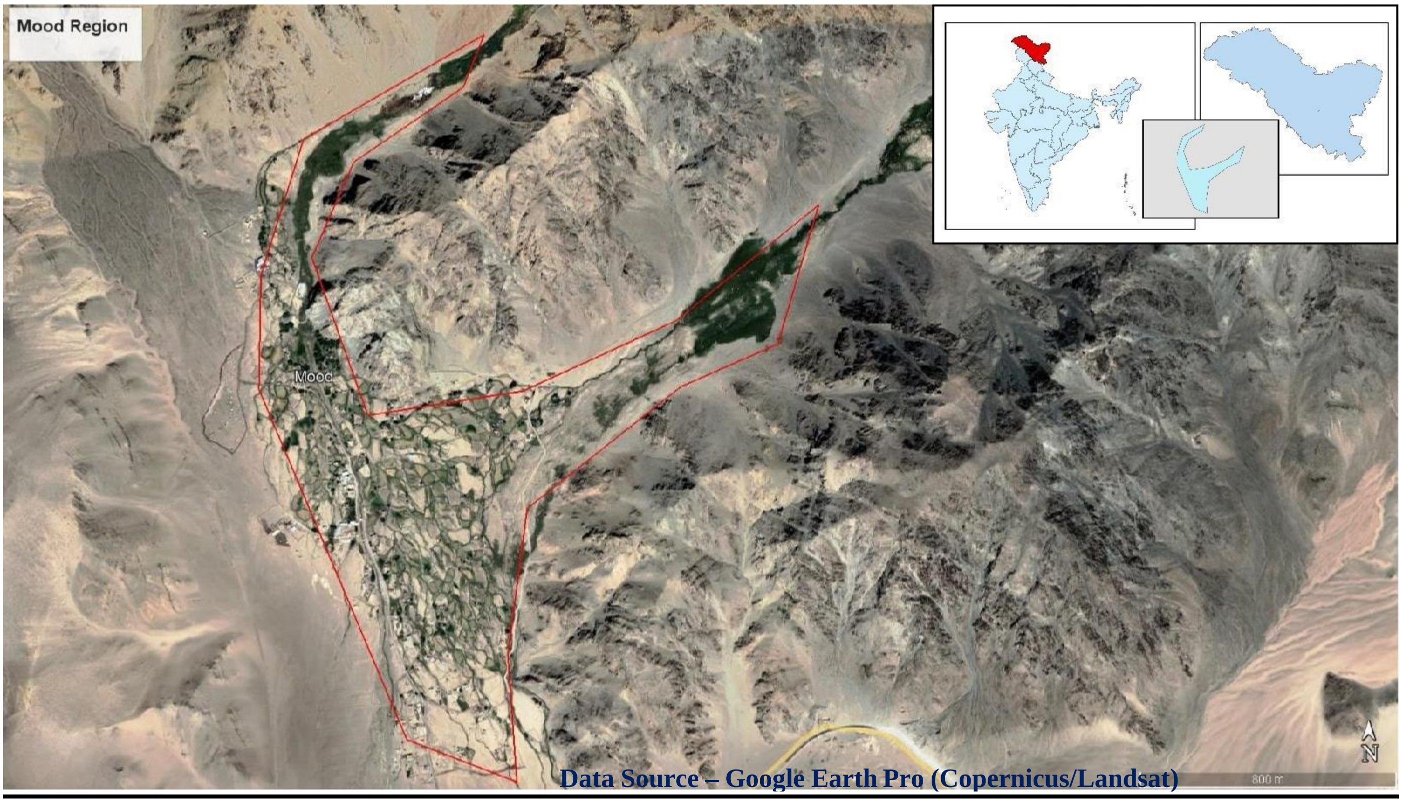


Fig 8.3 - *Mood Region Satellite Image with Study Area Boundary acquired from Google Earth Pro*

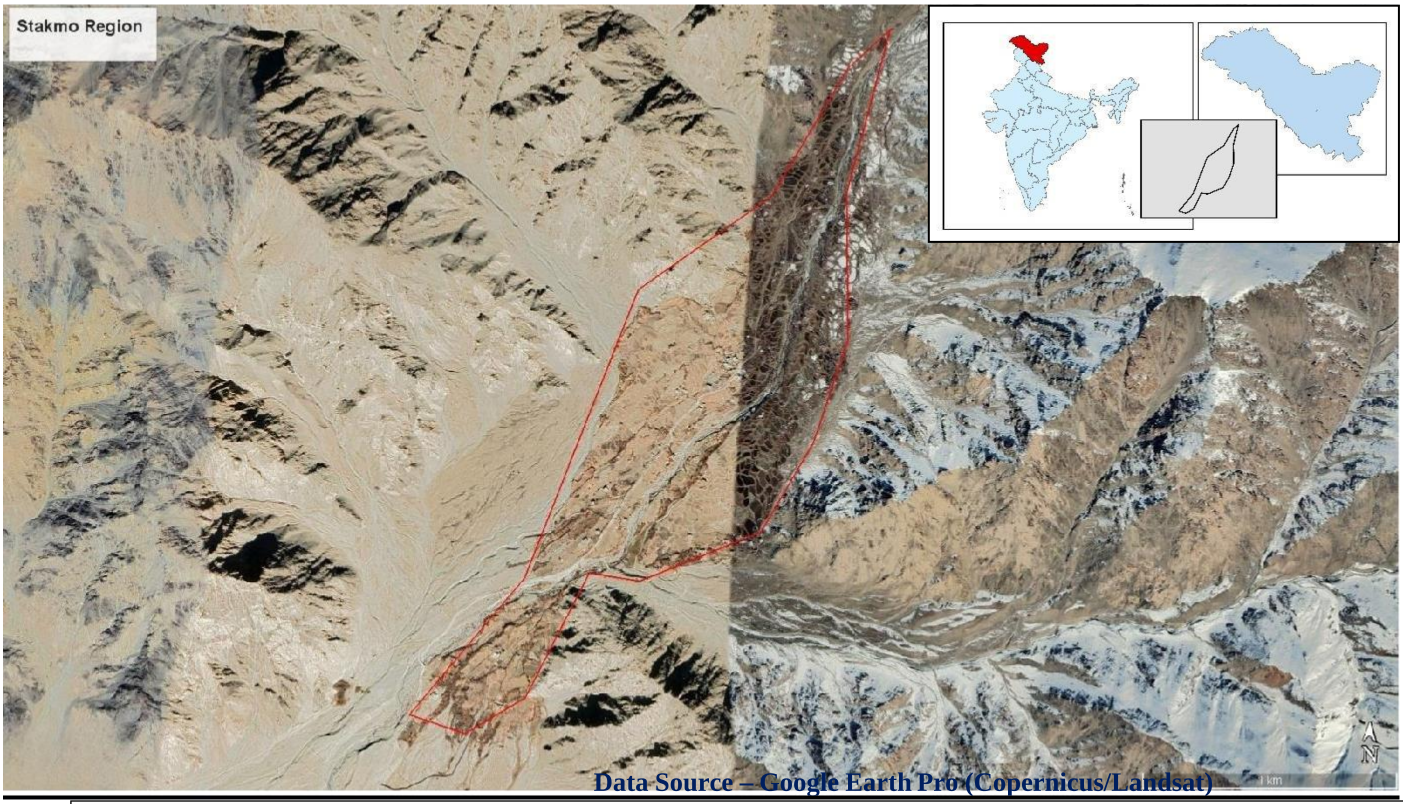


Fig 8.4 - *Stakmo Region Satellite Image with Study Area Boundary acquired from Google Earth Pro*

8.3 Results and Discussions

Following International standards (IS 10500:2012) the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^-, Cl^-, SO_4^{2-}, F^-, NO_3^-) are estimated from each sample through laboratory analysis which are listed in Table. The physicochemical parameter EC, pH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and HCO_3^-, Cl^-, SO_4^{2-}, F^-, NO_3^- are discussed below. The result obtained after the assessment of physicochemical parameters of the groundwater and surfacewater.

Table 8.1: Standard for drinking water {IS 10500 (2012)}

Sl. No	Substance or Characteristics	Requirement (acceptable Limit)	Permissible limit in the absence of alternative source	Undesirable effect outside the acceptable limit
1	Colour, Hazen unit, Max	5	15	Consumers acceptance decreases
2	Odour	Agreeable	Agreeable	-
3	Taste	Agreeable	Agreeable	
4	Turbidity, NTU, Max	1	5	Consumers acceptance decreases above 5
5	Dissolved solids, mg/l, Max	500	2000	Beyond this palatability decreases and may causegastrointestinal irritation
6	pH value	6.5 – 8.5	No relaxation	Beyond this, the water will affect the mucous membrane and/or water supply system
7	Total Hardness (as $CaCO_3$), mg/l, Max	200	600	Encrustation in water supply structure (scaling),excessive soap consumption, calcification of arteries. Leads to an unpleasant taste
8	Calcium (Ca^{2+}), mg/l, Max	75	200	Encrustation in the water supply system and adverse effect on domestic use
9	Magnesium (Mg^{2+}), mg/l, Max	30	100	Encrustation in the water supply system and adverse effect on domestic use
10	Sodium (Na^{+}), mg/l, Max	No guideline		Harmful to persons suffering from cardiac, renal & circulatory disease
11	Potassium (K^{+}), mg/l, Max	No guideline		An essential nutrient, but in excess is laxative
12	Chloride (Cl^-), mg/l, Max	250	1000	Taste, palatability, digestion are affected. Adverseto persons having heart & kidney disorder, cause corrosion

13	Sulphate (SO_4^{2-}), mg/l, Max	200	400	Beyond this causes gastro-intestinal irritation whenMg or Na is present
14	Nitrate (NO_3^-), mg/l, Max	45	No relaxation	Causes Methaemoglo-binamia in babies andindicative of pollution
15	Fluoride (F^-), mg/l, Max	1.0	1.5	High fluoride causes fluorosis

8.3.1 Temperature

Chemical and biological processes in water systems are greatly impacted by temperature. As temperatures rise, reaction rates accelerate, resulting in an increased dissolution of chemicals and minerals within the water.The temperature recorded in groundwater samples collected from the study area ranges from 7.7 to 12.2 Degree Celsius and in surface water from 5.3 to 8.9 Degree Celsius.

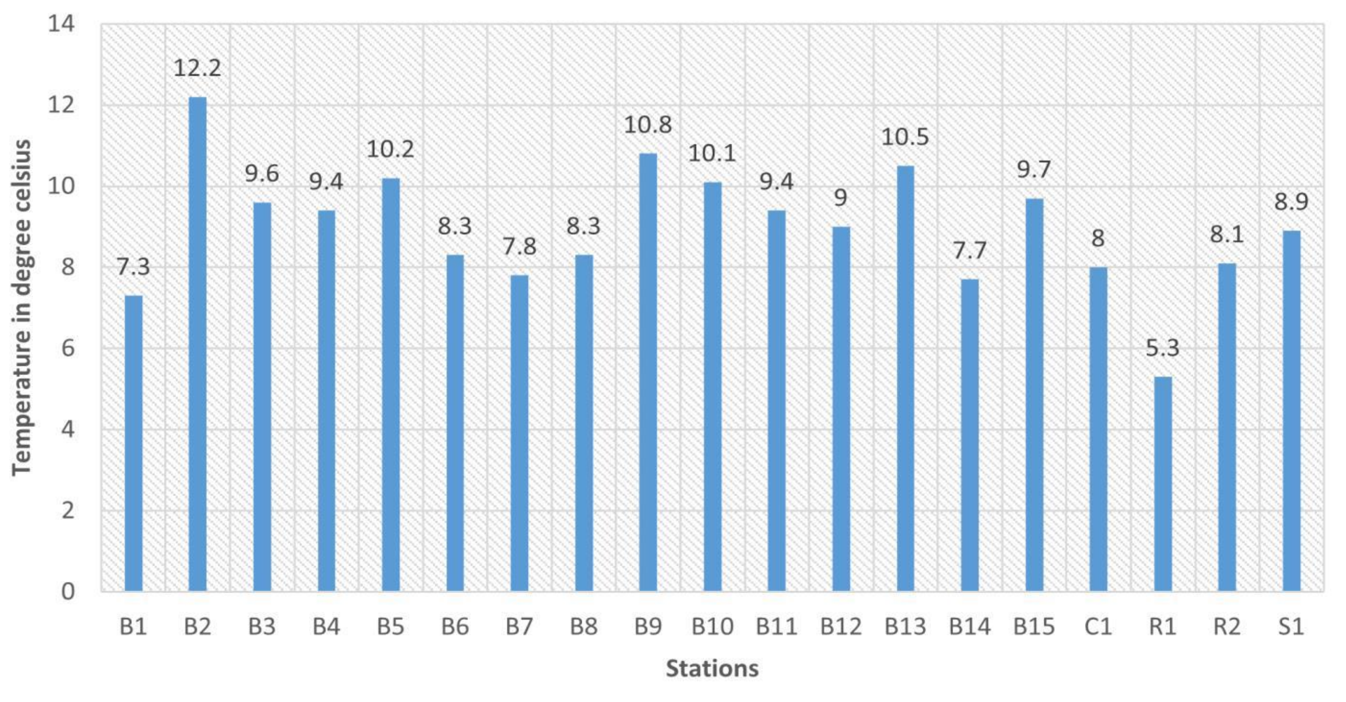


***Fig 8.5** – Temperature Variation in Water of Study Area based on Sampling result*

Plain Summary

Temperature is a key factor that influences chemical and biological processes in water. When temperatures rise, reactions happen faster, and chemicals and minerals dissolve more easily.

Cold temperatures can cause a decrease in biological processes, such as microbial activity. This could result in a slower breakdown of organic matter, which may lead to less organic pollutants in groundwater.

Dissolved oxygen levels are typically higher in cold groundwater when compared to warmer water. Aquatic life thrives in water that contains plenty of dissolved oxygen, which also helps to keep the water clean and healthy.The temperature range of 5.3 to 12.2 degrees Celsius has minimal influence on chemical reactions in groundwater. This is because the region experiences stable and relatively low.

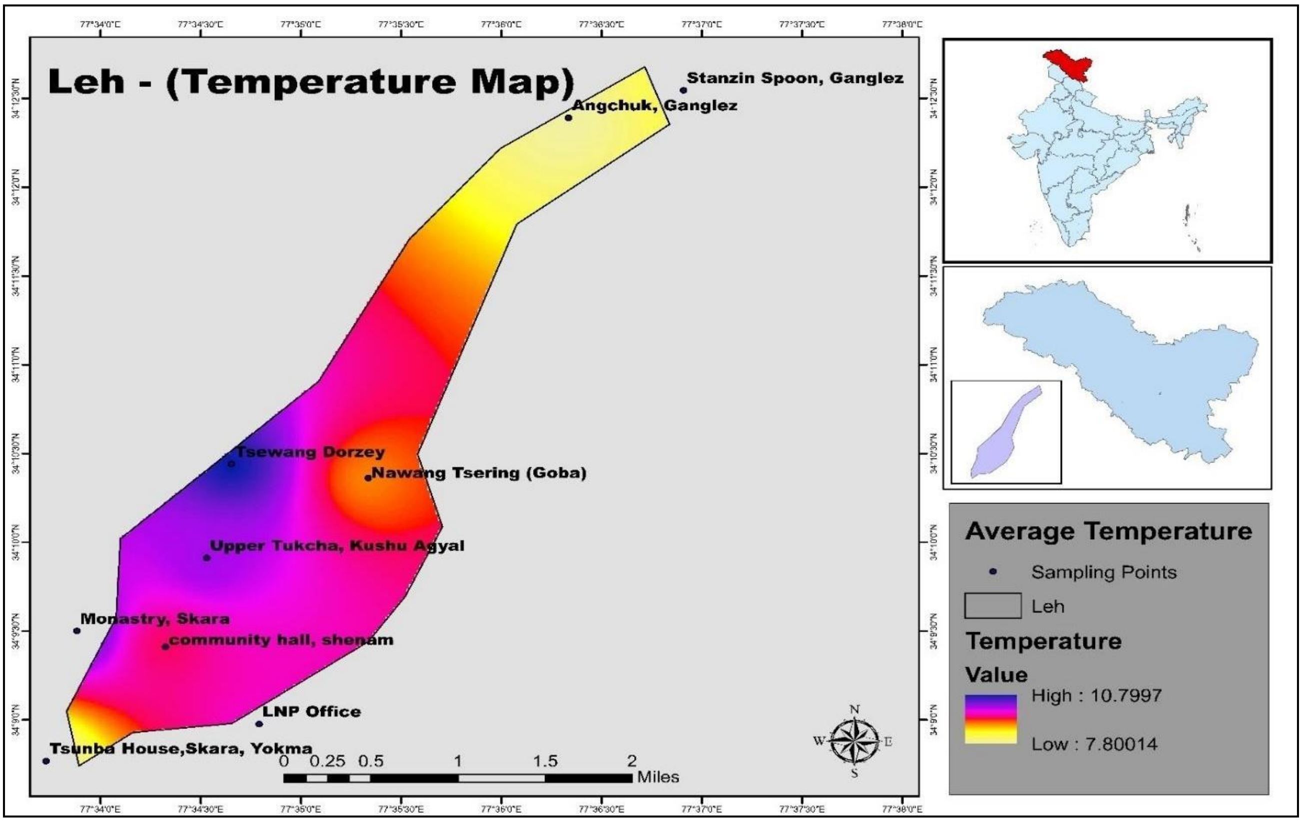


Fig 8.6 – *Temperature Variation in Water of Leh Region based on Sampling result*

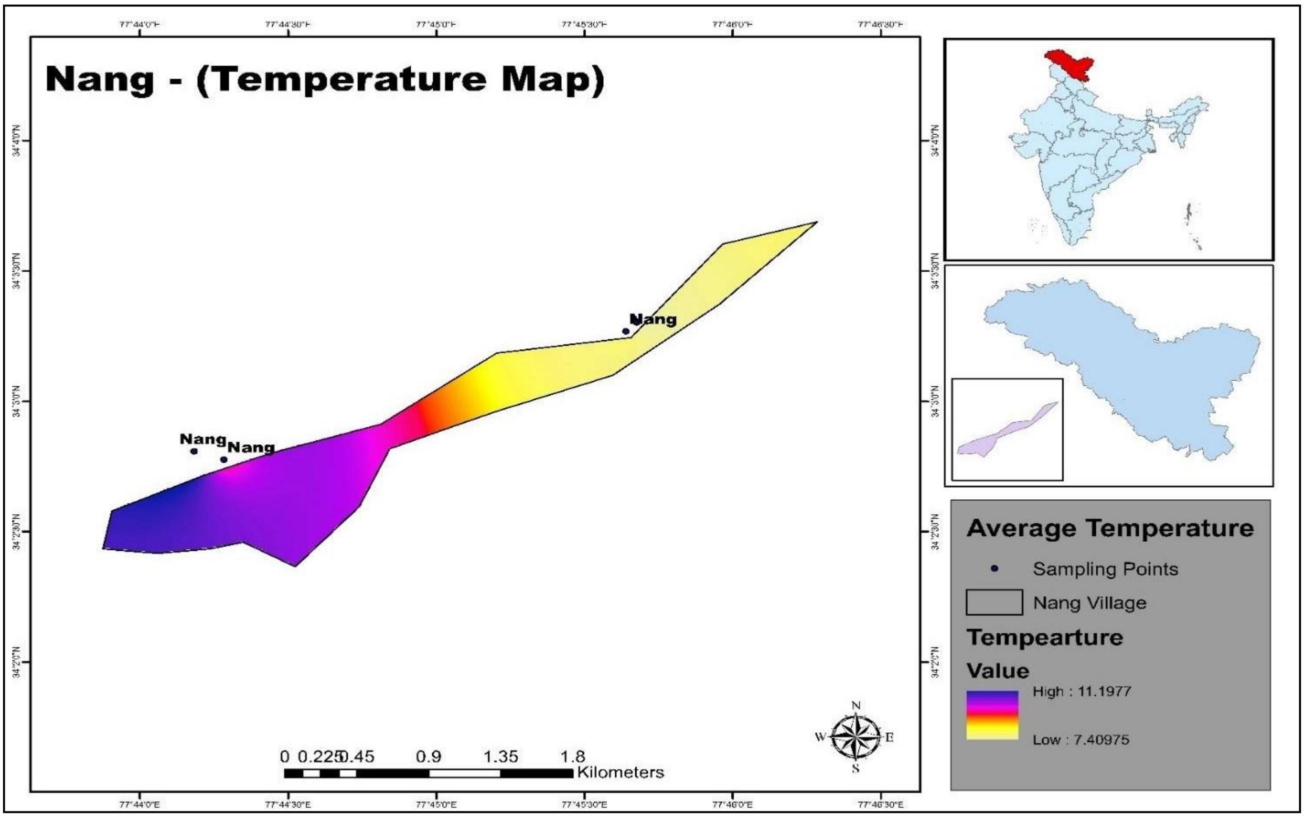


Fig 8.7 – *Temperature Variation in Water of Namg Region based on Sampling result*

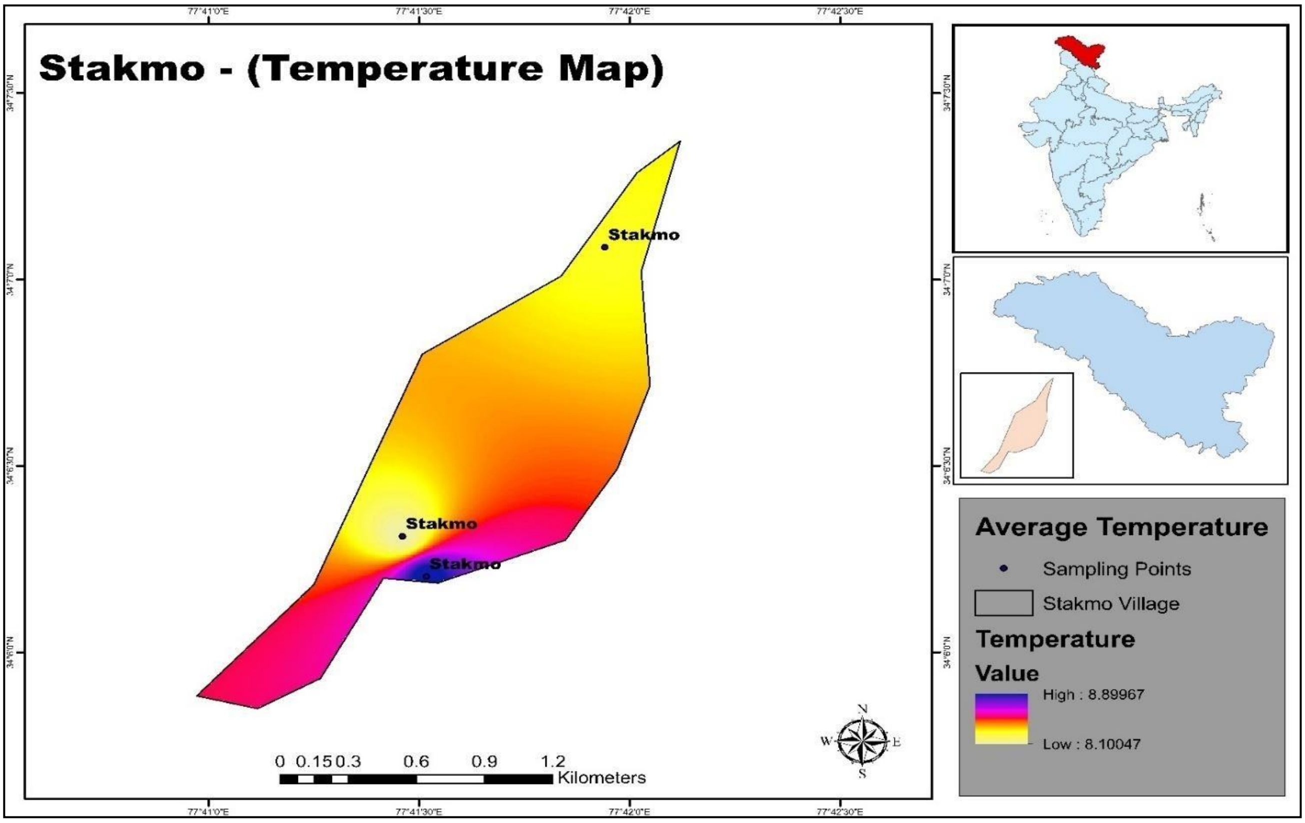


Fig 8.8 – Temperature Variation in Water of Stakmo Region based on Sampling result

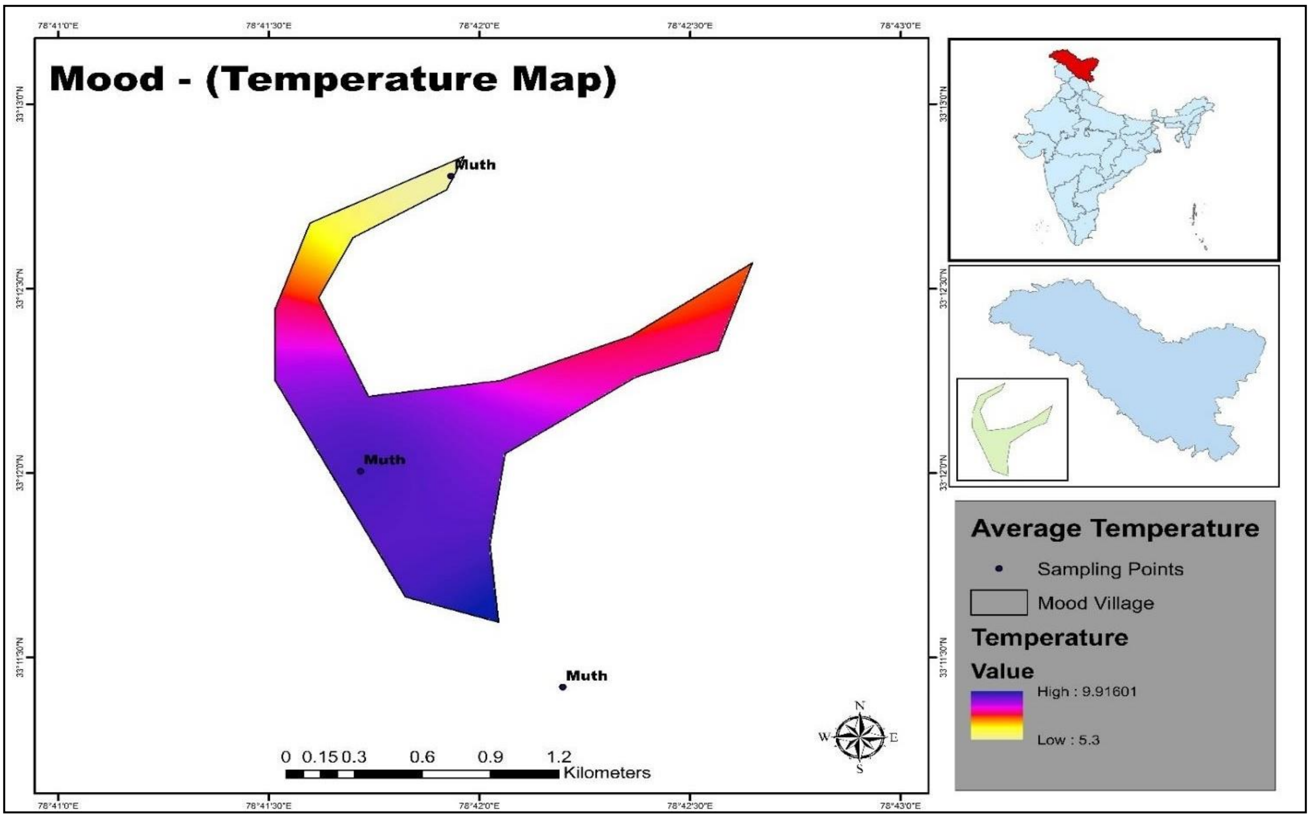


Fig 8.9 – Temperature Variation in Water of Mood Region based on Sampling result

8.3.2 PH Value

The pH level plays a significant role in determining whether water is acidic or alkaline. It measures the concentration of hydrogen ions in the water. A pH value of 7 signifies neutrality, whereas values below 7 indicate acidity and values above 7 indicate alkalinity. As per Indian standards, the acceptable pH range isbetween 6.5 and 8.5, without any specific limits mentioned.

The statistical analysis of groundwater in the area shows that the pH of the area varies from 3.05 to 5.3. The obtained mean value is 4.20 with a median of 4.25 and a standard deviation of 0.62. Whereas in the case of surface water the values varying from 3.96-8.5 with mean, median, and standard deviation values of 5.29, 4.83, and 2.04.

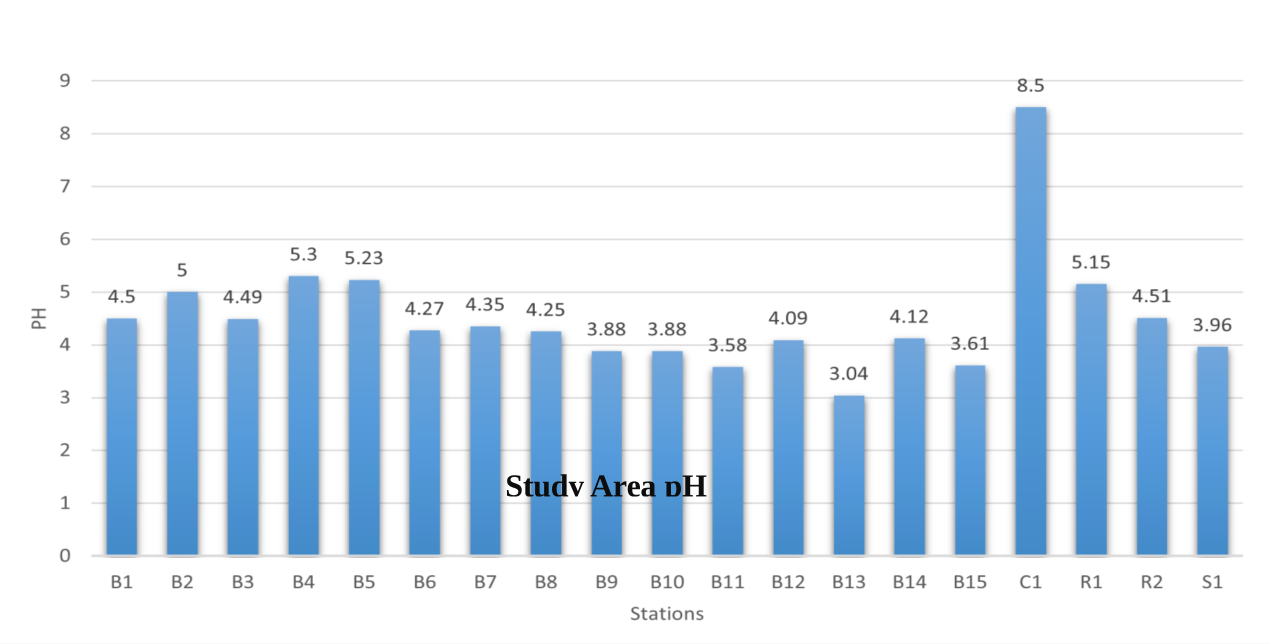


***Fig 8.10** – PH Value of Water of Study Area based on Sampling*

Plain Summary

The pH levels of both groundwater and surface water indicate different levels of acidity.

Under acidic conditions, some minerals and metals can dissolve more easily, which may resultin higher levels of harmful substances like lead and cadmium in the water.

Corrosion or scaling in water distribution systems, pipes, and infrastructure can occur whenpH levels become extremely high or low. Acidic water, in particular, can corrode metal pipesand cause metals to leach into the water supply, leading to infrastructure damage.

When the pH levels of water are either too low or too high, it can result in unpleasant tastes andOdors, making it less desirable for consumers.

8.3.3 Total Dissolved Solids (TDS)

The determination of Total Dissolved Solids (TDS) involves the multiplication of Electrical Conductivity (EC)by 0.65. The relationship between TDS and EC is expressed as S = EC*K, where EC is measured in µS/cm. S represents TDS in milligrams per litre, and K is a proportionality constant typically ranging from 0.55 to

0.75. Higher values of K indicate elevated Sulphate concentrations. According to BIS standards, the acceptableand permissible limits for TDS are defined as 500 and 2000 mg/l, respectively.

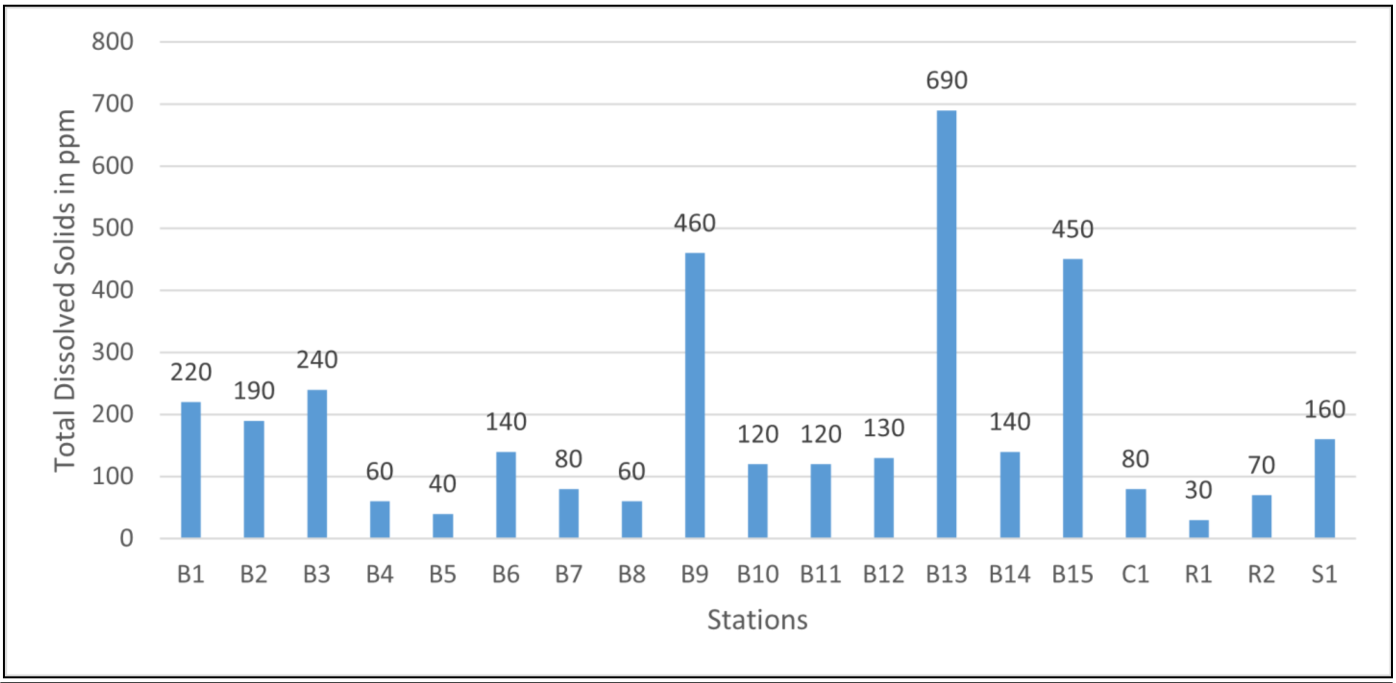


Fig 8.11 *– Total Dissolved Solids in Water of Study Area based on Sampling result*

The maximum value to TDS reported in the groundwater is 690 mg/l and for the surface water it is 160 mg/l and the minimum value reported from the calculation is 40 mg/l and 30 mg/l respectively.

Summary

TDS levels between 30 ppm and 690 ppm are usually considered safe for drinking water. Lower TDS levels, like 30 ppm, indicate purer water with fewer minerals. On the other hand, higher TDS levels, such as 690 ppm, suggest a higher concentration of dissolved minerals and salts.

Water that has lower TDS levels might have a fresher taste and a more neutral flavour, whereas water with higher TDS levels could taste slightly salty or mineral-like.

Groundwater with high total dissolved solids (TDS) may indicate the entry of salty water sources or pollution from human activities. This can pose challenges for agricultural irrigation, the availability of safe drinking water, and the overall health of ecosystems.

TDS of the groundwater always shows a higher concentration than the surface water, which is more of dynamic nature.

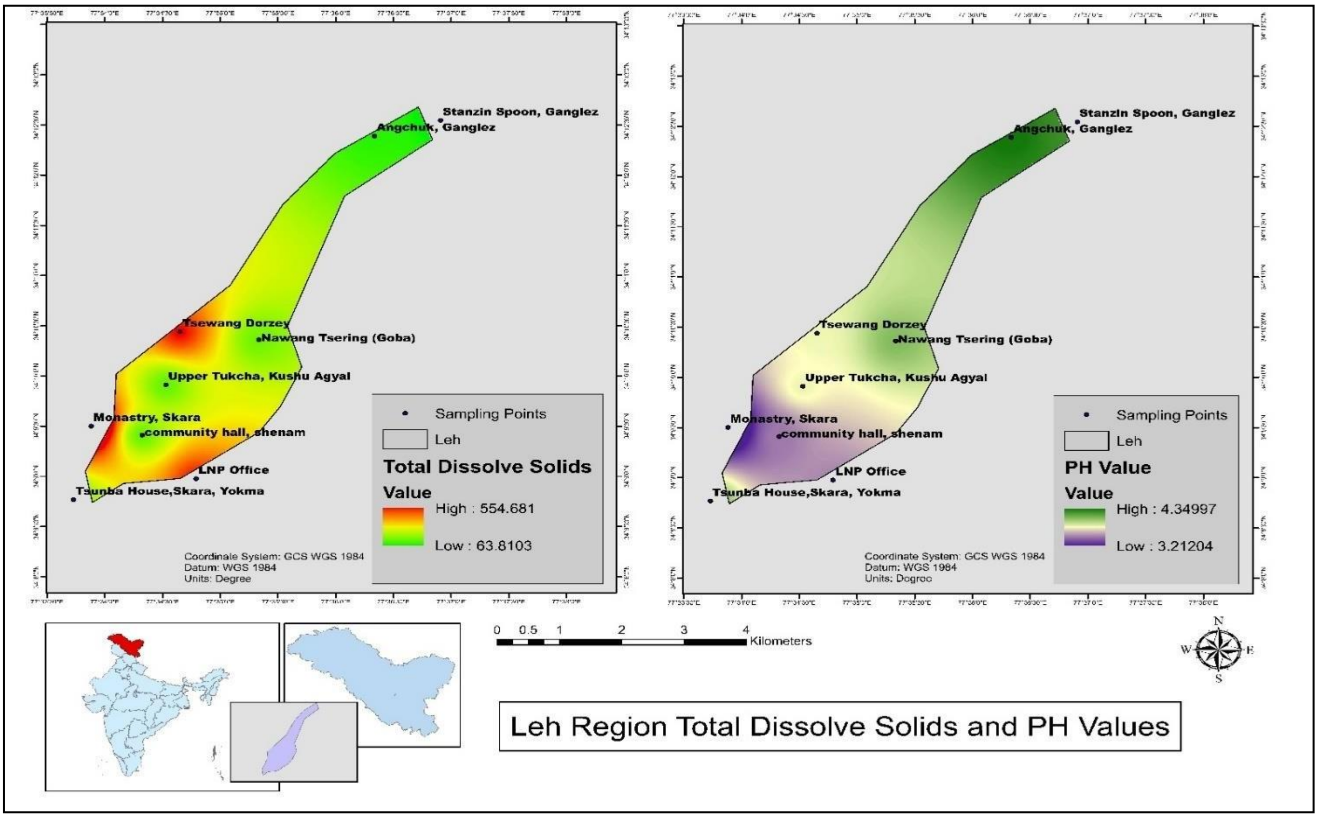


***Fig. 8.12** – PH Value and TDS of Water of Leh Region based on Sampling result*

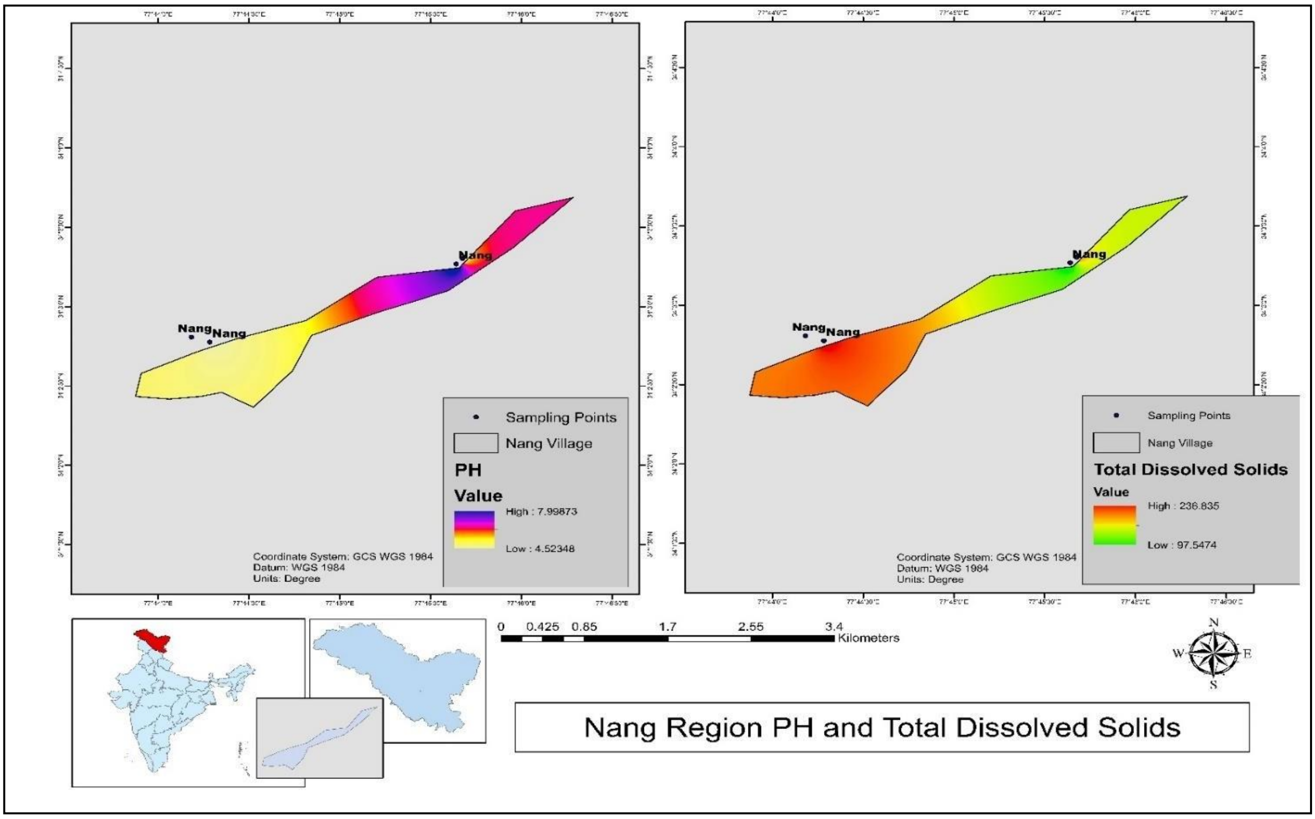


***Fig. 8.13** – PH Value and TDS of Water of Nang Region based on Sampling result*

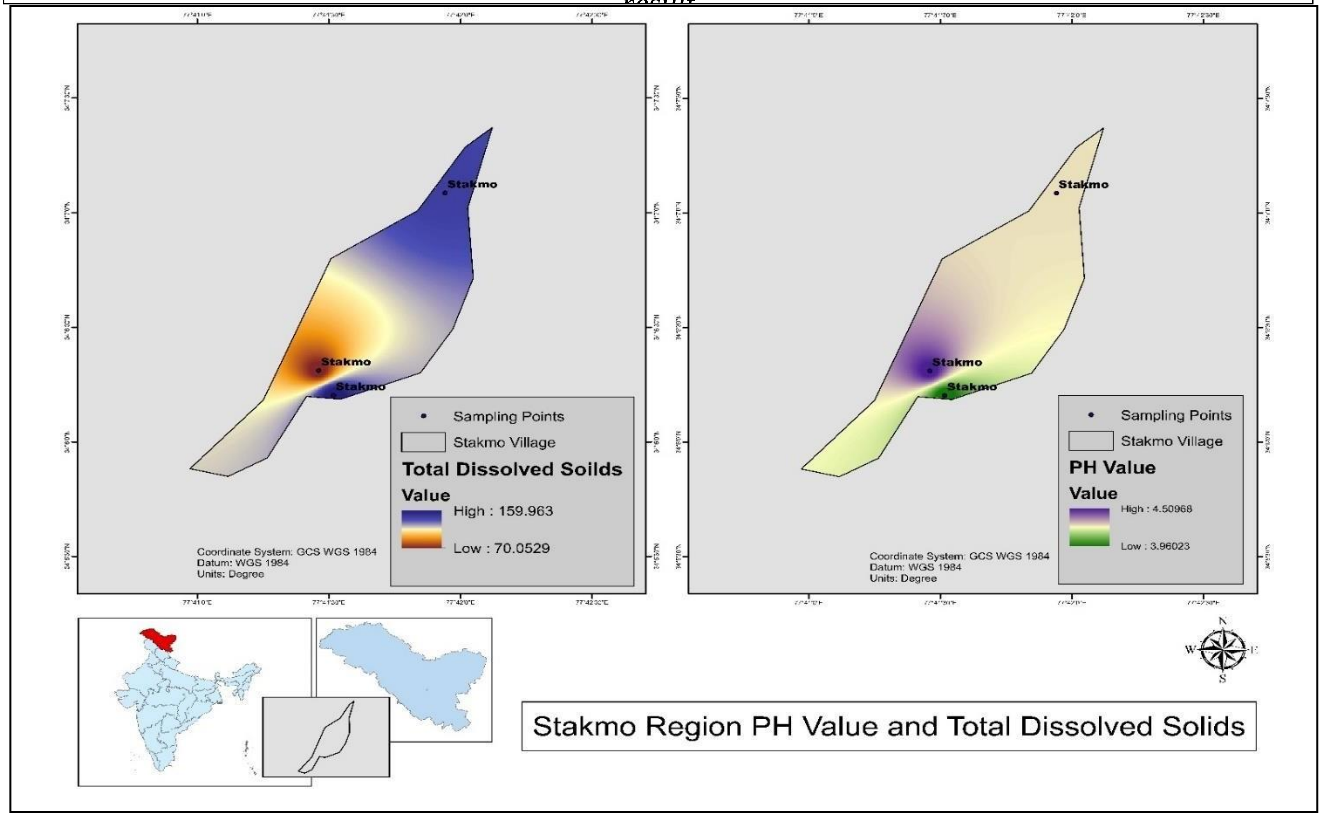


***Fig. 8.14** – PH Value and TDS of Water of Stakmo Region based on Sampling result*

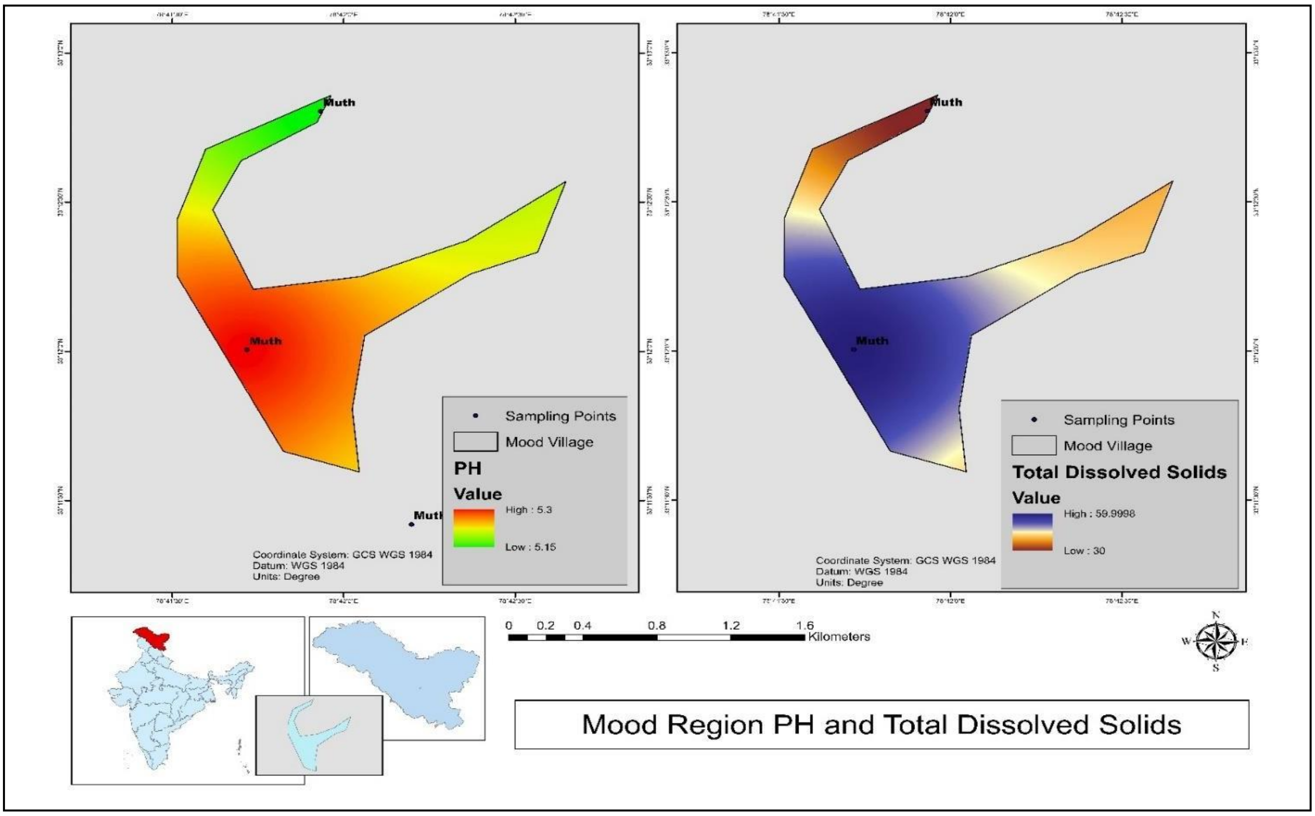


***Fig. 8.15** – PH Value and TDS of Water of Mood Region based on Sampling result*

8.3.4 Alkalinity

The presence of bicarbonates, carbonates, and hydroxides in water gives rise to alkalinity, often originating from the weathering of rocks. When alkalinity levels are high, it can result in a bitter taste and have detrimentaleffects on irrigation, causing damage to the soil and reducing crop yields. Groundwater typically contains carbonate and bicarbonate ions that come from dissolved carbon dioxide in rain and snow, which further dissolves carbon dioxide upon entering the soil. The solubility of carbon dioxide in water decreases with decreased pressure and increased temperature. Additionally, the decomposition of organic matter releases carbon dioxide, which can dissolve in water. The pH of water indicates the form of carbon dioxide present: carbonic acid below pH 4.5, bicarbonate between pH 4.5 and 8.3, and carbonate above pH 8.2. Under normalcircumstances, bicarbonate levels in groundwater may vary from 100 to 800 ppm, contributing to water alkalinity and hardness.

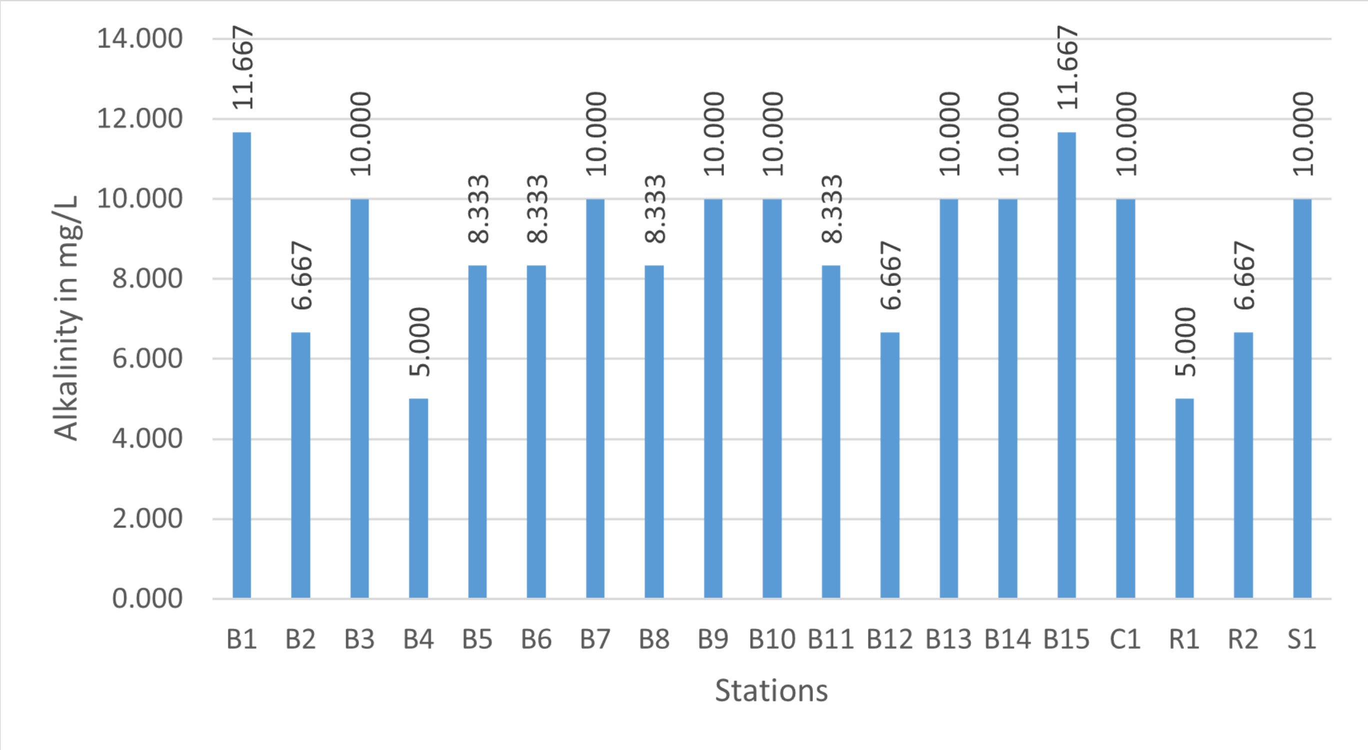


***Fig8.16** – Alkalinity of Water of Study Area based on Sampling result*

The alkalinity in the groundwater of the study area ranges from 5 mg/l to 11.67 mg/l as $CaCO_3$ and of surfacewater, it varies from 5 mg/l to 10 mg/l.

8.3.5 Chloride

Despite its minimal occurrence in crustal rocks, chloride plays a significant role in groundwater. The processes of evaporation, multiple cycles of evaporation and salt dissolution, interaction with evaporitic bodies, water entrapment during sedimentation, and intrusion of seawater all contribute to the elevated levels of chloride ingroundwater. Chloride salts have high solubility and do not undergo chemical reactions with minerals in reservoir rocks, thus existing as sodium chloride. The pollution caused by chloride-rich effluents from sewageand municipal waste is a contributing factor to the higher chloride levels in water.

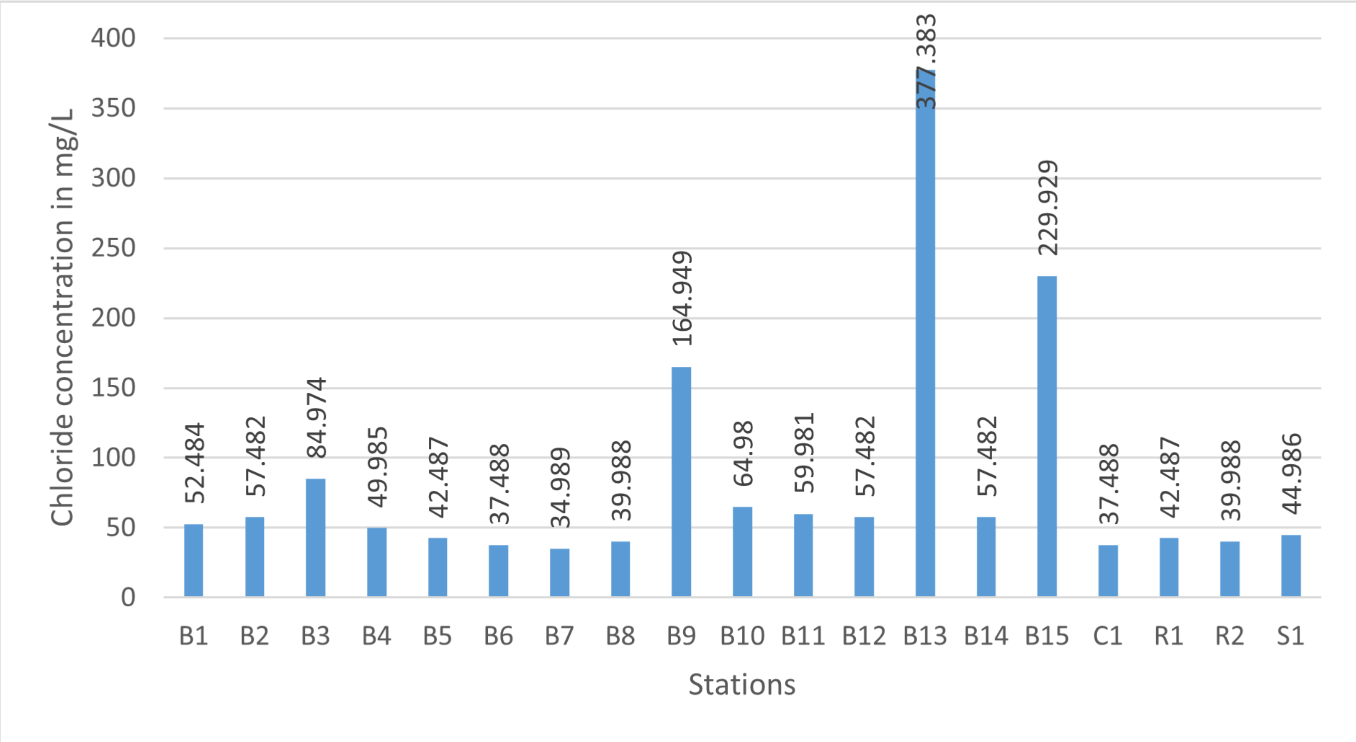


Fig.8.17 *– Chloride concentration in Water of Study Area based on Sampling result*

The measured chloride content shows that the range of 34.99 to 377.38 mg/l in groundwater and 37.488 to 44.986 mg/l is present in the surface water which is well within the BIS maximum permissible limits of 1000mg/l.

Plain Summary

The chloride concentrations within this range are generally within the acceptable limits for drinking water quality. However, if the levels approach the maximum value of 377 mg/l, it may suggest the presence of potential sources of contamination like industrial discharge, sewage effluent, or road runoff.

When the chloride levels in water are closer to the maximum value, it may have a salty or brackish taste, making it less pleasant for consumers.

Corrosion in metal pipes, fittings, and infrastructure can be accelerated by the presence of high chloride concentrations, resulting in deterioration and structural damage over time.

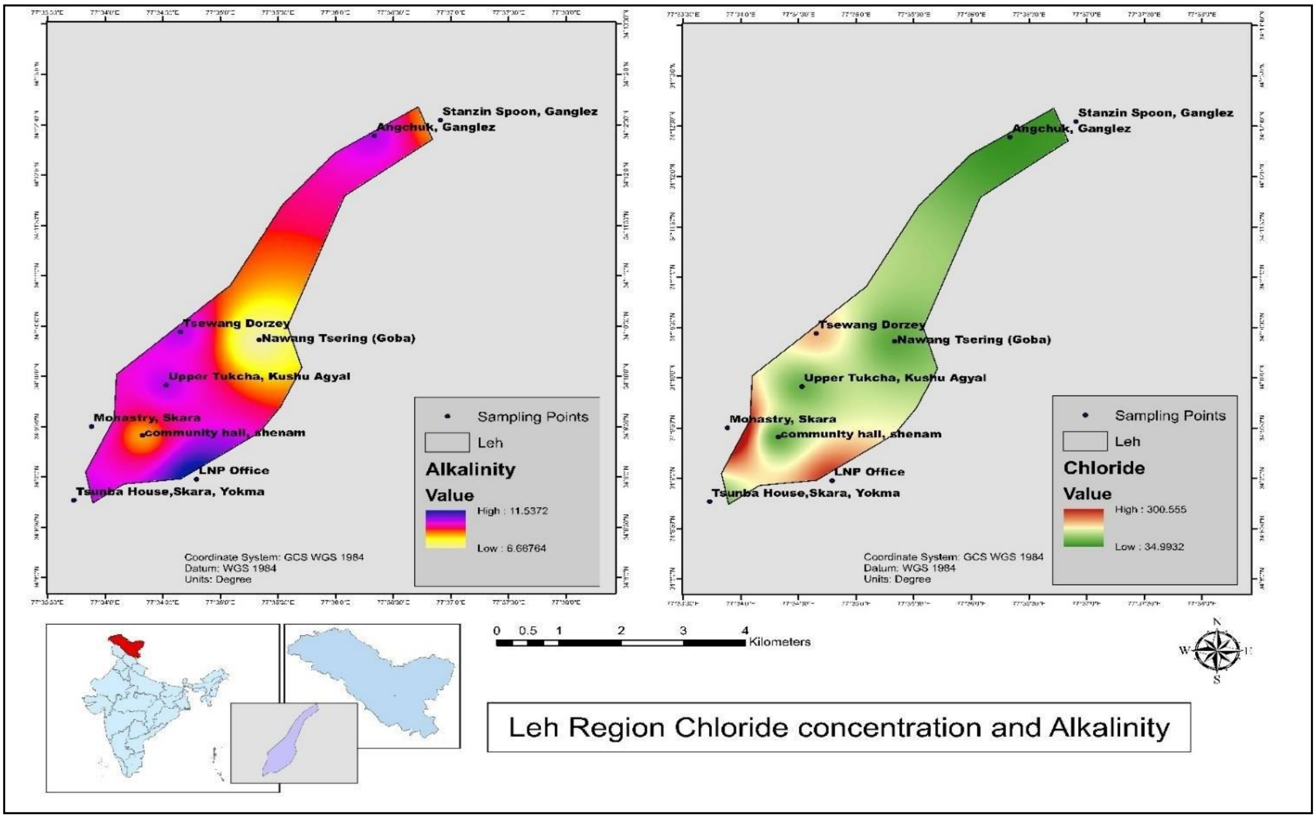


Fig 8.18 – *Alkalinity and Chloride conc of Water of Leh Region based on Sampling result*

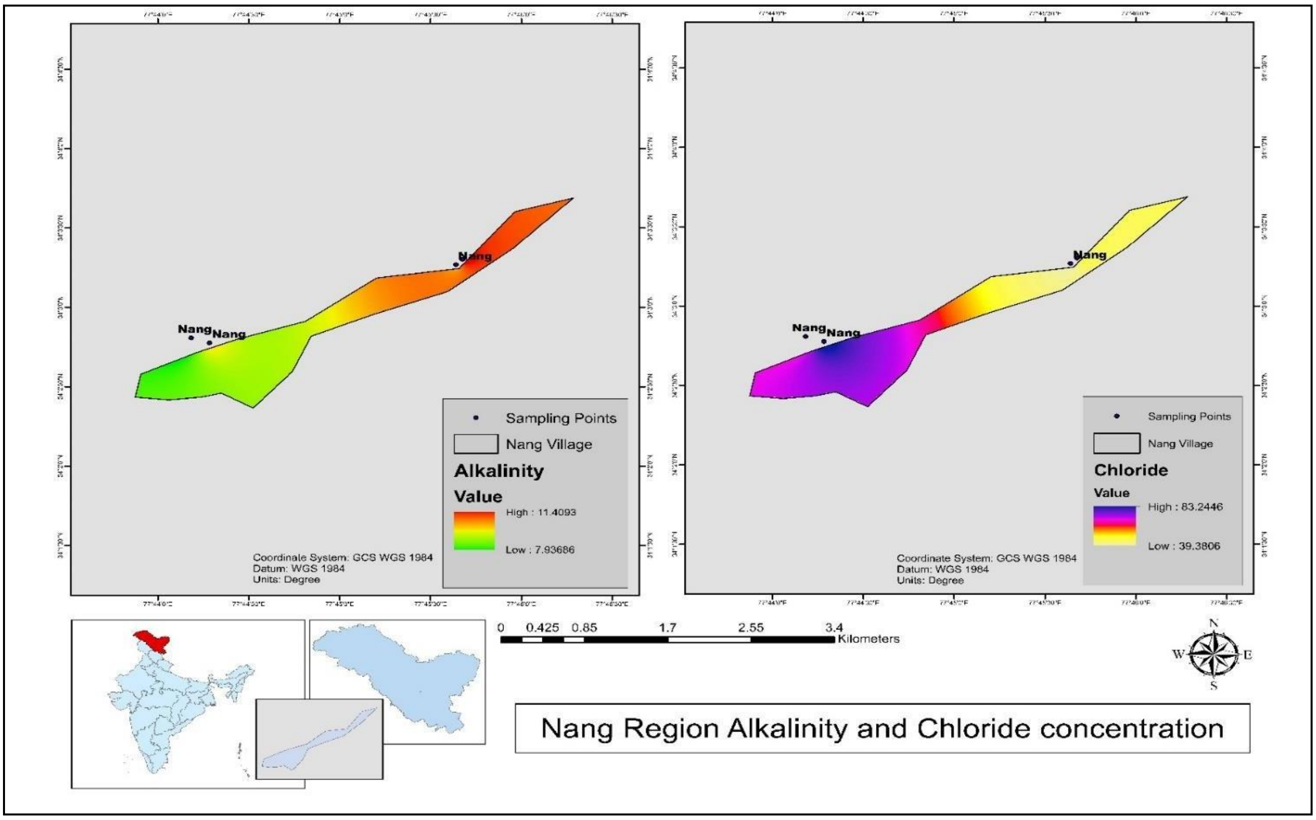


Fig 8.19 *– Alkalinity and Chloride conc of Water of Nang Region based on Sampling result*

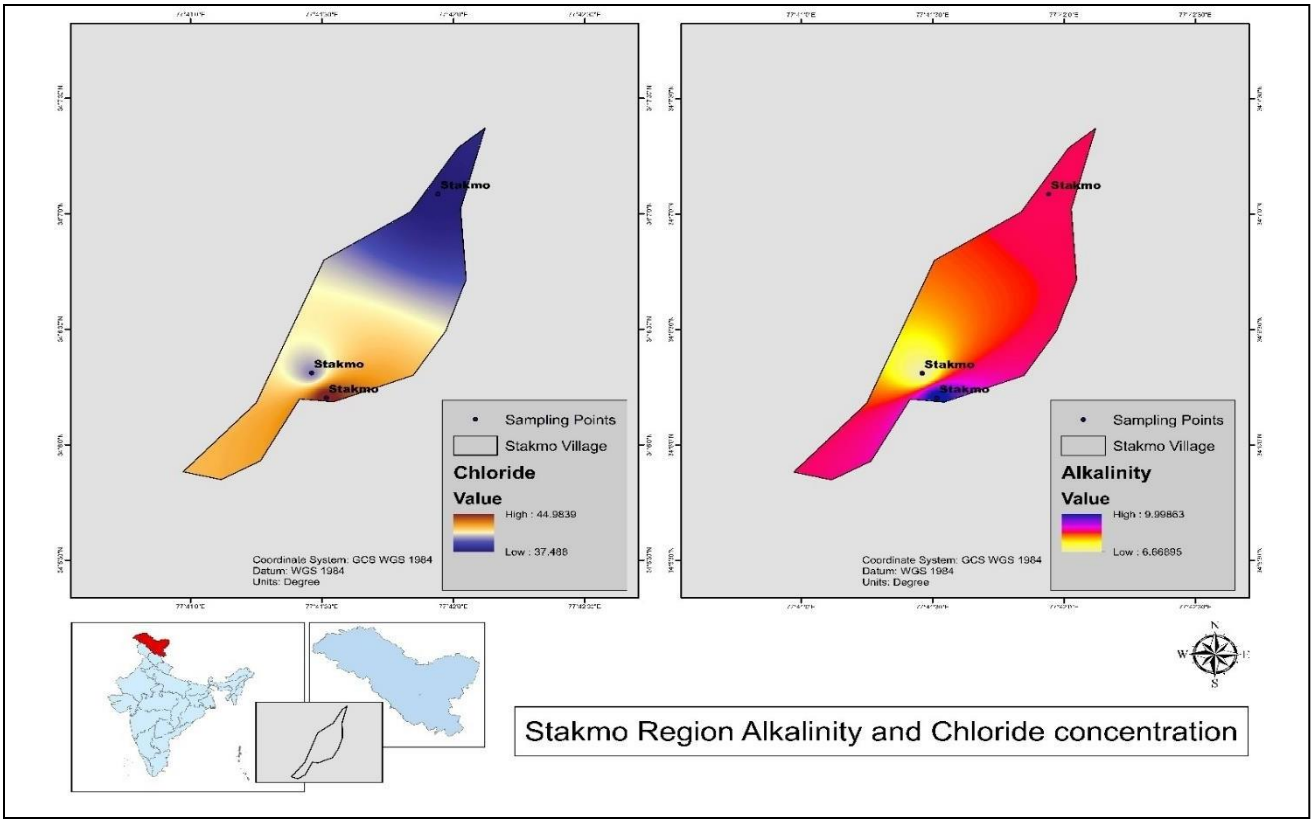


***Fig 8.20** – Alkalinity and Chloride conc of Water of Stakmo Region based on Sampling result*

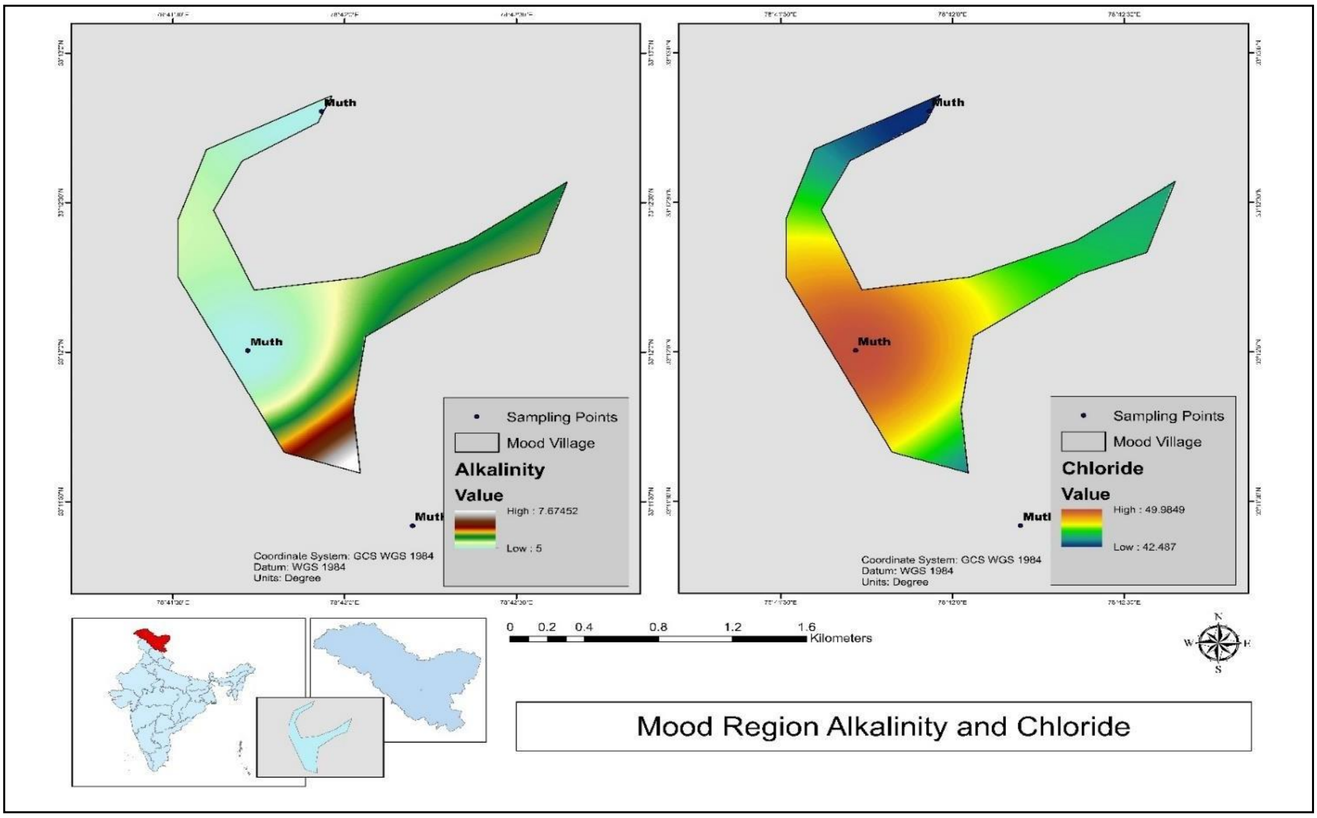


***Fig 8.21** – Alkalinity and Chloride conc of Water of Mood Region based on Sampling result*

8.3.6 Sodium

Sodium, ranking as the sixth most abundant element on Earth, is widely distributed across soils, plants, water,and food sources. Numerous regions globally possess significant reservoirs of sodium-rich minerals, with sodium chloride (common salt) being particularly prominent. In groundwater, sodium occurs naturally and lacks Odor, but most individuals can detect it when its concentration exceeds 200 milligrams per Liter (mg/L).The prevalence of sodium compounds in rocks and soils facilitates its easy dissolution, resulting in its ubiquitous presence in groundwater.

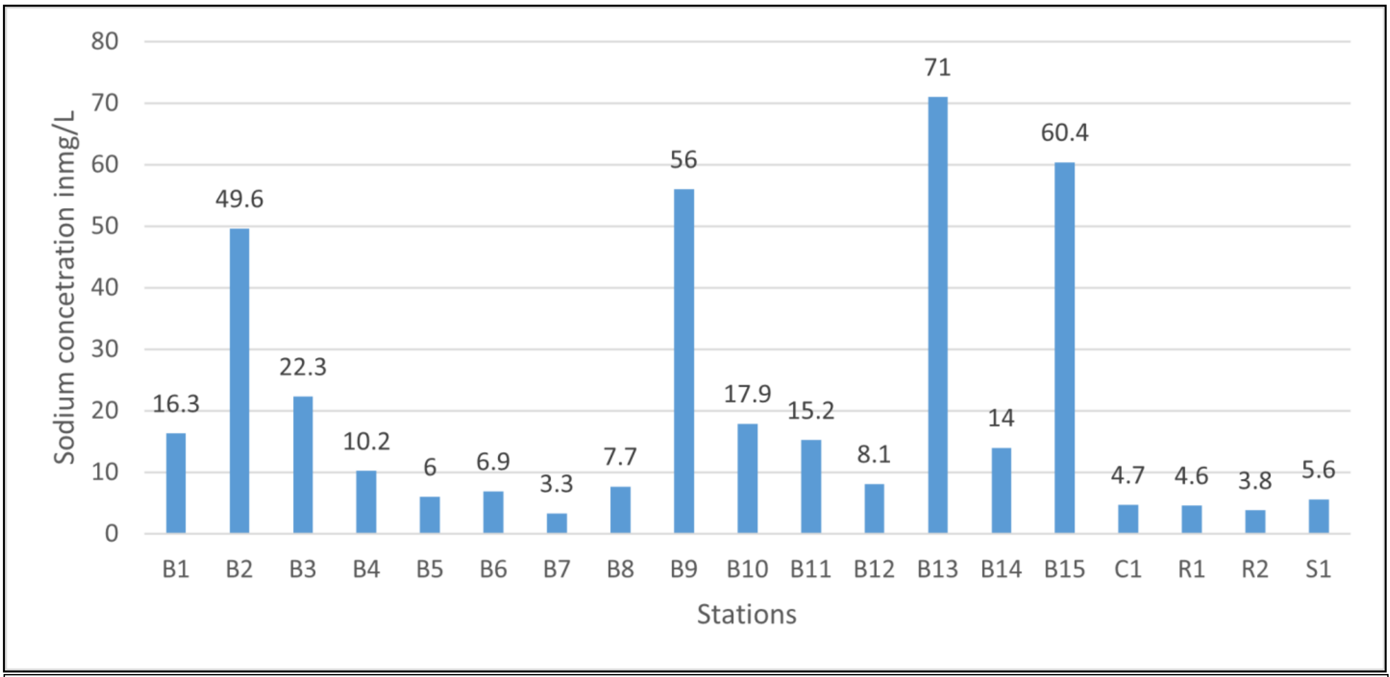


***Fig 8.22** – Sodium concentration in Water of Study Area based on Sampling result*

The range of Na^+ ions in the groundwater samples of the study area varies from 3.3 to 71 mg/l with a mean, median, and standard deviation of 16.23 mg/l, 15.20 mg/l, and 22.74. The range of Na^+ ions in the surface water samples analysed are varies from 3.8 to 5.6 mg/l with mean, median, and standard deviation of 4.63 mg/l, 4.65 mg/l, and 0.74.

8.3.7 Potassium

Potassium, a commonly found element in soils and rocks, does not have any smell or color when dissolved inwater. However, it does have the ability to give water a salty taste. Due to its positive charge, potassium ionscan be taken up by the negatively charged colloidal constituents present in soil and rock. These colloidal constituents include silicate clay minerals, iron and aluminum oxides, and organic colloids. The extent of potassium absorption depends on the type and quantity of colloids that are present. As a result, peat, which isknown for having a large number of highly charged organic colloids, will absorb a significantly higher amountof potassium compared to sand, which has fewer colloids.

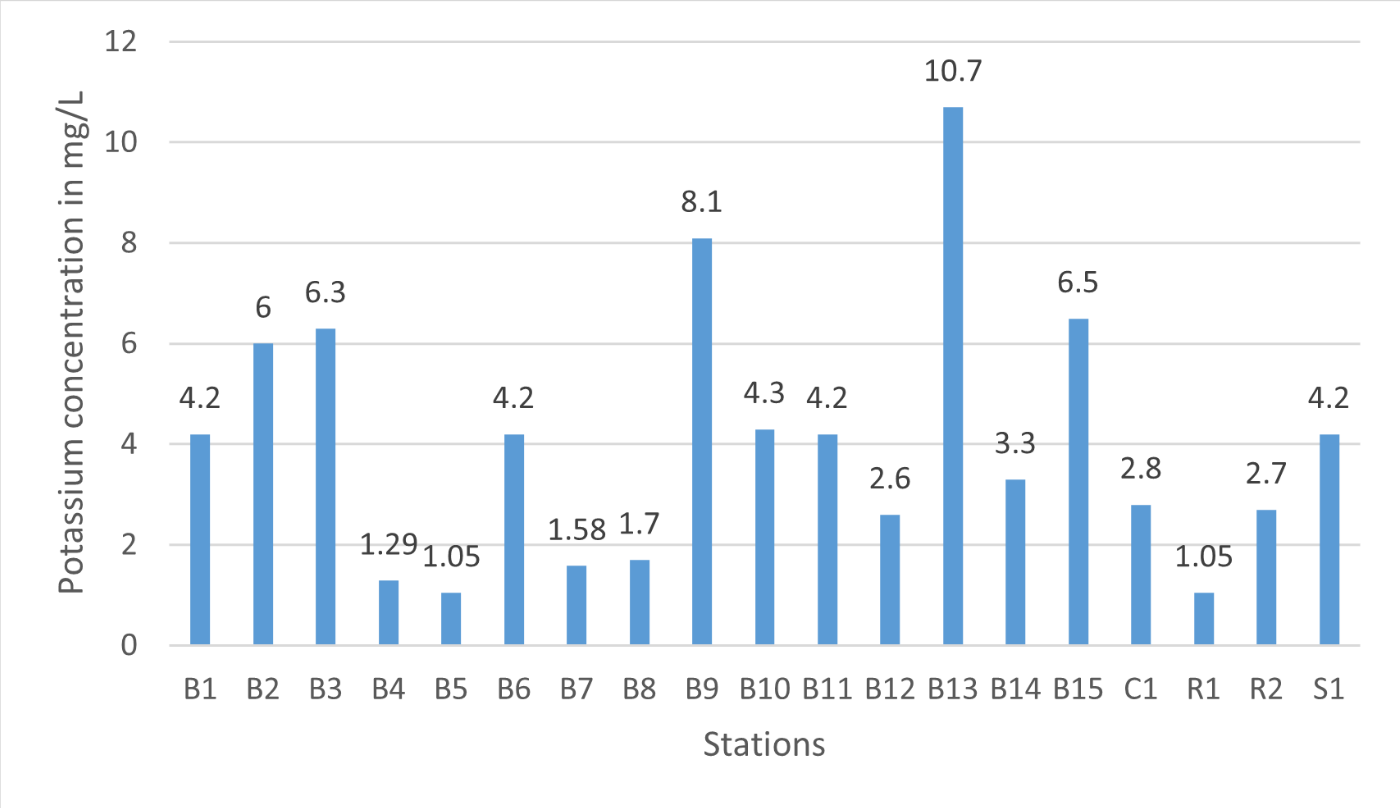


***Fig 8.23** – Potassium concentration in Water of Study Area based on Sampling result*

The range of K^+ ions in water samples varies from 1.05 to 10.7 mg/l with a mean value of 3.59 mg/l ingroundwater and 1.05 to 4.2 mg/l and 2.40 mg/l in surface water.

Palin Summary

Sodium and potassium levels in the given ranges are usually considered safe for drinking water. But if the concentrations are higher, especially towards the upper end, it could suggestcontamination or natural mineral deposits.

Water that contains more sodium may not be as appealing to drink because of its taste andpossible effects on health.

Drinking water with high sodium levels can be harmful to people with hypertension, cardiovascular disease, or other health conditions that are affected by sodium intake.

Water sources that have potassium in the given range can help increase nutrient intake andassist in agricultural irrigation practices.

The sodium and potassium found in irrigation water can have an impact on soil salinity and nutrient availability, which can affect the growth of plants, crop productivity, and

the fertilityof the soil. If the irrigation water has high levels of sodium, it can lead to soil sodicity and harm the health of plants and agricultural yields.

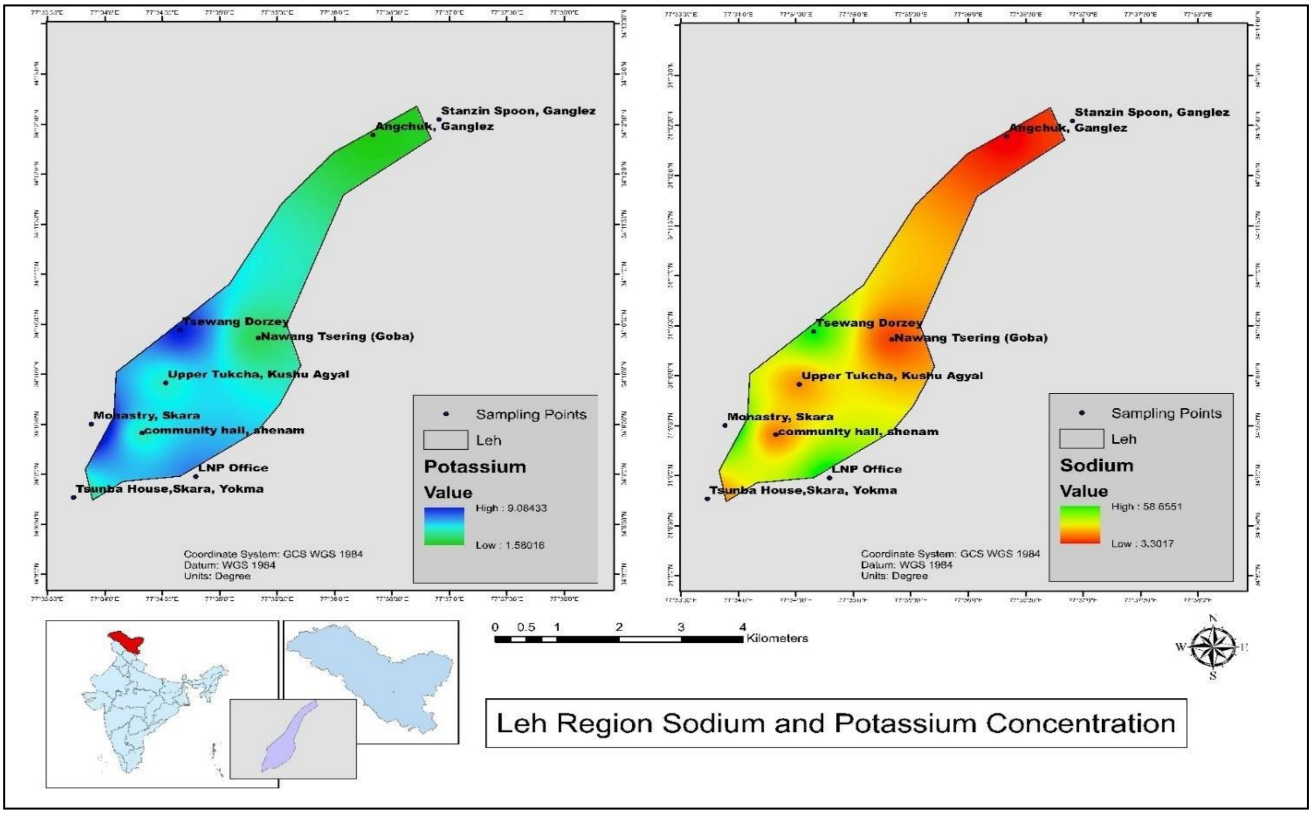


Fig 8.24 *–Sodium and Potassium conc of Water of Leh Region based on Sampling result*

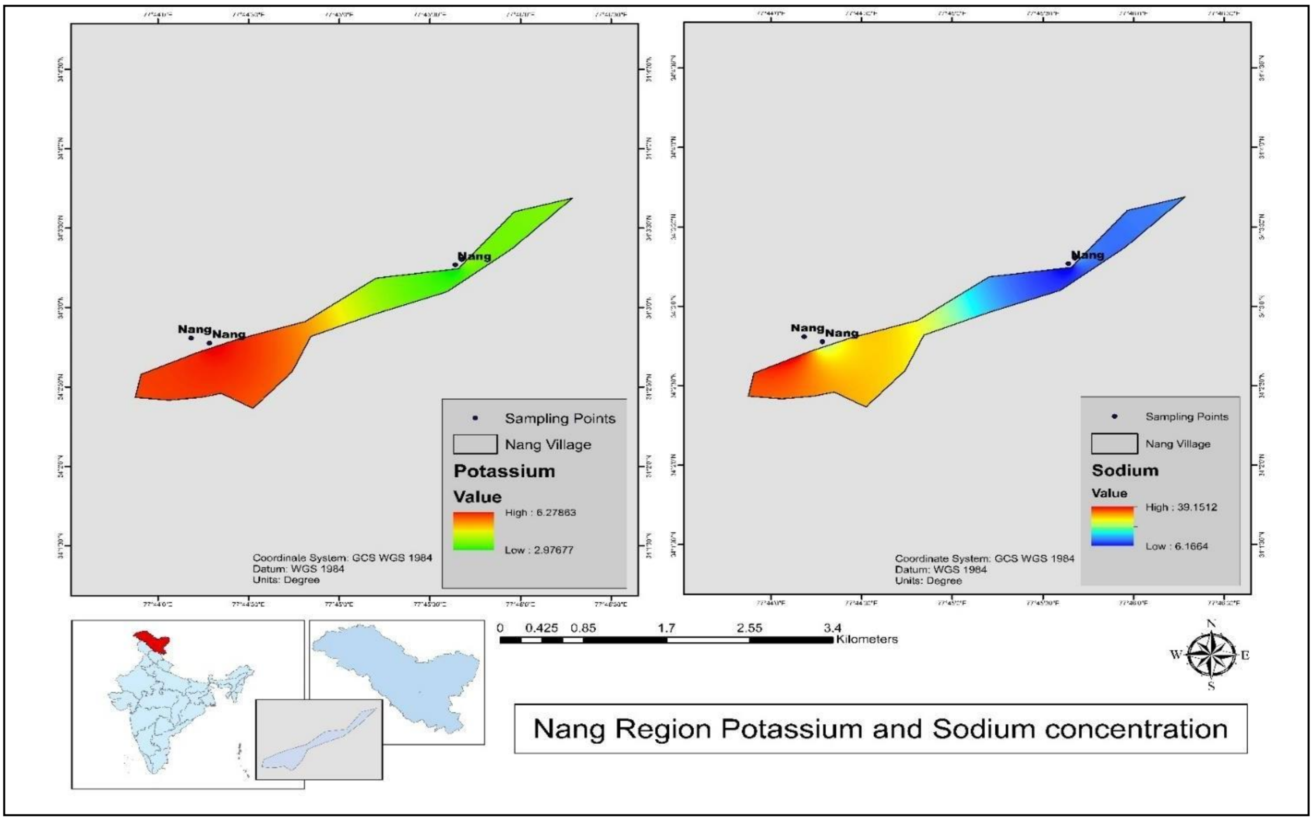


***Fig 8.25** – Sodium and Potassium conc of Water of Nang Region based on Sampling result*

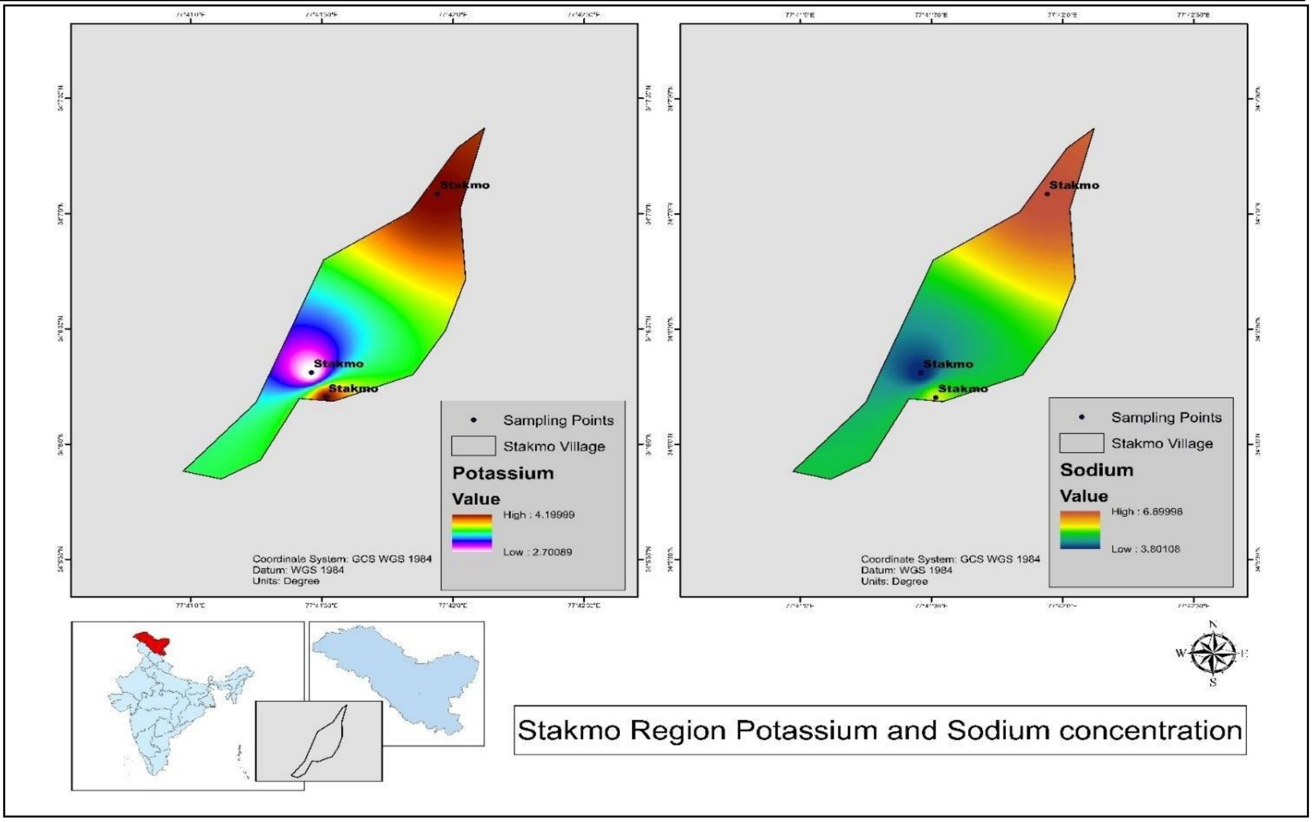


***Fig 8.26** – Sodium and Potassium conc of Water of Stakmo Region based on Sampling result*

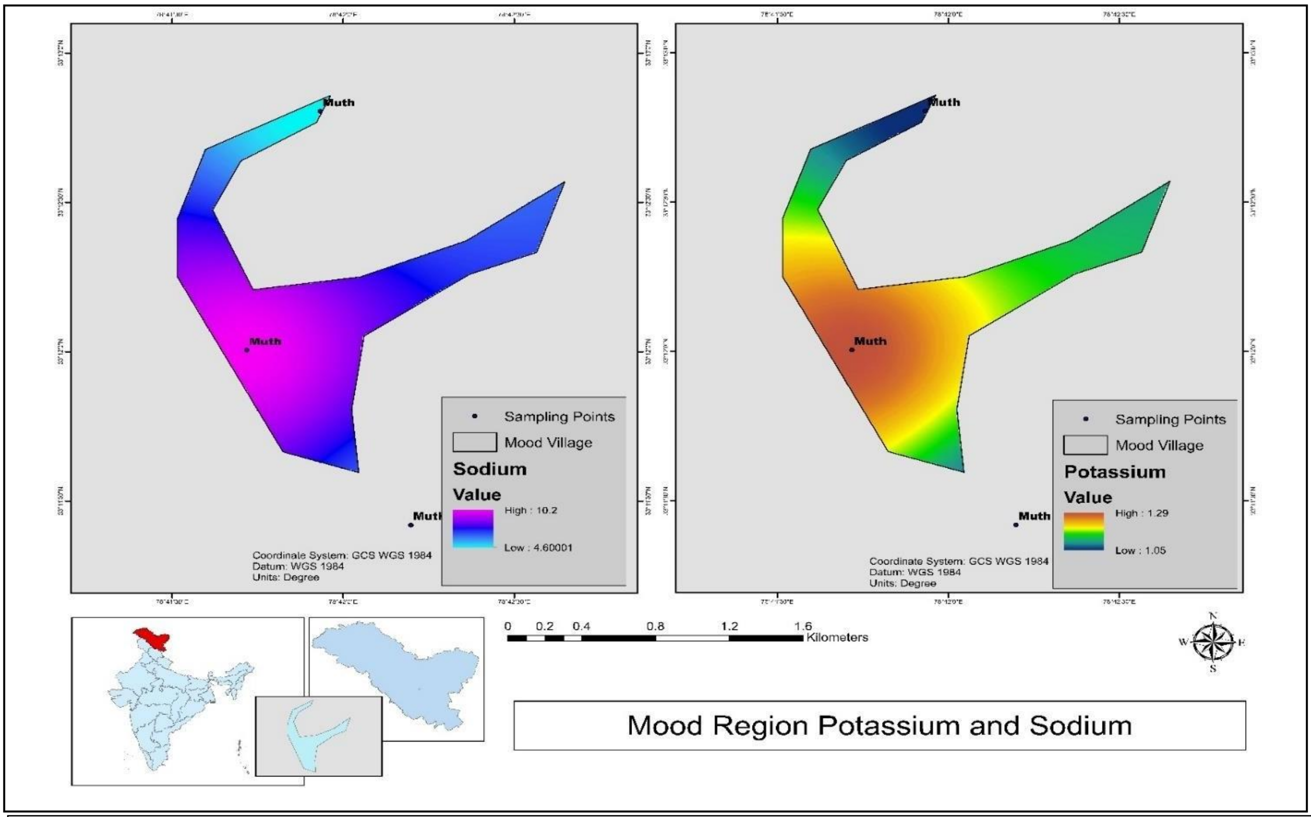


Fig 8.27 – *Sodium and Potassium conc of Water of Mood Region based on Sampling result*

8.3.8 Total Hardness

Water hardness refers to the concentration of calcium and magnesium ions dissolved in water. It is commonlymeasured in milligrams per Liter (mg/L) or parts per million (ppm) of calcium carbonate ($CaCO_3$) equivalent.The hardness of water is mainly caused by calcium and magnesium salts, such as calcium carbonate ($CaCO_3$),calcium sulphate ($CaSO_4$), magnesium carbonate ($MgCO_3$), and magnesium sulphate ($MgSO_4$).

Calcium Hardness

Calcium hardness in water refers to the concentration of dissolved calcium ions, typically measured in milligrams per Liter (mg/L) or parts per million (ppm) of calcium carbonate equivalent. High calcium hardnesscan lead to scale formation in plumbing, reduce soap effectiveness, cause skin and hair dryness, and affect aquatic health.

Magnesium Hardness

Magnesium hardness in water is the measure of how much dissolved magnesium ions (Mg2+) are present. This is usually measured in milligrams per liter (mg/L) or parts per million (ppm) of magnesium carbonate equivalent. It is one of the factors that contribute to the overall hardness of water, affecting its quality and

usability.

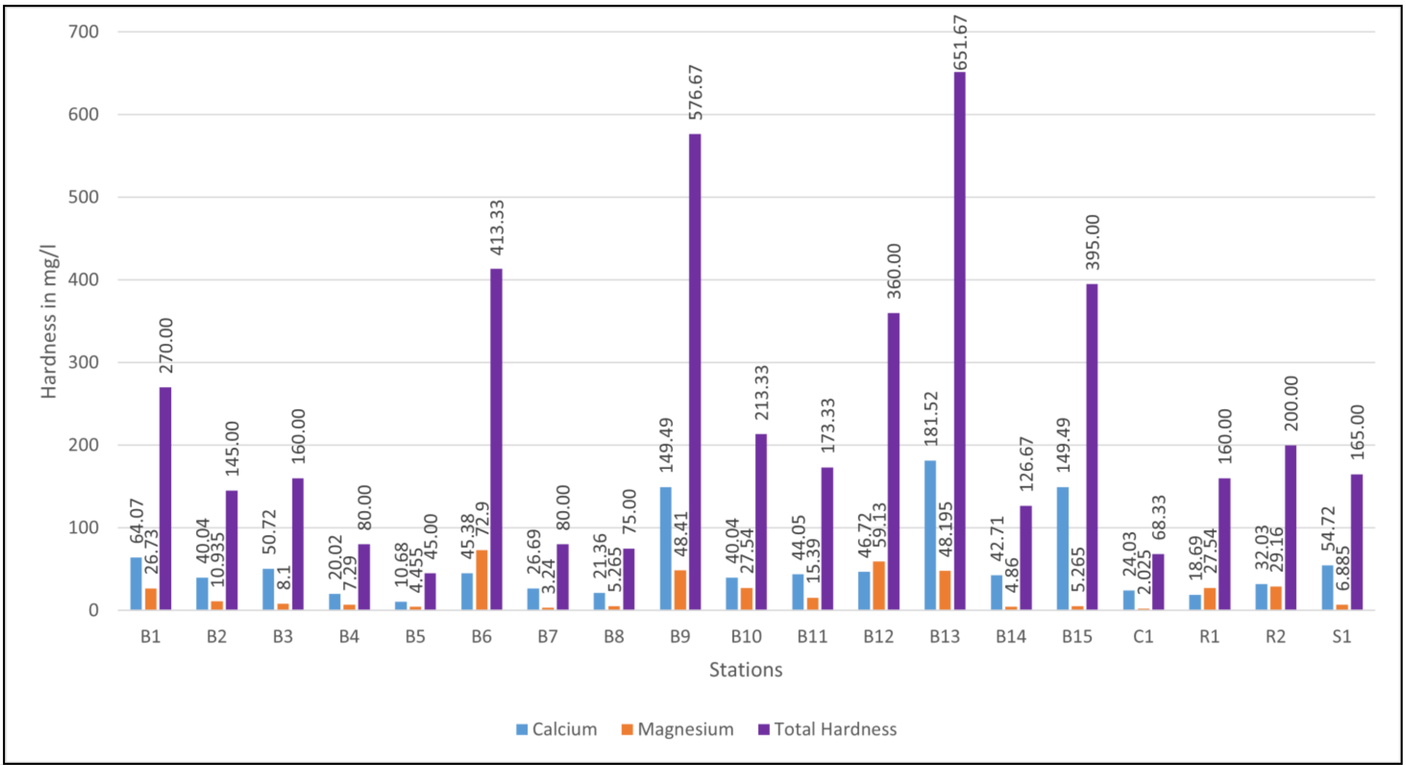


Fig 8.28 – Hardness of Water of Study Area based on Sampling

Table 8.2 - Physicochemical parameters in water quality of the study area.

ID	Source	Lat.	Long.	Temp °C	pH	(mg/L)											
						TDS	HCO_3	Cl^-	SO_4^{2-}	F^-	NO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Si^{4+}
1	Borewell	34.0550	77.7613	7.3	4.5	220	11.667	52.484	-	-	-	270	64.07	26.73	16.3	4.2	-
2	Borewell	34.0468	77.7364	12.2	5	190	6.667	57.482	-	-	-	145	40.04	10.935	49.6	6	-
3	Borewell	34.0463	77.7381	9.6	4.49	240	10.000	84.974	-	-	-	160	50.72	8.1	22.3	6.3	-
4	Borewell	33.2001	78.6953	9.4	5.3	60	5.000	49.985	-	-	-	80	20.02	7.29	10.2	1.29	-
5	Borewell	33.1903	78.7033	10.2	5.23	40	8.333	42.487	-	-	-	45	10.68	4.455	6	1.05	-
6	Borewe	34.118	77.699		4.2				-	-	-	413.3	45.38	72.9			-

	ll	1	0	8.3	7	140	8.333	37.488				3			6.9	4.2	
7	Borewell	34.2065	77.6056	7.8	4.35	80	10.000	34.989	-	-	-	80	26.69	3.24	3.3	1.58	-
8	Borewell	34.2091	77.6151	8.3	4.25	60	8.333	39.988	-	-	-	75	21.36	5.265	7.7	1.7	-
9	Borewell	34.1740	77.5776	10.8	3.88	460	10.000	164.949	-	-	-	576.67	149.49	49.41	56	8.1	-
10	Borewell	34.1652	77.5755	10.1	3.88	120	10.000	64.98	-	-	-	213.33	40.04	27.54	17.9	4.3	-
11	Borewell	34.1568	77.5721	9.4	3.58	120	8.333	59.981	-	-	-	173.33	44.05	15.39	15.2	4.2	-
12	Borewell	34.1727	77.5889	9	4.09	130	6.667	57.482	-	-	-	360	46.72	59.13	8.1	2.6	-
13	Borewell	34.1583	77.5647	10.5	3.04	690	10.000	377.383	-	-	-	651.67	181.52	48.195	71	10.7	-
14	Borewell	34.1461	77.5622	7.7	4.12	140	10.000	57.482	-	-	-	126.67	42.71	4.86	14	3.3	-
15	Borewell	34.1496	77.5799	9.7	3.61	450	11.667	229.929	-	-	-	395	149.49	5.265	60.4	6.5	-
16	Canal	34.0545	77.7607	8	8.5	80	10.000	37.488	-	-	-	68.33	24.03	2.025	4.7	2.8	-
17	Stream	33.2134	78.6989	5.3	5.15	30	5.000	42.487	-	-	-	160	18.69	27.54	4.6	1.05	-
18	Glacial River Stream	34.1052	77.6910	8.1	4.51	70	6.667	39.988	-	-	-	200	32.03	29.16	3.8	2.7	-
19	Spring	34.1034	77.6920	8.9	3.96	160	10.000	44.986	-	-	-	165	54.72	6.885	5.6	4.2	-

Table 8.3 - Statistical Analysis of Groundwater Samples

Parameter	Max	Min	Mean	Median	Std Dev
Temperature	12.20	7.30	9.27	9.40	1.33
pH	5.30	3.04	4.20	4.25	0.62
TDS (mg/l)	690.00	40.00	153.28	140.00	184.22
HCO_3^- (mg/l)	11.67	5.00	8.80	10.00	1.87
Cl^- (mg/l)	377.38	34.99	70.48	57.48	94.80
SO_4^{2-} (mg/l)	-	-	-	-	-
F^-(mg/l)	-	-	-	-	-
NO_3^- (mg/l)	-	-	-	-	-
TH(mg/l)	651.67	45	188.97	173.33	189.03
Ca^{2+}(mg/l)	181.52	10.68	46.50	44.05	52.91
Mg^{2+}(mg/l)	72.90	3.24	13.92	10.94	23.11
Na^+(mg/l)	71.00	3.30	16.23	15.20	22.74
K^+(mg/l)	10.70	1.05	3.59	4.20	2.73
Si^{4+}(mg/l)	-	-	-	-	-

Table 8.4 - Statistical Analysis of Surface Samples

Parameter	Max	Min	Mean	Median	Std Dev
Temperature	8.90	5.30	7.44	8.05	1.57
pH	8.50	3.96	5.29	4.83	2.04
TDS (mg/l)	160.00	30.00	72.00	75.00	54.47
HCO_3^- (mg/l)	10	5	7.60	8.33	2.50
Cl^- (mg/l)	44.99	37.49	41.14	41.14	3.23
SO_4^{2-} (mg/l)	-	-	-	-	-
F^-(mg/l)	-	-	-	-	-
NO_3^- (mg/l)	-	-	-	-	-
TH(mg/l)	200	68.33	137.82	162.50	56.22
Ca^{2+}(mg/l)	54.72	18.69	29.79	28.03	15.88
Mg^{2+}(mg/l)	29.16	2.03	10.29	17.21	13.95
Na^+(mg/l)	5.60	3.80	4.63	4.65	0.74
K^+(mg/l)	4.20	1.05	2.40	2.75	1.29
Si^{4+}(mg/l)					

CHAPTER –9

SUMMARY AND RECOMMENDATIONS

9.0 Summary and Recommendations

In the present study, three villages namely Nang, Muth, Stakmo, and Leh city were covered for hydrogeological study. In this study, 27 electrical resistivity survey data, 101 groundwater level data, and 19 water samples were collected. As per the electrical resistivity surveys, it is found that the thickness of unconsolidated sediments is higher in the downstream side which is a good aquifer for groundwater extraction.

Physical and chemical water properties were measured in fields such as TDS, pH, and temperature, calcium, magnesium, chloride, alkalinity, sodium, potassium, etc. Overall, most of the water quality parameters were found to be within the acceptable limits as per the Indian Standard Code. However, some parameters like total hardness and Chloride at one location in the Leh City are above the acceptable limits. These findings indicate that there is a need for continuous groundwater quality and quantity monitoring that will ensure the suitability of safe and adequate water for drinking, industrial and irrigation purposes. Detailed water quality analysis for different months in a year will support the recommendation of surface water suitability for groundwater recharge.

In order to attain the desired objectives of the ongoing research project, there is a strong need to carry out more surveys and data collection of the study area to make a robust hydrogeological model. This will help to understand the occurrence of groundwater, aquifer recharge response, movement of groundwater, groundwater quality under changing seasons and weather conditions in the study area, and the long-term groundwater sustainability under changing climate with increasing demand.

In addition, out of ten water scarcity locations/ villages, we covered only four locations/ villages due to time and weather constraints. As per the scope of the project, there is a further need to investigate the remaining villages and also data collection from the earlier covered villages.

About the Institute

National Institute of Technology Raipur formerly Government Engineering College Raipur, situated in the capital of state of Chhattisgarh, has proven to be "avant-garde' in the field of science and technology over the past decades in the central region. With sweet memory of foundation ceremony by our First President Hon'ble Dr. Rajendra Prasad on 14th September 1956, the institute started with two departments namely Metallurgical and Mining Engineering. The then Prime Minister Hon'ble Pt. Jawaharlal Nehru inaugurated the Institute building on 14^{th} March 1963.

The status of Government Engineering College, Raipur had been recognized as a National Institute of Technology by the Central Govt. with effect from 1^{st} Dec. 2005 and was later elevated to an Institute of National Importance. Since then, the Institute had been working with a mission to support the growth and promotion of industries and communities of the region. The institute offers twelve undergraduate degrees, fourteen postgraduate programs and offers Ph.D. programs in all the disciplines. To hone up the skills of the students required in their specific fields, a separate Career Development Centre with verticals as Training, Placement, Innovation, and Entrepreneurship has also been established. Further, the institute also offers certificate courses through its Continuing Education Cell to cater to the needs of society in general. The institute has continuously achieved new heights by improving its NIRF ranking with each passing year. It has significantly moved from 100-150 Rank band in 2017 to 81 in 2018, 74 in 2019, and 67 in 2020. The institute has also proven its strength in providing the necessary ecosystem for innovation by acquiring 4-star rating from Ministry of Education (MoE) for the last two years. It has also attained a position in Band A in ARIIA (Atal Ranking of Institutions on Innovation Achievements) ranking in the central region. NIT Raipur is well connected with Mumbai, Delhi, and all metro cities by regular flights and is on the main Howrah-Mumbai railway route. The institute is 5 km from the Raipur railway station and 18 km from the airport on NH-6, the Great Eastern Road.

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