AQUIFER MAPPING
&
MANAGEMENT PLAN OF LEH DISTRICT, LADAKH UT (NAQUIM AREA 714 SQ.KM)

Central Ground Water Board
Ministry of Jal Shakti
Government of India
North Western Himalayan Region
Jammu
February 2022

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CONTRIBUTORS

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PREFACE

Aquifer mapping studies have been carried out in the Naquim area of Leh district, UT of Ladakh with an objective to identify and map the aquifers at the micro level, quantify the availability of groundwater resources and suggest Aquifer Management Plans to address the basic groundwater-related issues in the area. Aquifer Mapping study involves integration and analysis of multidisciplinary scientific aspects including geological, hydrogeological, geophysical, hydrological, and hydrochemical. These studies help to characterize the quantity, quality, and groundwater movement in the aquifers and devise their optimal management plans. The representative area of the study was in the Union territory of Ladakh, forming the valley part of Leh district in the fluvial tract and spread over an area of 714 Sq. Km.

The report on "Aquifer Mapping & Management Plan of Naquim area of Leh, UT of Ladakh" elaborates the outcome of the Aquifer Mapping Study, in particular, the vertical and lateral extent of the aquifer units, their characteristics, and the response of the aquifer units to different stress conditions and their redressal through appropriate management plans. Various water stress mitigation options by integrating technical and scientific measures are also recommended for sustainable groundwater development and management in the area.

The untiring efforts put forth by a team of Scientists of North Western Himalayan Region, Jammu namely Shri B Abhishek, Shri V N Negi in bringing this report are duly appreciated, as this report would not have seen the light of the day without their hard work and dedication.

The report shall be of immense use for the planners and managers as well as academicians /researchers as a guide and reference volume in the field of Ground Water Resource Management.

Place: Jammu **(Shri M L Angurala)**
Date : **Head of Office**

AQUIFER MAPPING & MANAGEMENT PLAN
OF LEH DISTRICT, LADAKH UT
NAQUIM AREA (714 Sq.Km)

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1. INTRODUCTION

The Leh district is a part of the Union Territory of Ladakh, comprising over 45,110 Sq. Km. Three prominent valley sections, i.e., Phyang Valley, Nubra Valley, and Chusul Valley, cover 714 Sq Km. The Reappraisal hydrogeological survey in Leh district was carried out in 2001, and thereafter frequent groundwater sampling was taken up in the year 2013 and 2019. C.G.W.B started its drilling program from 1974 onwards, and till now, 31 Exploratory wells have been drilled till now. Under the aquifer mapping, five Exploratory wells were drilled in Leh Valley.

The delineation of aquifers and their extent and potential through groundwater surveys, exploration, and monitoring is an ongoing activity of the Central Ground Water Board. The entire country has already been covered under Systematic Hydrogeological Surveys to generate basic hydrogeological data. Reappraisal Hydrogeological Surveys/ Ground Water Management Studies have been conducted to study the changes in the groundwater regime. The hydrogeological map of the entire country was compiled on a 1: 2,000,000 scale and was first published in 1984. Subsequently, it was revised and again published in 2002 based on the data collected by CGWB through groundwater survey, investigation, and exploration program supported by exploratory drilling, geophysical investigations, and hydrochemical studies. Aquifer Atlas of Jammu & Kashmir was prepared on a 1:250,000 scale in the year 2013.

In today's scenario, increasing population, rapid urbanization, industrial development, and human interventions in the ecosystem pose a challenge for water resource managers. Any strategy for the management of groundwater resources on a sustainable basis depends on a proper understanding of the characteristics of the aquifer system. Considering the emergent challenges in the groundwater sector in the country, an urgent need was felt for comprehensive and realistic information about various aspects of groundwater resources available in different hydrogeological settings through a process of systematic data collection, compilation, data generation, analysis, and synthesis.

In light of this, the micro-level aquifer mapping program has been taken up by the Central Ground Water Board (CGWB) during the XII Five Year Plan. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological, and water quality data are integrated to characterize the quantity, quality, and movement of groundwater in the aquifers. Under the National Aquifer Management Programme (NAQUIM) North Western Himalayan Region had undertaken aquifer mapping of Kashmir Valley of Kashmir Province, Jammu & Kashmir.

1.1 OBJECTIVES

The objective of aquifer mapping is to delineate the geometry of the underlying aquifer systems in horizontal and vertical domains and their characterization, estimating their yield potential, and formulating aquifer management plans to ensure water availability on a sustainable basis.

1.2 SCOPE OF THE STUDY

The scope of the present study is broadly within the framework of NAQUIM being implemented by CGWB. There are four major components of this activity viz.: (i) Data collection /compilation (ii) Data gap analysis (iii) Data generation, and (iv) Preparation of aquifer maps and management plan.

Data compilation included collection and, wherever required procurement, of related maps from concerned Agencies, such as the Survey of India, Geological Survey of India, State Governments, etc., computerization and analyses of all acquired data, and preparation of a knowledge base.

Identification of Data Gaps was included to ascertain the requirement for further data generation in respect of hydrogeological, geophysical, chemical, hydrological studies, etc.

Data generation included those about exploratory drilling and aquifer characteristics, sub-surface geophysics, the chemical quality of groundwater, and geophysical survey. The generation of chemical quality data of groundwater was accomplished by collecting water samples and their laboratory analyses for all major parameters and heavy metals. Sub-surface geophysical studies incorporated Vertical Electrical Sounding and borehole logging.

Based on the integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared to bring out the Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical), quality, water level, and potential (quality & quantity). Finally, a suitable strategy for sustainable development and management of the aquifer in the area has been evolved based on the acquired data.

1.3 APPROACH AND METHODOLOGY

The study involves collecting existing data from various sources including CGWB records, State Government agencies, available literature, and other relevant sources for aquifer mapping and management.

The data was compiled, analyzed, examined, synthesized, and interpreted from available sources. Since some of these sources had predominantly non-computerized data, all the data available and collected was converted into computer-based GIS data sets, which were used to prepare various thematic layers. These layers were integrated to generate aquifer maps. Finally, an attempt was made to formulate aquifer management plans.

1.4 STUDY AREA

Leh district is a part of Ladakh union territory comprising over an area of 45,110 Sq.km. Tibet borders it to the east, and to the west, it is surrounded by the Indian state of Himachal Pradesh to the south, Jammu and Kashmir and Gilgit-Baltistan, and the southwest corner of Xinjiang across the Karakoram Pass in the far north. It extends from the Siachen Glacier in the Karakoram range to the north to the main Great Himalayas to the south. Until 2019, Ladakh was a region of the state of Jammu and Kashmir. In August 2019, the Parliament of India passed an act by which Ladakh became a union territory on 31 October 2019.

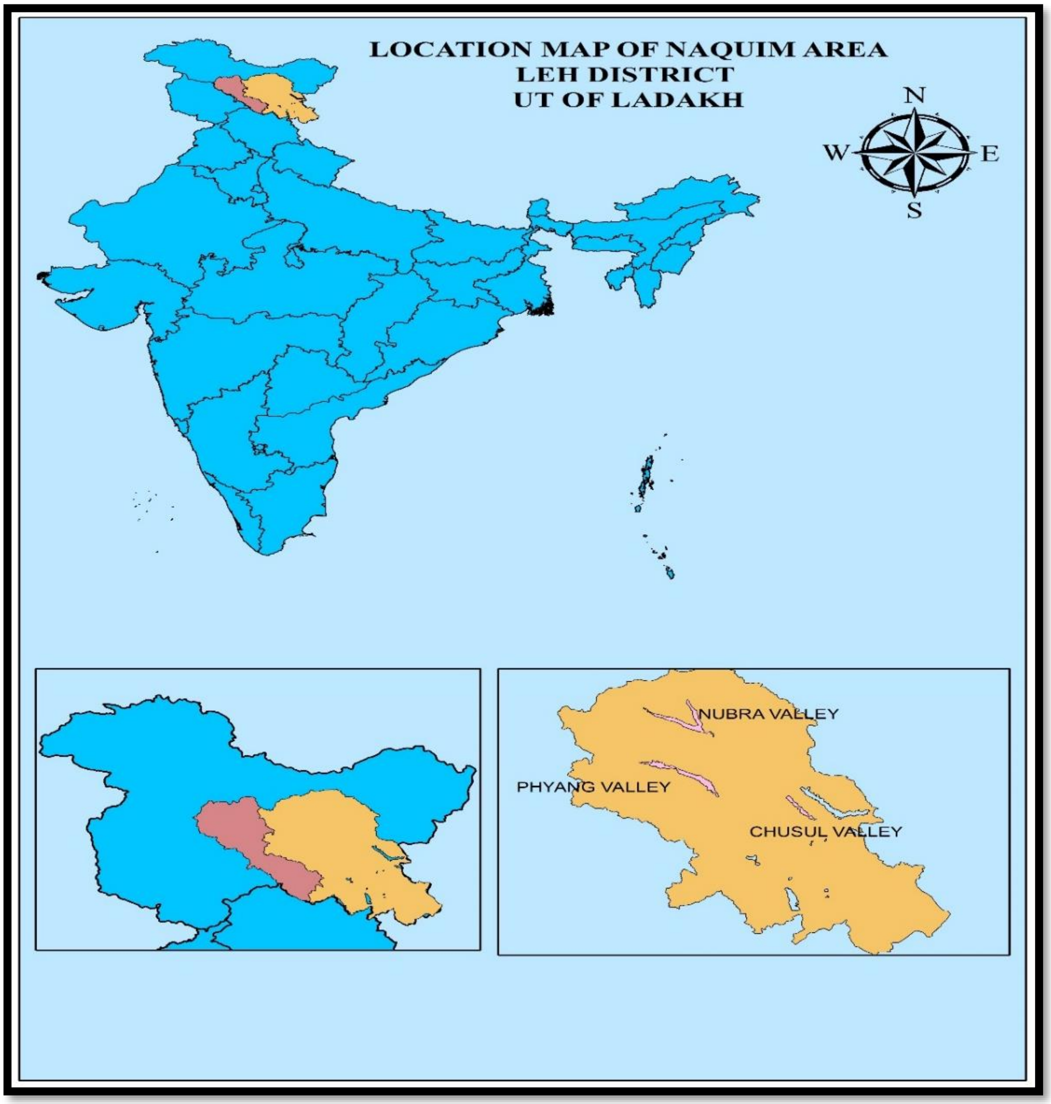

Figure 1 Location of the Aquifer mapping area.

Geographically Leh is situated between 35°08´ and 32°19´ N latitudes and 76°24' and 79°03´ E longitudes covering an area of 45,110 sq. km. Leh is renowned for its Buddhist Monasteries and hot water Springs, and also it has the highest motorable road (Khardung la). Ladakh also has numerous mountain passes, namely Khardung La, Zoji La, Taglang La, Chang La. The Leh district consists of Indus, Shyok, and Nubra river valleys. Ladakh is the highest plateau in India, with much of it being over 3000 m. The mountain ranges are formed by the folding of the Indian Plate due to collision with the Eurasian Plate.

The study area consists of three isolated patches covering an area of about 714sq km. The national highway NH-1A (Delhi-Srinagar-Leh) connects the area with the remaining parts of the country (Figure-1).

1.5 GEOLOGY

The tectonic framework of the NAQUIM area of Ladakh consists of Trans Himalayan Tectogen, Island Arc/ Accreted Arc accompanied with sediments, and an Accretionary complex belonging to the Mesozoic age followed by late to post tectonic granitoids of Mesozoic to Cenozoic age and Alluvial fills in Superposed basins of Cenozoic age. A major part of the Phyang valley area consists of late to post Tectonic granitoids covering the northeastern portion of the valley, whereas the accretionary complex covers the southwestern part. The gross stratigraphy of the area is summarized in table-1.

Trans Himalayan Tectogen occupies most of the area of the Nubra valley section, whereas Island arc/Accreted arc accompanied by sediments occupies left bank of Nubra and Shyok river, and Late to Post Tectonic Granitoids are present on the left bank of Shyok river in the western part (Figure-2).

Late to post tectonic granitoids occupy a greater portion in the Chusul valley Section. Trans Himalayan Tectogen forms the hilly areas exposed in the North-East part. Island arc/Accreted arc accompanied by sediments forms the upper part of the Chusul valley section, whereas the lower south-eastern part consists of alluvial fills in the superposed basin.

The most striking lineament feature of the northwest Himalaya is the Indus tectonic zone, which extends up to 2500 Km from Nanga Parbat in the northwest to Namcha Barwa in the southeast demarcates the Himalayan Tethyan basin from the Tibetan Tethyan basin. The Indus group represents a non-ophiolitic sedimentary belt occurring unconformably over the Ladakh Granitic complex; on the other hand, the Sageluma group is an ophiolitic sedimentary belt defined by Pashkyum thrust in the north and Wakha-Sanko thrust in the south. Being a parautochthon unit, the Sangeluma group is tectonically transgressive over the Ladakh Granitoid-Indus group autochthon along Pashkyum Thrust.

The Shyok-Nubra zone is a highly tectonized zone made up of thrust slabs of the Shyok group of rocks. Shyok thrust is a major lineament that affects the northeastern limits of Ladakh Granitoid batholith and Khardung Volcanic along which the obducted masses of ophiolite have come up. It is well defined in the southeastern part of the zone where it comes very close to the main Karakoram Thrust, coalescing with it in the Darbuk-Tangste area, thereby reducing the width of the Shyok-Nubra zone to continue up to Chusul and further into Tibet.

The rocks of the Karakoram belt are folded into Karakoram Synclinorium and Saltaro Synclinorium with a geanticline in between. The Karakoram batholith is emplaced along with the core of the Geanticline.

The Karakoram range extends from NW-SE in the Ladakh region. Two different facies of rock, i.e., sedimentary formation and metamorphic facies in the northern and southern part, are separated by Axial granite Batholith. The older metamorphic facies is called the Pangong Tso formation consisting of schists, gneisses, marbles, and metabasics of the Precambrian to Silurian age. It is exposed near the Shyok river Bed.

Many igneous, sedimentary, and metamorphic rocks are sandwiched between the Karakoram Batholith in the north and Ladakh Batholith in the south. The Hundri formation represents the Shyok suture in the eastern Karakoram. This unit comprises of massive grey limestone in the lower part and carbonaceous shale and grey to green shale in the upper part. The presence of foraminiferal taxa indicates Aptian to Albian age.

The Shyok suture zone and Indus suture zone are separated by intrusive Ladakh Granitoids (Late Cretaceous- Early Eocene) to the south and Karakoram granitoids to the north. In this belt, the Hundri formation is represented by the volcano-sedimentary and marine Sedimentary Succession.

In the Naquim area, rocks belonging in age from Palaeocene to Oligocene are exposed in the Indus suture zone and Shyok-Nubra belt of trans-Himalaya. In the Indus Suture Zone, Kuksho formation of the Indus group of rocks of Eocene age comprises alternate beds of siltstone, shale, and fine-grained sandstone with minor gritstone and local Diamictite (Figure-3).

The quaternary deposits of Ladakh and Kashmir are represented by unclassified inhomogeneous glacial, fluvioglacial, fluvial aeolian, and lacustrine deposits occurring as moraines, hill wash, scree, fan deposits, and sandy dunes. It comprises unconsolidated and ill-sorted fine to medium-grained sand, silt, gravel, cobble, and occasional boulder size, angular to subangular rock fragments. The sand and silt are restricted to the present-day channel courses.

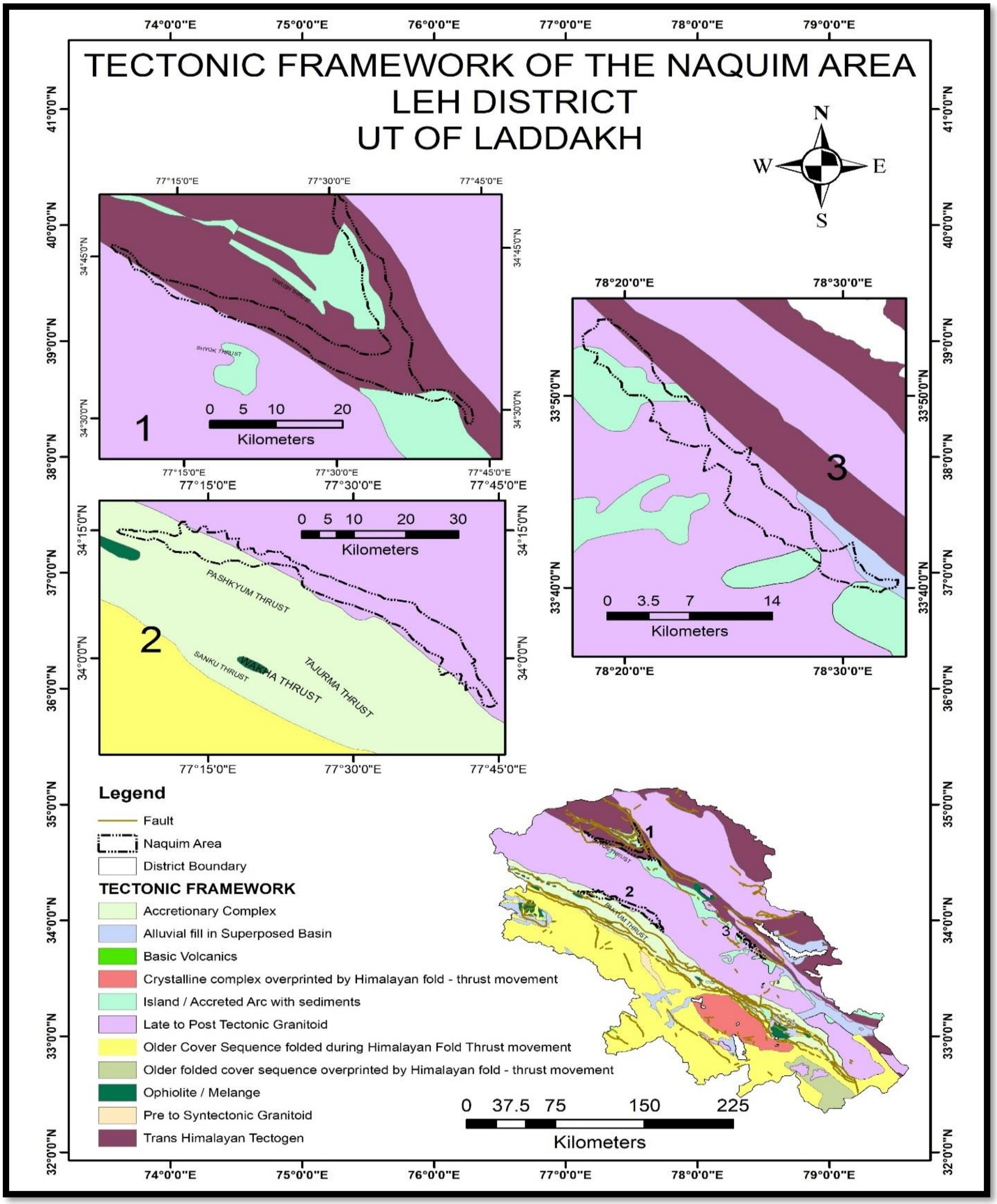

Figure 2 Tectonic framework of the Naquim area 1. Nubra valley section 2. Phyang valley section 3. Chusul valley section

Table 1 Stratigraphy of the NAQUIM area

Age	Group	Formation	Lithology	Remark
Pleistocene to Holocene		Undifferentiated Quaternary	Alluvium, moraines, hillwas, and Scree	
Miocene	Indus Group	Karit (Undifferentiated)	Conglomerate, sandstone, shale, and siltstone	
Eocene to Oligocene	Indus Group	Kuksho	Sandstone, conglomerate and gypsiferous shale and Siltstone	
Eocene	Shyok Group	Hundiri	Sandstone, limestone, shale with fossils	
Cretaceous to Eocene	Ladakh Granitoid Complex	Grkhun	Migmatite	
			Leucocratic Granite	
		Hanugoma Formation	Hbl-Bio granite, ranodiorite, tonalite, gabbro, diorite and	
Tertiary		Tirit Granitoid	Hornblende-biotite Granite	Intrusive
Tertiary		Khardung Volcanics= Koyul=Chusul Volcanics	Rhyolite, dacite, agglomerate, and ultrabasics	
Paleozoic		Pangong Tso Granitoid	Hornblende granite and Diorite	Intrusive
Paleozoic		Pangong Tso (Undifferentiated)	Slate, schist, Phyllite and Quartzite	

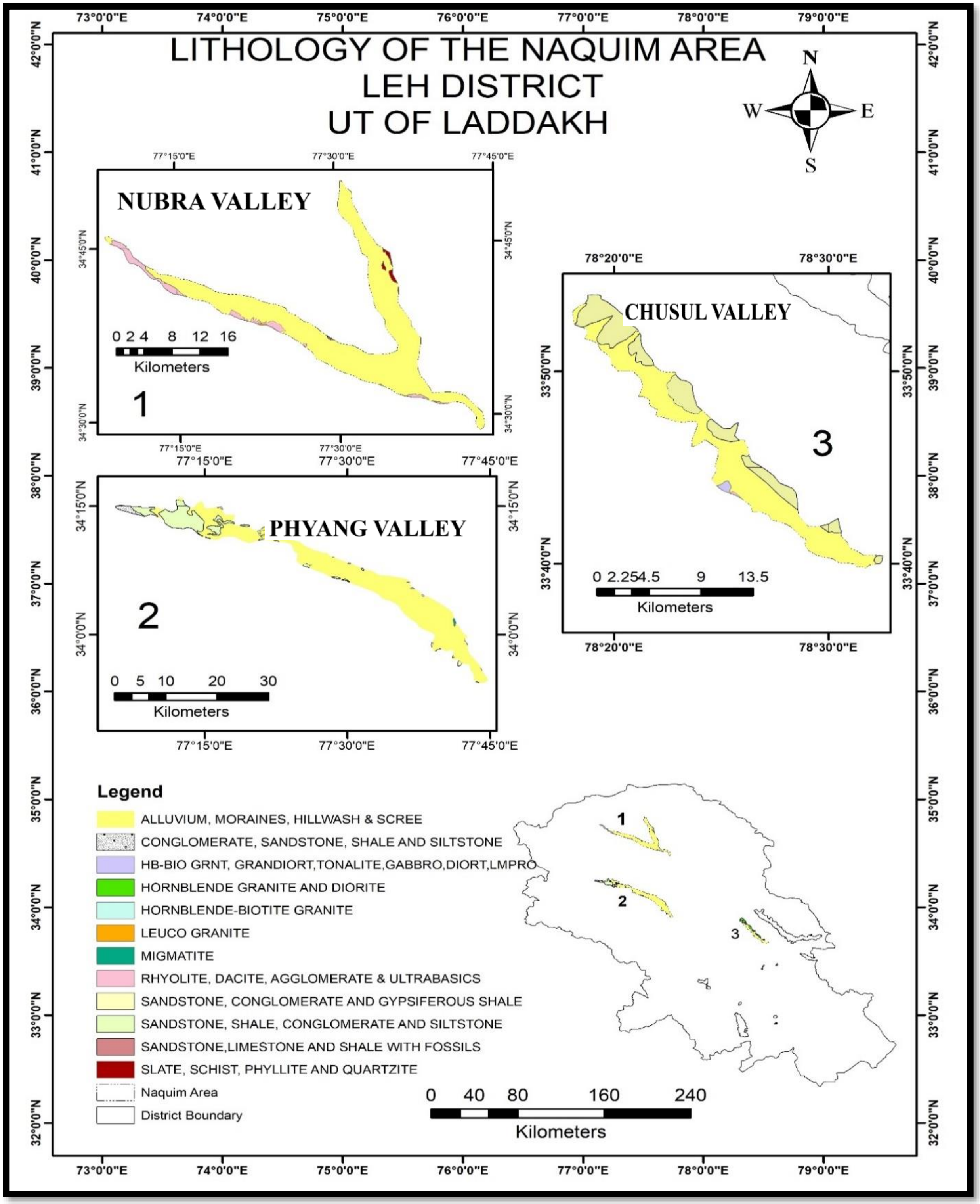

Figure 3 Geology of the Naquim area 1. Nubra valley section 2. Phyang valley section 3. Chusul valley section

1.6 CLIMATE

Ladakh experiences Temperate-cum-Mediterranean type of climate characterized by rainfall distribution mainly concentrated in winter, spring, and autumn. Summer is the period of scarce or null rainfall. The precipitation in the valley is received in the form of snowfall as well as rains and average annual precipitation is 60 mm. Summer temperatures are not usually higher than 35°C, and winter temperatures are lower than -5°C. Definitely, seasons are clearly drawn: Winter is very cold lasts from November to March. During these months, strong winds bring snow and rain from the Mediterranean depressions. Summer is warm and dry; July and August are the warmest months. Autumn i.e., September and October, are almost cloudless, quite rainy, but never severe. Spring begins after the 15th of March when rain falls heavily and days are sunny. The longest sunshine hours are in September, October, and November.

Ladakh lies on the rain shadow side of the Himalayan. Dry monsoon winds reach Leh after being robbed of its moisture in plains and the Himalayan Mountain. The district combines the condition of both the arctic and desert climate. Therefore, Ladakh is often called “COLD DESERT” characterized by Wide diurnal and seasonal fluctuations in temperature with - 40°C in winter and + 35°C in summer. Precipitation is very low, with annual precipitation of 10 cm, mainly in the form of snow. Air is very dry, and relative humidity ranges from 6-24%. Due to high altitude and low humidity, the radiation level is very high. The global solar radiation is as high as 6-7 Kwh/mm (which is among the highest in the World). Dust storms are very common in the afternoon. Soil cover is thin, sandy, and porous. The entire area is devoid of any natural vegetation. Irrigation is mainly through channels from the glacier and melted snow.

1.7 PHYSIOGRAPHY

Leh comprises of the highest altitude plateau region in India (much of it being over 3,000 m), incorporating parts of the Himalayan and Karakoram mountain ranges and the upper Indus River valley.

The mountain ranges in this region were formed over a period of 45 million years by the folding of the Indian Plate into the stationary landmass of Asia. While the Himalayas were formed from the base material of the Indian plate, the Zanskar Range consists of layers of sediment from the ocean floor, and the Ladakh Range of granite was born of the immense heat generated by the friction between the two plates. In Ladakh, the suture zone between the continental masses runs a little to the south of the Indus Valley. The drift continues and is the cause of the frequent earthquakes in the Himalayan region. Crossing the Himalayas by the dip of the Zoji-La, the crest-line of the range remains at a relatively modest level; the highest peaks near the pass are little more than 5000–5500 m above sea level. South-east of Zoji-la, the scale increases, reaching a climax in the mighty massif of Nun-Kun, with two summits over 7000 m.

The Ladakh Range has no major peaks; its average height is a little less than 6000 meters, and few of its passes are less than 5000 m. Within the Ladakh, it forms the northern boundary wall of the Indus valley. However, when the river enters present-day Indian-controlled Ladakh at

Demchok, some 250 km southeast of Leh, it is flowing along the foot of the northern flank of these granite mountains, which it crosses by a great gorge close to its confluence with the Hanle River. The Pangong range runs parallel to the Ladakh range some 100 km northwest from Chushul, along the southern shore of the Pangong Lake. It is divided from the main range by the Tangtse River. Its highest range is 6700 m, and the northern slopes are heavily glaciated.

The Shyok River rises near the Karakoram Pass. The region comprising the valley of Shyok and Nubra rivers is known as Nubra. The Karakoram Range in Ladakh is not as mighty as in Baltistan. The massifs to the north and east of the Nubra-Siachen valley include the Apsarasas group (highest point 7245 m), the Rimo group (highest point 7385 m), and the Teram Kangri group (highest point 7464 m), together with Mamostong Kangri (7526 m) and Singhi Kangri (7202 m.) North of the Karakoram lies the Kun Lun Mountains. Thus, between Leh and eastern Central Asia, there is a triple barrier: the Ladakh Range, the Karakoram Range, and the Kun Lun.

1.8 GEOMORPHOLOGY

The area is rugged and mountainous, with little or no vegetation. The mountains are of sedimentary rocks and are in the process of disintegration due to weathering. The altitude varies between 5934-8510 m AMSL. It is drained by Nubra and Shyok Rivers. The former river takes its origin from Siachian glacier and later originates from the South and Central Rimo glacier. The lower altitude is in the valley and foothill and the highest being peaks of the Karakoram Range. The area constitutes of well-delineated southeast-northwest and northeast-trending parallel mountain range such as Laddakh and Karakoram Range. The area has the distinction of the highest motorable road in the World, passing through Khardungla (5490 m amsl).

The chief geomorphological elements of the Naquim area Alluvial plain and flood plains of Shyok, Nubra, and Indus rivers consisting of poorly sorted sediments with grain size ranging from large boulders to fine sand. The valley portions are bordered on either side with seep to gently sloping hills. Aeolian sand dunes are observed in Diskit and Hundair area in the Nubra Valley (Figure-4,5and 6).

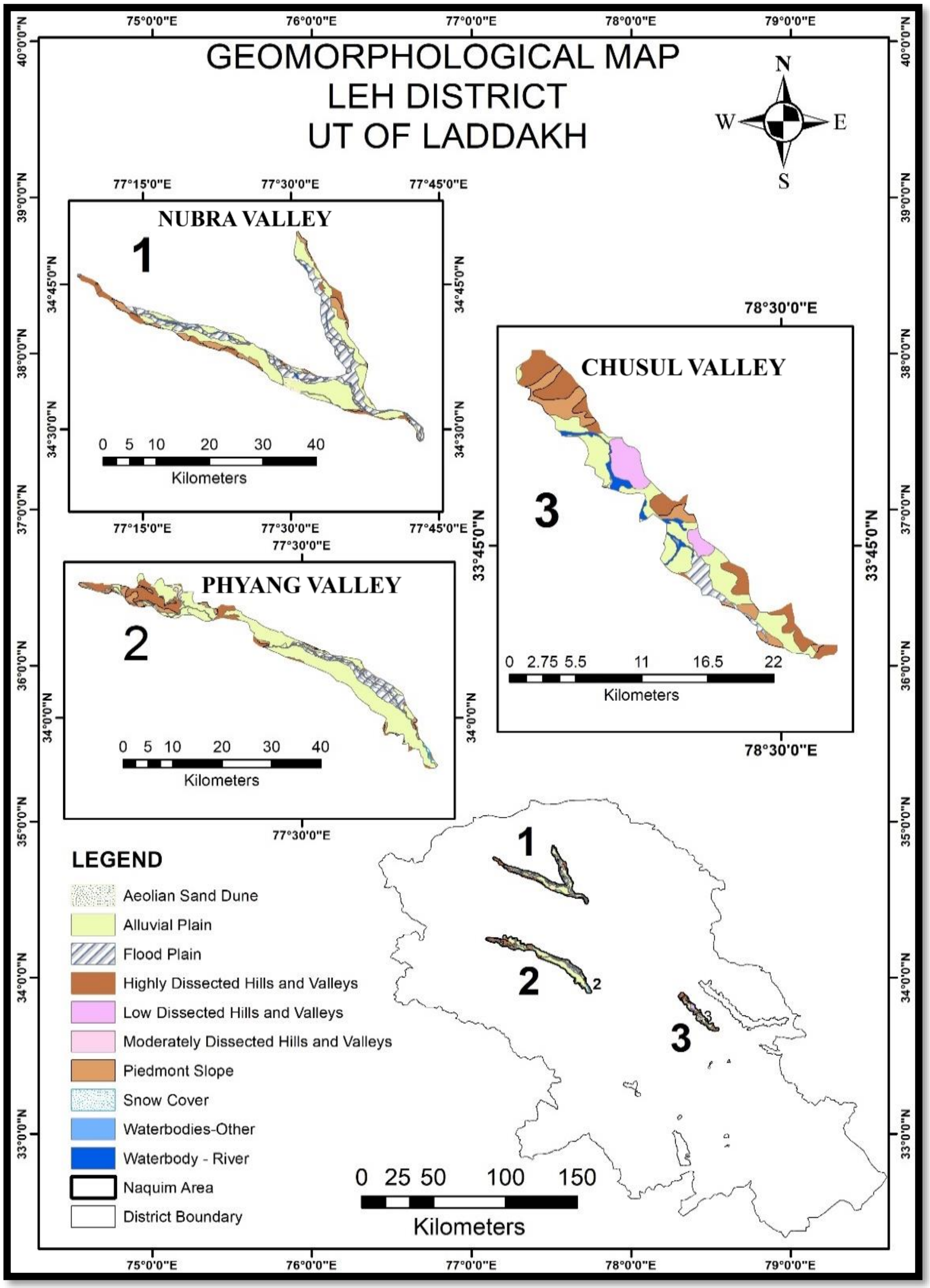

Figure 4 Geomorphological Map of the Naquim Area 1. Nubra Valley 2. Phyang Valley 3. Chusul Valley

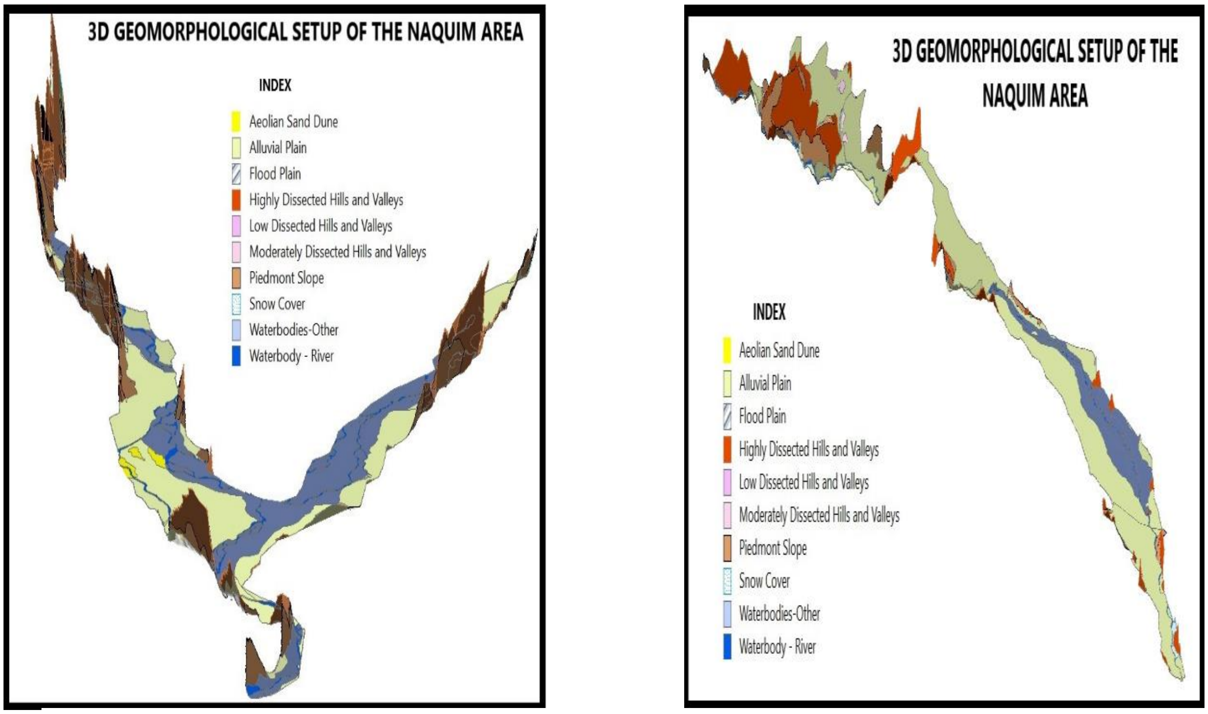

Figure 5, 3D Geomorphological representation of the Naquim area (a) Nubra valley, (b) Phyang valley.

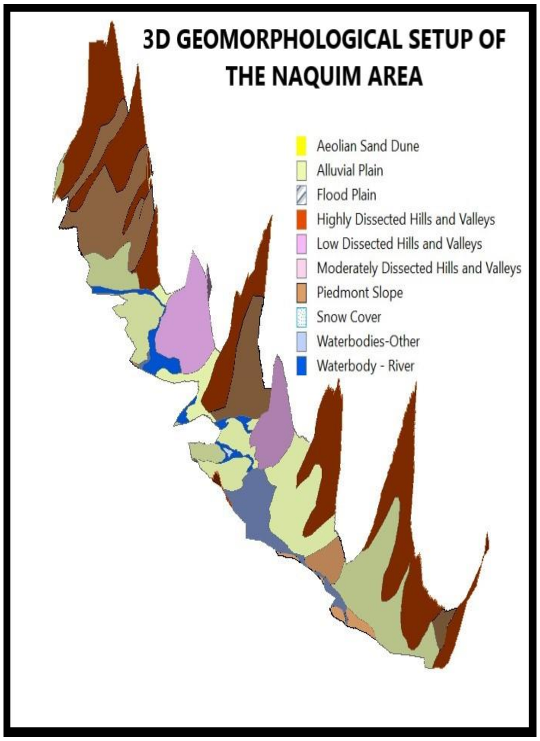

Figure 6 3D Geomorphological representation of Nubra valley

1.9 DRAINAGE

The aquifer mapping area is part of the Indus River basin, Nubra and Shyok Rivers basins. Nubra is a perennial river and is originated from Siachan Glacier and flows from northwest to southeast direction. Many nalas originating from the higher peaks of the mountains flow into Nobra. The nalas are locally termed as Lungpa. The main perennial Lungpas are Warshi Lungpa originating from Warhi glacier, Phukpochhe lungpa originating from Phukpochhe glacier, Panamic lungpa originating from Panamic glacier, Chameshan lungpa originating from Stondok & Phukatang glacier and Sumulungpa originating from snowfall at the higher reaches. All these have origin from Karakoram Range and flow in Northeast to southwest direction. The other nalas which flow from South-West to Northeast direction are Nyungsted lungpa originating from Nyungsted glacier, Khimi lungpa originating from Khimi glacier, and Kubed lungpa originating from Kubed glacier.

North West to southeast direction. It takes a turn toward North-West near the village Shyok. It meets Nobra River near Disket. In Nobra block, there are many perennial and ephemeral rivulets. The main rivulets which flow from north to south and meets Shyok River are Starga lungpa, Fastman lungpa originating from Thursa Glacier, Warshi Lungpa originating from Urdolep Glacier. The rivulets flowing from South to North in direction and join Shyok River are Khalsr Dok, Tashi lungpa, Sumdo lungpa, Glachurap lungpa, Taru lungpa, Yaglung lungpa, and Malasha lungpa (Figure 7,8 and 9).

1.10 LAKE

There are several salt water lakes in the Leh district namely Pangong Tso, Tso Moririe. This lake is of large diameter.

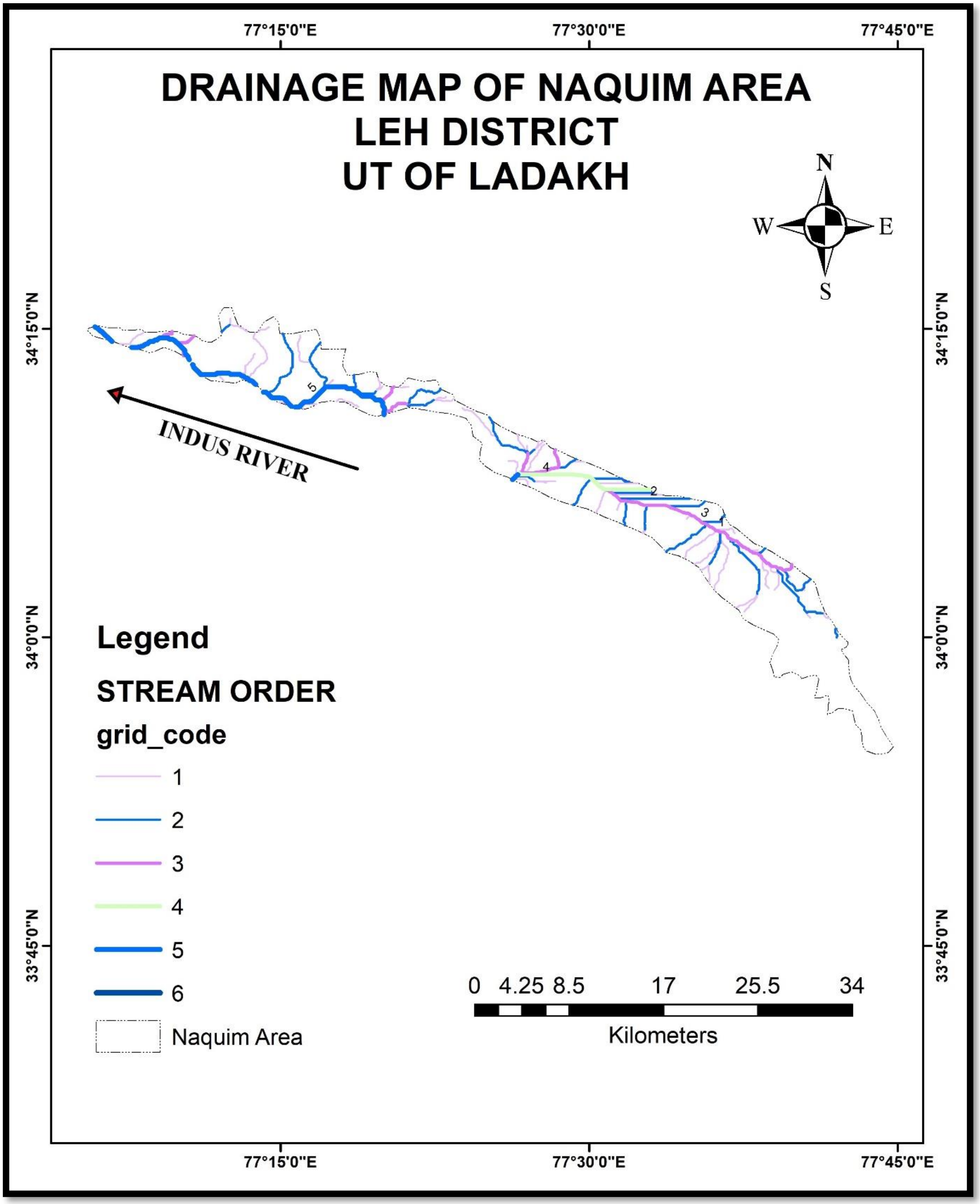

Figure 7 Stream order of Phyang Valley,

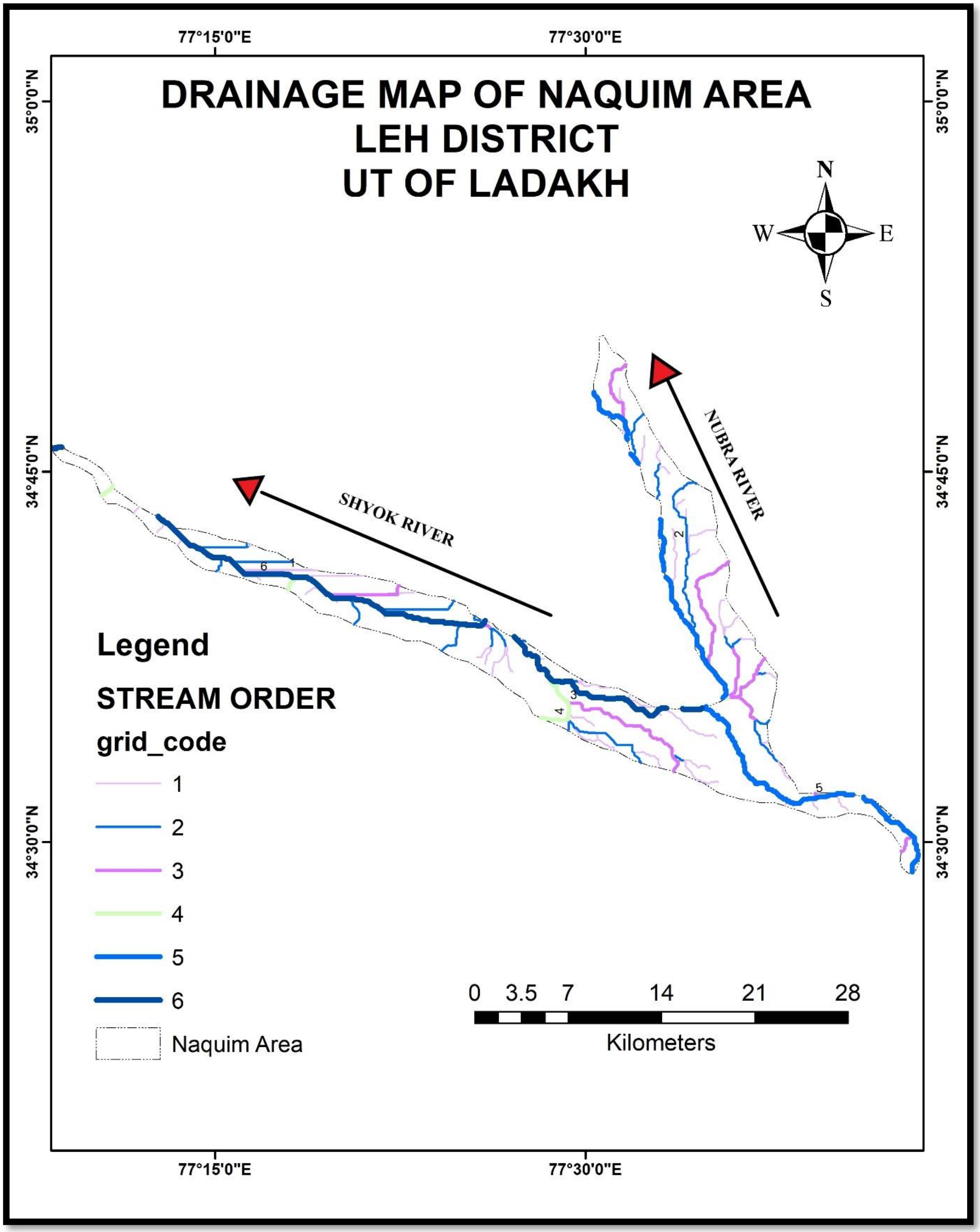

Figure 8 Stream order of Nubra Valley

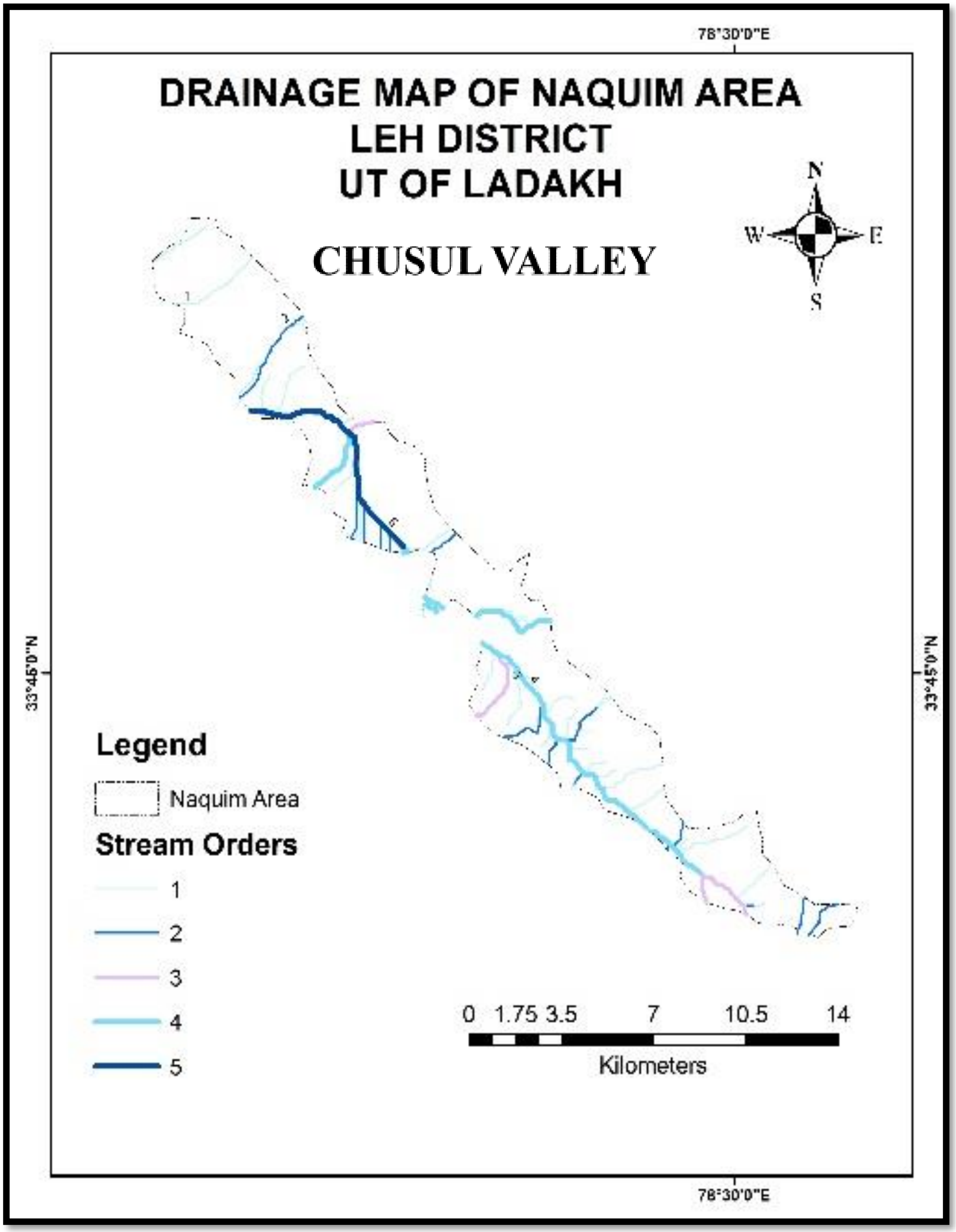

Figure 9 Stream order of Chusul Valley

1.11 CROPPING PATTERN

The data of the cropping pattern of Leh district during 2016-17 is given in table 2.

Table 2 ***Crops irrigated in the Valley portions of Ladakh in hectares***

Crops	Area irrigated in hectares
Pulses	265
Rice	0
Maize	0
Condiment and Spices	6
Fruit and vegetable	439
Wheat	2713
Barley	5
Other Cereals, Pulses & millets	548
Oilseeds	97
other non-food crops including Oats	0
Fodder crop	2082

1.12 IRRIGATION

Ladakh area falls in the rain shadow zone; most of the area is snow-covered for five to six months hence providing less time for cultivation. Irrigation in the Valley regions of Leh district is done mostly through canals/Kuhls, accounting for 97 %. In comparison, 3% is received from seasonal snow-fed spring flows that are diverted to fields for irrigation.

Most of the habitat of the Ladakh areas is confined to valley portions spread in isolated patches in the valley where the sediment thickness is considerably high to support vegetation and along the sides of seasonal snow-fed flows.

Different types of irrigation sources irrigate the total area of the valley. The source-wise net irrigated area of Leh district in 2015-16 is given in table 3.

Table 3 Source-wise (Type) of Irrigation & Net Irrigated Area in Leh

Type of Irrigation	Net Irrigation Area (hectares)
Canal Irrigation	9667
Other sources	296
Total	**9963**

Digest of Statistics 2016-17

1.13 LAND USE

The data of land use of Leh district during 2015-16 is given in table 3 (digest of Statistics 2015-16). The Land-use classification was prepared using the Land Sat 8 imagery from the USGS Global Explorer using Unsupervised classification. The available map is shown in the figure. The major land use/land cover classes such as built upland (4%), agriculture (6.59%), plantation (3.83%), forest land (0.064%), wastelands (60.82%), and water bodies and marshy land (3%) were identified in the study area. The area with water bodies such as Indus, Nubra, and Shyok river is flowing through Quaternary Alluvium in the specified areas so there is a good probability for groundwater recharge. The maximum part of the land is a barren land and the usable areas are situated in Alluvial fans containing glacial till, hill wash, and Scree (Figure 10, 11, 12, 13).

From the image analysis of the Naquim area, it was clear that the habitat and agriculture were confined to narrow patches of land in the piedmont zone. These villages get water from the snowmelt from the upper reaches of the mountains.

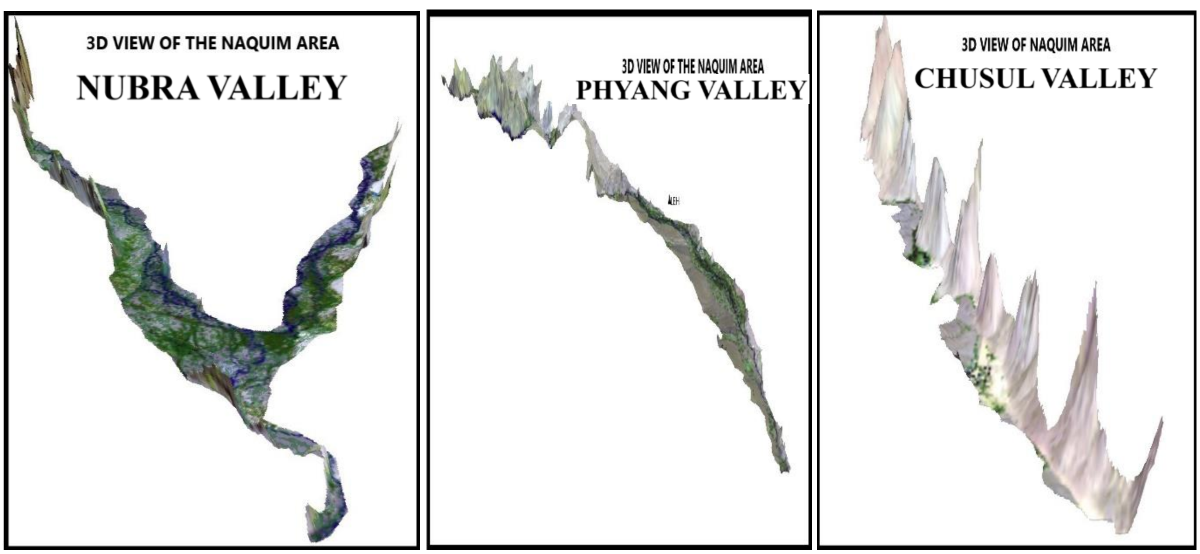

Figure 10 3D imagery of the Naquim area Nubra valley, Phyang valley and Chusul valley arranged left to right prepared from Cartoset Dem data (Bhuvan) and Land Sat 8 imagery (USGS Earth Explorer)

Farming is also practiced in the broad valley areas of the Indus and Nubra river. The Shrubland consists of thorny bushes. The plantation species is mostly Willow and Apricot, providing timbers for furniture.

Table 4 Land use and land cover of Naquim area in Ha

Land Use	Area in Hectare
Total Area according to Village Papers (Ha)	45167
Area Under Forests (Ha)	29
Land put to non-agricultural uses (Ha)	2978
Barren & Uncultivable Land (Ha)	27474
Marshy & Waterlogged Land (Ha)	0
Land under still water (Ha)	0
Social Forestry (Ha)	21
Permanent Pastures & other Grazing lands (Ha)	0
Land under Miscellaneous Tree Crops not included in area sown (Ha)	1732
Culturable Wasteland (Ha)	2567
Fallow land other fallows than current (Ha)	32
Current Fallows (Ha)	439
Net Area Sown (Ha)	9924

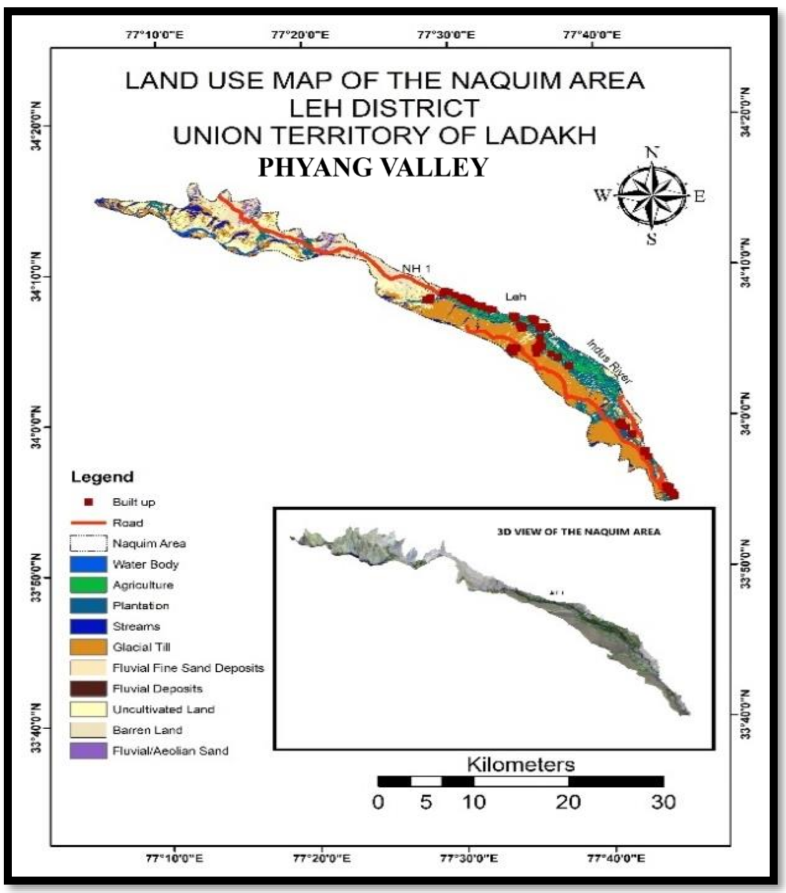

Figure 11 land Use map of Phyang Valley

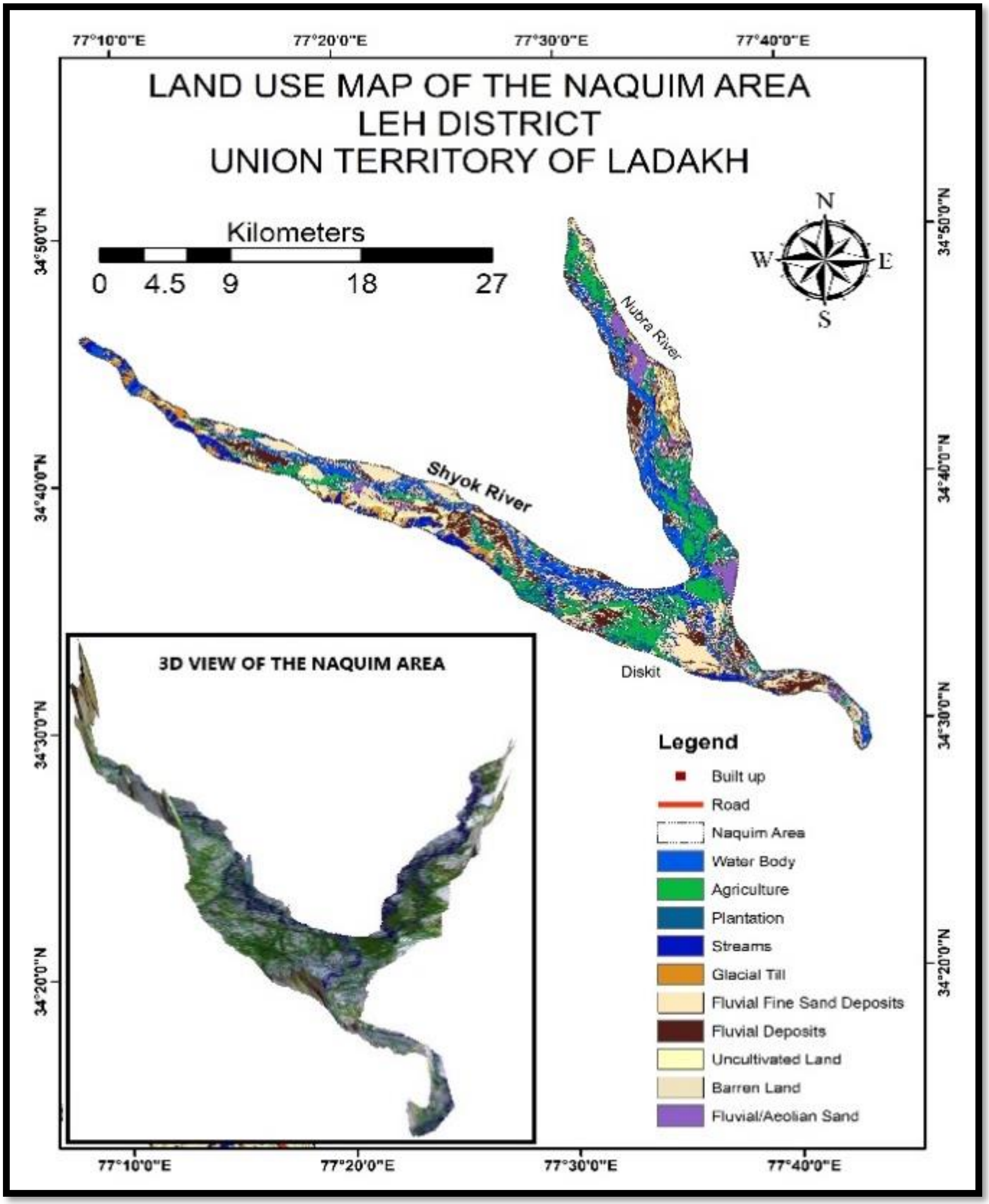

Figure 12 land Use map of Nubra Valley

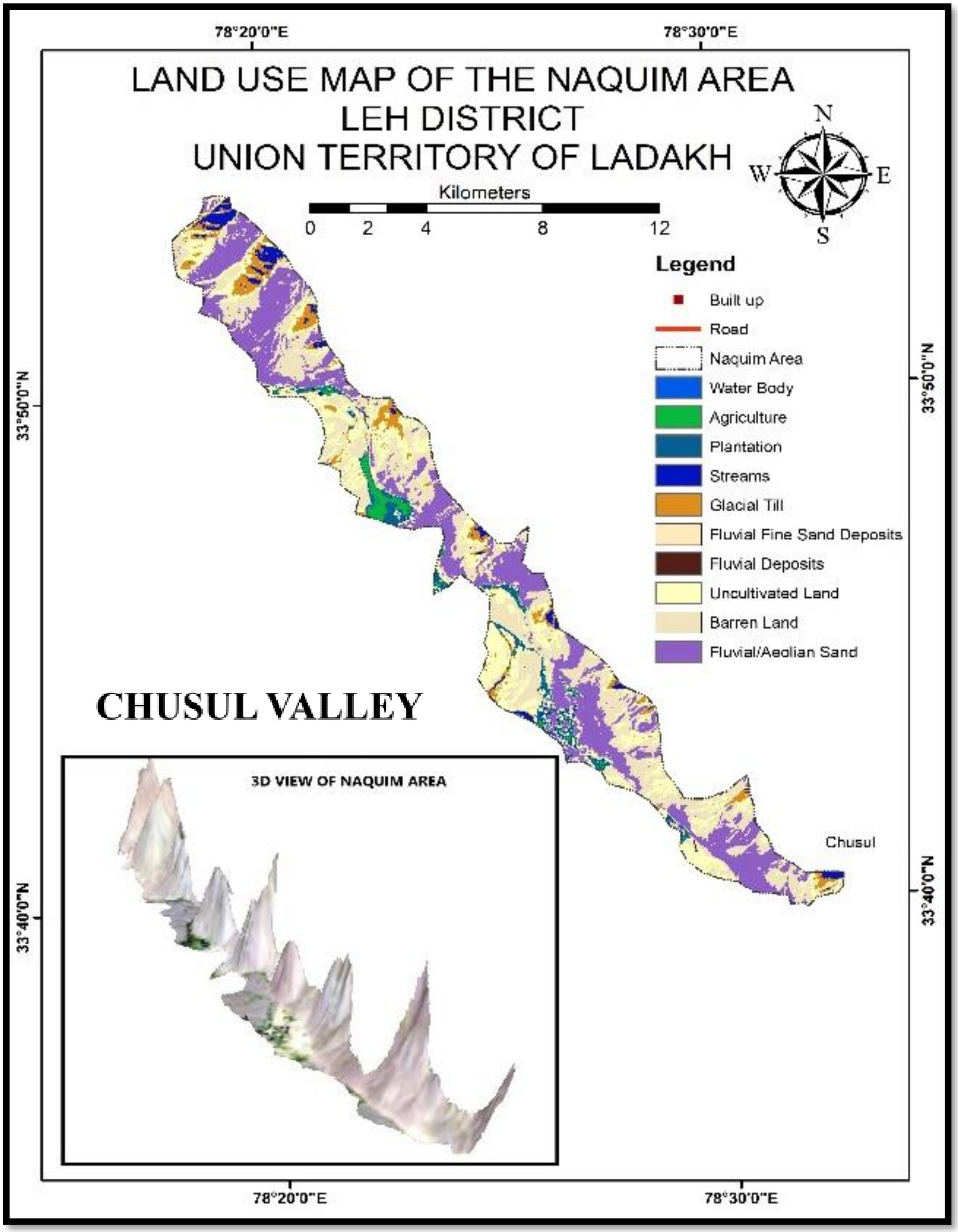

Figure 13 land Use map of Chusul Valley

1.14 GROUNDWATER RECHARGE AND DISCHARGE

The topography of the area is steep, and the valley areas are bordered on both sides by igneous and metamorphic rocks over which quaternary alluvium of considerable thickness is deposited. The groundwater condition is deeper in the piedmont zone and shallower towards the valley area. It was also observed that in the upper reaches of the Remo river the water was flowing within the sediments, leaving behind only a small amount of water flowing over the surface. The size of the sediments varies from large boulders to sand size providing enough space for the percolation of water.

Discharge of groundwater occurs both in natural and artificial ways. Natural discharge is through spring flow and subsurface groundwater flow to the effluent system. Withdrawal of groundwater through tube well for domestic, irrigational, and allied uses also contributes to the artificial discharge.

1.15 WATER CONSERVATION

The NAQUIM area of Ladakh consists of alluvial plains as well as flood plains of Indus, Nubra, and Shyok Rivers and their tributaries, rivulets, streams. The melting of glaciers has sustained the flow of these rivers. All the water flowing in this river drains out of the watershed at a faster rate due to steep topography.

Glaciers serve as a lifeline for these rivers, therefore the people of Ladakh had taken a unique initiative of preserving water through artificial glaciers. Ladakh is creating awareness of water conservation through Ice stupas.

Besides this, attempts are made to devise the technique of artificially freezing the melted glaciers. Successful attempts are made towards water conservation by diverting some of the water towards valley areas and slowing their speed by artificial breaks.

2. DATA AVAILABILITY

The compiled data were plotted on a 1:50000 scale map, and analysis of the data gap was carried out. The summarized table presenting the data requirement, data availability, and data gap analysis is presented in the following table.

Table 5 Data Requirement, Data Availability, and Data Gap Analysis

S. No	Items	Data Requirement	Data Availability	Data Gap
1.	Rainfall Data	Meteorological stations spread over the project area.	India-Wris	
2.	Soil	Soil map and Soil infiltration rate	Not available on any scale.	
3.	Land Use	Latest Land Use Pattern	Prepared from Land Sat 8 Imagery in GIS.	
4.	Geomorphology	Digitized Geomorphological Map	Bhukosh.	
5.	Geophysics	Geophysical data in each Quadrant	30 VES in Phyang Valley	
6.	Exploration Data	EW in each Quadrant with Aquifer Parameters	31 Exploratory Wells	
7.	Aquifer Parameters	Aquifer parameters for all the quadrants	Available for 5 quadrant	
8.	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Not available	
9.	Discharge Parameters / Draft Data	Discharge parameters for different GW abstraction structures	GEC 2020	
10.	Geology	All the maps on a 1:50000 scale	Bhukosh	

2.1 DATA COLLECTION AND GENERATION

Data on all the attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis. The data generated and data collected from various state governments agencies are summarized in the following table.

Table 6 Data Generated and Data collected for Aquifer Mapping Area.

S.No	Items	Data Generated	Data Collected
1.	Rainfall Data		INDIA-WRIS
2.	Ground Water Exploration	Construction of 2 EW.	Data not available with state.
3.	GW Regime Monitoring	Not generated	Not Available
4.	Chemical Quality	28 Samples in 2019 and 56 samples in 2013.	

2.2 RAINFALL

Most of the winter precipitation is in the form of snowfall, and the summer precipitation is very less. The villages located at higher altitudes receive snowfall during the winter season. The low-lying areas receive very less precipitation, whereas the higher reaches of the mountain receive snowfall throughout the year.

2.3 WATER LEVEL MONITORING

There is no Dug-well in both Leh and Kargil districts of UT of Ladakh. So, the water level was monitored by the Hand pumps. For proper management, water levels must be taken via hand pumps during April, May, June, July, August, and September to know the monthly water level fluctuation in stress periods.

2.4 WATER LEVEL SCENARIO

Due to the absence of Dug wells in the aquifer mapping area Water level cannot be taken.

2.5 WATER QUALITY

The Aquifer mapping area of Ladakh comprises of 714 Sq Km distributed in three different valley areas viz Phyang Valley, Nubra Valley, and Chusul Valley. The total area and the samples collected from each valley are as follows.

1. **Phyang Valley : 330.2 Sq. Km**
2. **Nubra Valley : 290.5 Sq. Km**
3. **Chusul Valley : 93.30 Sq. Km**

Phyang valley comprises 46% of the area, and 50% of samples were collected from this area. Nubra and Chusul Valley comprise 41% and 13% area, and a total of 43% and 7% of samples were collected.

The quality of groundwater was interpreted by the results of water samples collected from the hand pumps and tube wells of Leh District. The hand pump sample reflects the quality of shallow aquifers and the samples collected from the tube wells are considered to be of deeper aquifers. Thus, for the purpose of aquifer mapping, the results of 28 samples collected from hand pumps, spring, and tube well, are discussed below. The basic chemical parameters determined for evaluating the groundwater quality of Leh district are pH, EC, CO3, HCO3, Cl, NO3, S04, F, Ca, Mg, TH, Na, K, TDS, Alkalinity, and Fe.

Hydrogeochemical facies
Piper Trilinear diagram and Gibbs diagram and Chaddha plot

The Piper diagram reflects the hydrogeochemical characteristics of ions (anions and cations) in an aquifer system. The groundwater is Calcium bicarbonate type. In the study área, approximately 72% of groundwater samples show the distribution of mixed cations, 28 % are Ca type, wáter on Piper Trilinear Diagram. Among the major anions, 85% are plotted within the HCO3 type, 7% are mixed type, 7% are SO4 type. The majority of the studied samples, are plotted in the Ca-HCO3 type of water (82.5%), 3.5% are Na-CaHCO3 type, 7% are Ca-Mg-Cl type and 7% are Ca-Cl type water on Piper Diagram. The Gibbs diagram was used to elucidate the process and mechanism controlling the water chemistry and understand the relationships between water chemistry and aquifer lithologies. The values plotted show rock dominance on groundwater chemistry. From the Chaddha plot, maximum samples fall in the field-1, which shows the dominance of Alkaline earth and weak acidic anions over alkali metal and strong acidic anion, respectively.

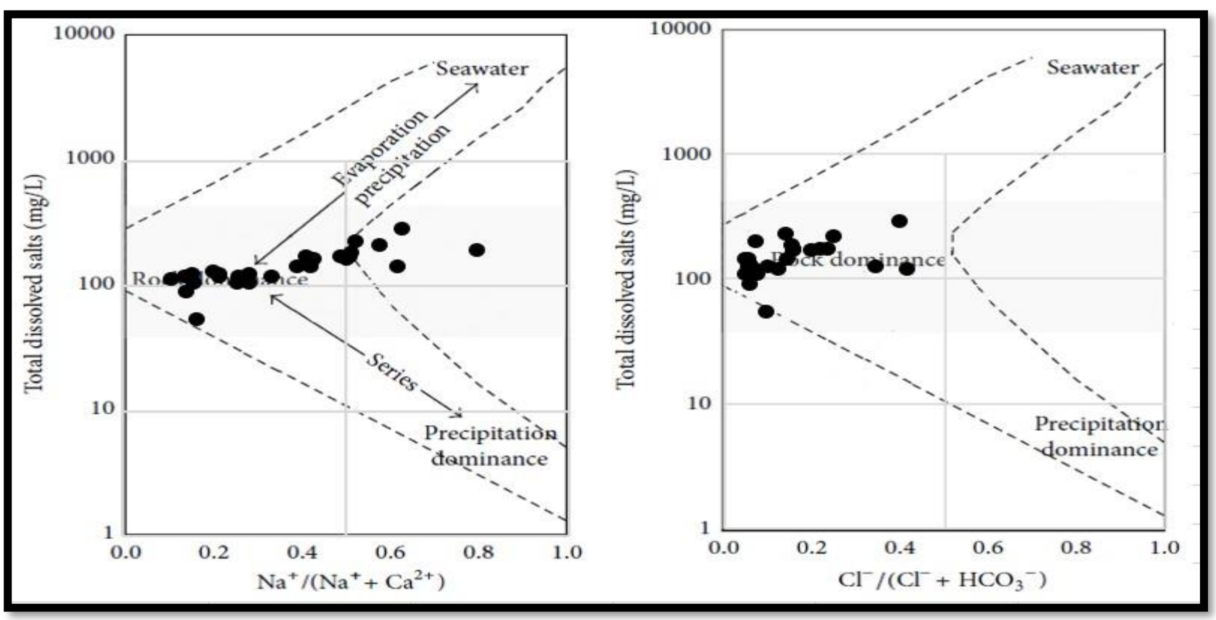

Figure 14 Gibbs Plot

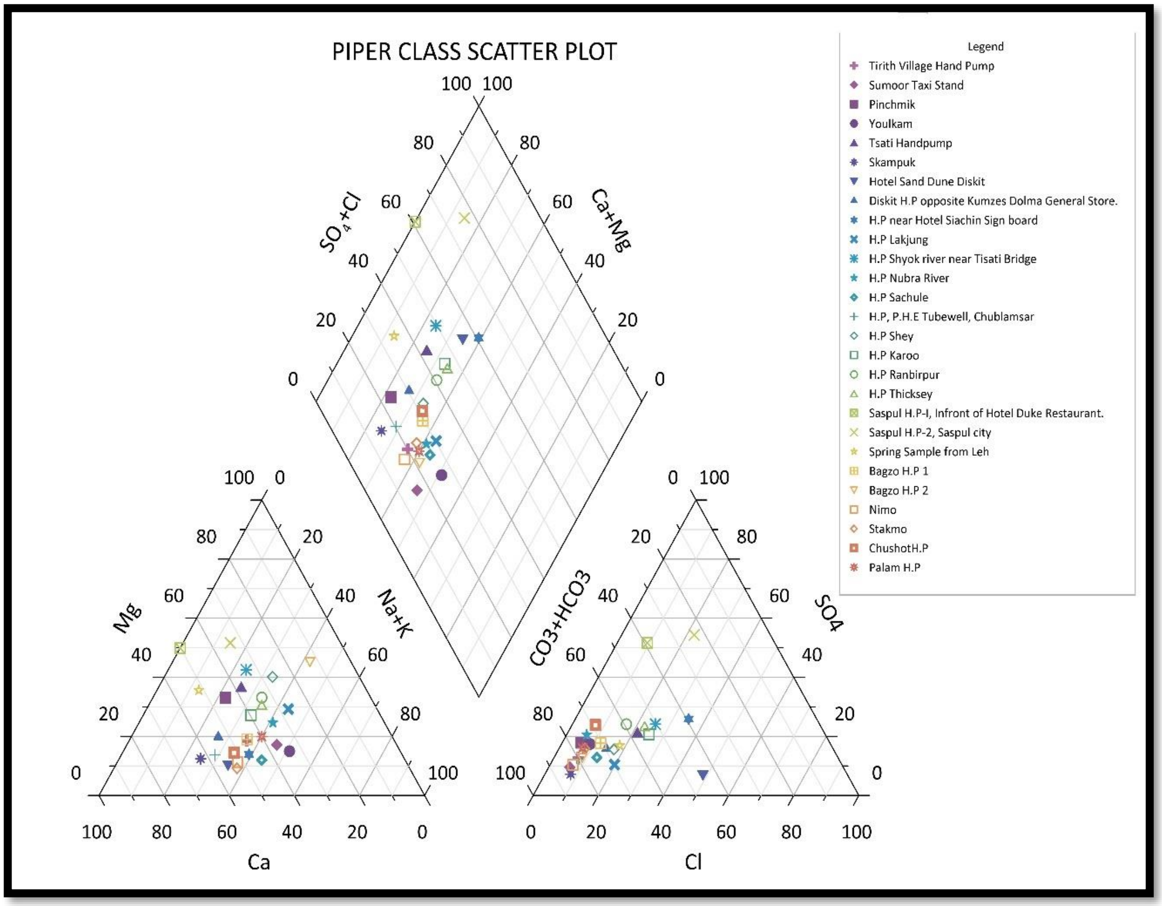

Figure 16 Piper class Scatter Plot.

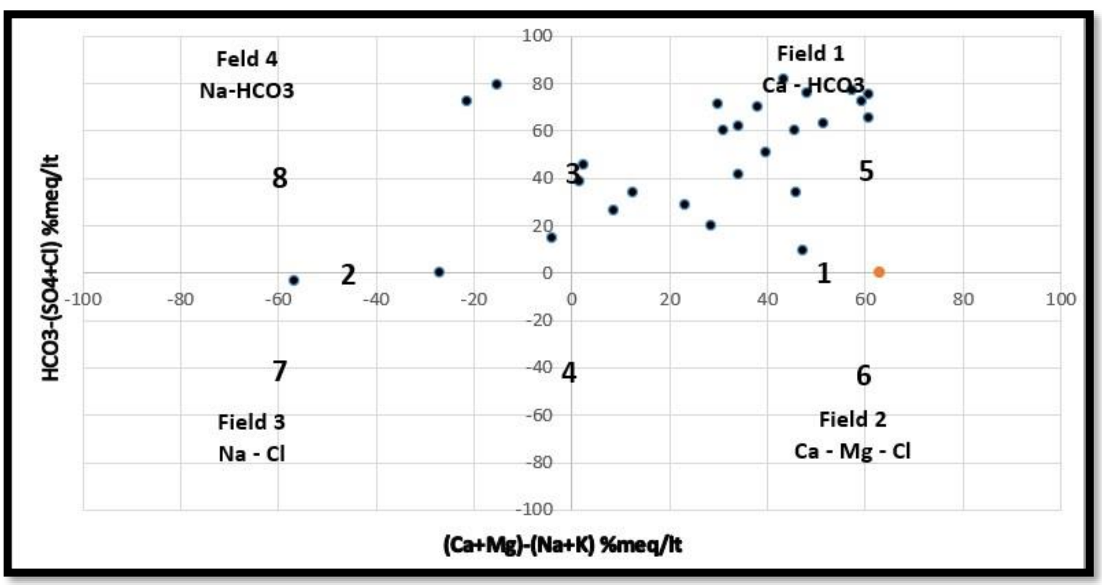

Figure 15 Chaddha Plot

Groundwater Suitability for drinking water:

The groundwater samples were compared with the BIS drinking water standards 2012. The pH and TDS, Ca and Mg, NO_3 and SO_4 of all the samples collected from handpumps, tubewell and springs were within acceptable limit.

Parameters	min	max
pH	7.58	9
EC (µS/cm at 25°C)	120	710
HCO3 (mg/lt)	42.7	341.6
Alkalinity (mg/lt)	45	280
Cl (mg/lt)	7.1	113.6
SO_4 (mg/lt)	1.4	159.1
NO_3 (mg/lt)	0	11
F (mg/lt)	0.02	11.3
Ca (mg/lt)	0.5	4.2
Mg (mg/lt)	0	3.1
Na (mg/lt)	1.9	107
K (mg/lt)	0.7	10.4
TH (mg/lt)	70	300
TDS (mg/lt)	62.4	369.2

Fluoride above permissible limit was recoded in Tirisha (6.37 mg/lt) and Panamic Springs (11.3 mg/lt) Four samples from the Chusul valley region and Nubra valley region showed fluoride levels above the permissible limit and were not fit for use. Overall the Quality of water is good. The detailed analysis of the groundwater quality parameter is attached in annexure 1.

Groundwater Suitability for Irrigation:

The groundwater suitability for irrigation was analyzed using electrical conductivity, sodium percentage, sodium adsorption ratio, permeability index, and magnesium hazard. (Annexure-2)

The EC and Sodium% of the groundwater samples were within the permissible limit and fit for irrigation. The area's salinity hazard and sodium hazard lie between low to medium. The Sodium adsorption ratio ranges between 0.19 meq/lt to 3.01 meq/lt with mean SAR value less than 10 meq/lt. The Residual Sodium Carbonate is less than 0.25 meq/lt, and both show that the groundwater is excellent for irrigation use. The Magnesium adsorption ratio ranges foom 19.99 meq/lt to 76.91 meq/lt where 79% of samples had values less than 50% hence were good for irrigation use while in 21% the value was greater than 50%; hence, the samples were found unsuitable for irrigation use.

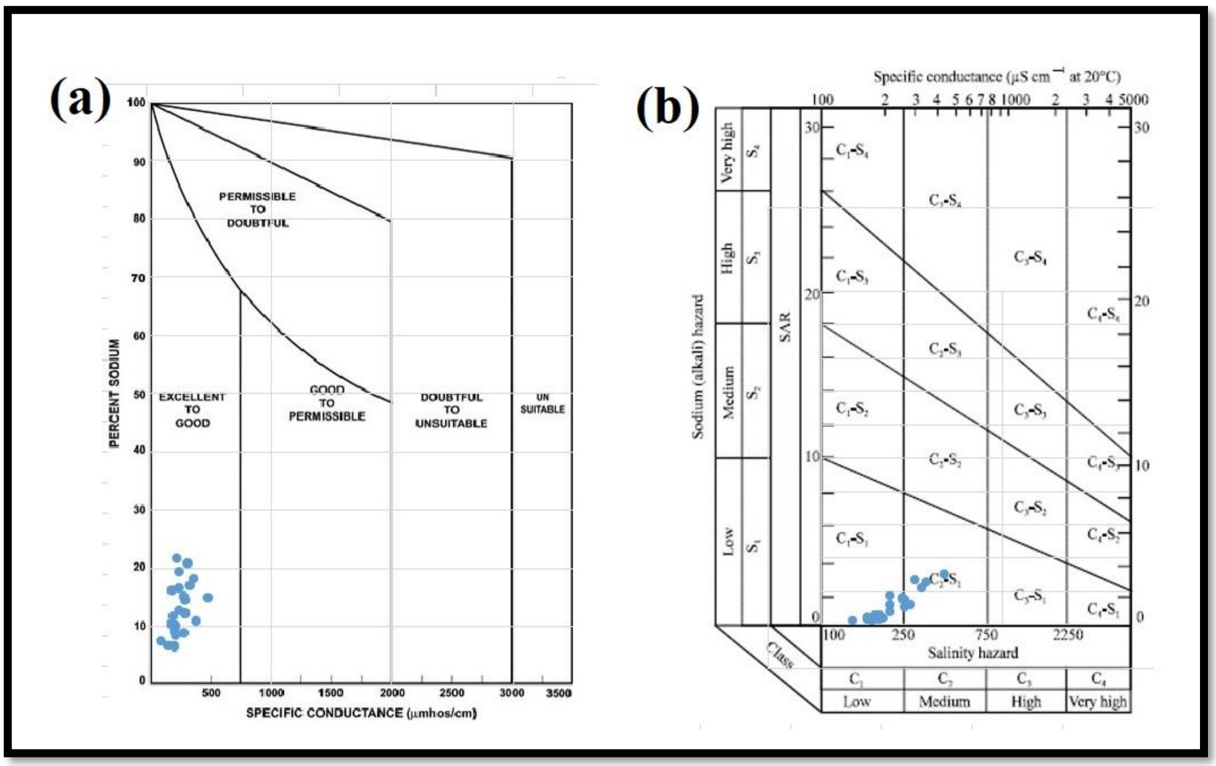

Figure 17(a) %Na Vs EC, (b) Wilcox daigram

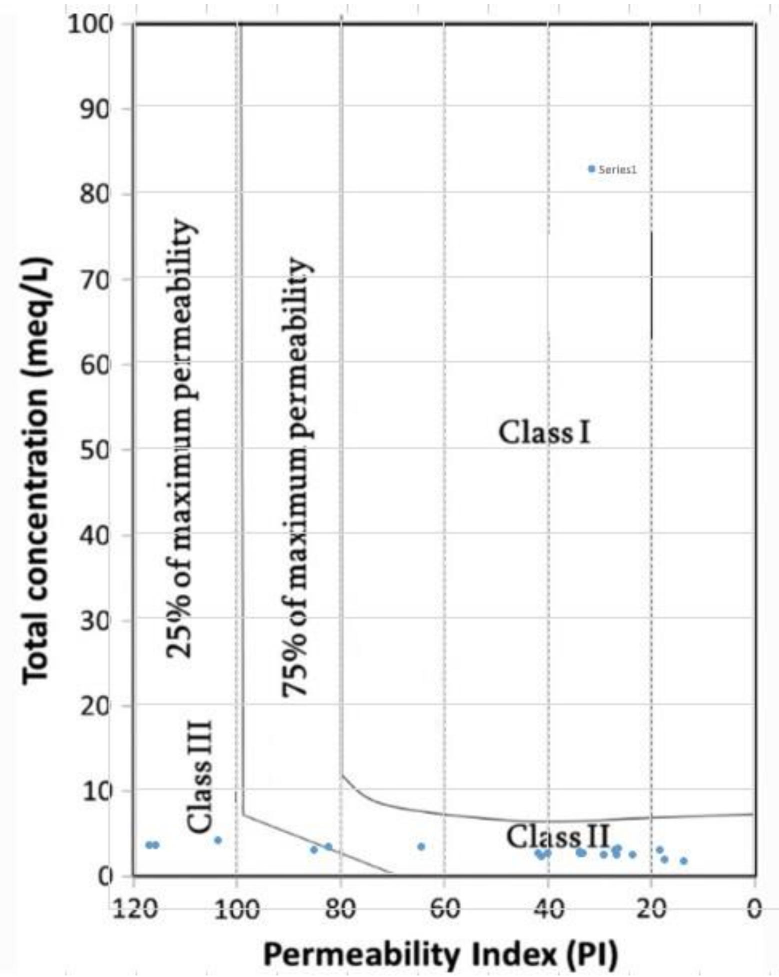

Figure 18 Permibility index for irrigation water Quality

Groundwater Suitability for Industry:

Corrosivity index

The effects of corrosion are losses in the hydraulic capacity of the pipes. Therefore, the corrosivity ratio >1 is considered unsafe and the CR value <1 polyvinyl chloride (PVC) pipes should be used. The corrosivity ratio ranges from 0.26 to 3.41. 82% samples showed a corrosivity ratio <1 while 18% samples, i.e., Saspool, Thicksey, Karoo, Tsati and Diskit had more than one.

The groundwater quality data were compared with BIS standards and all the samples were found good for Industrial Use.

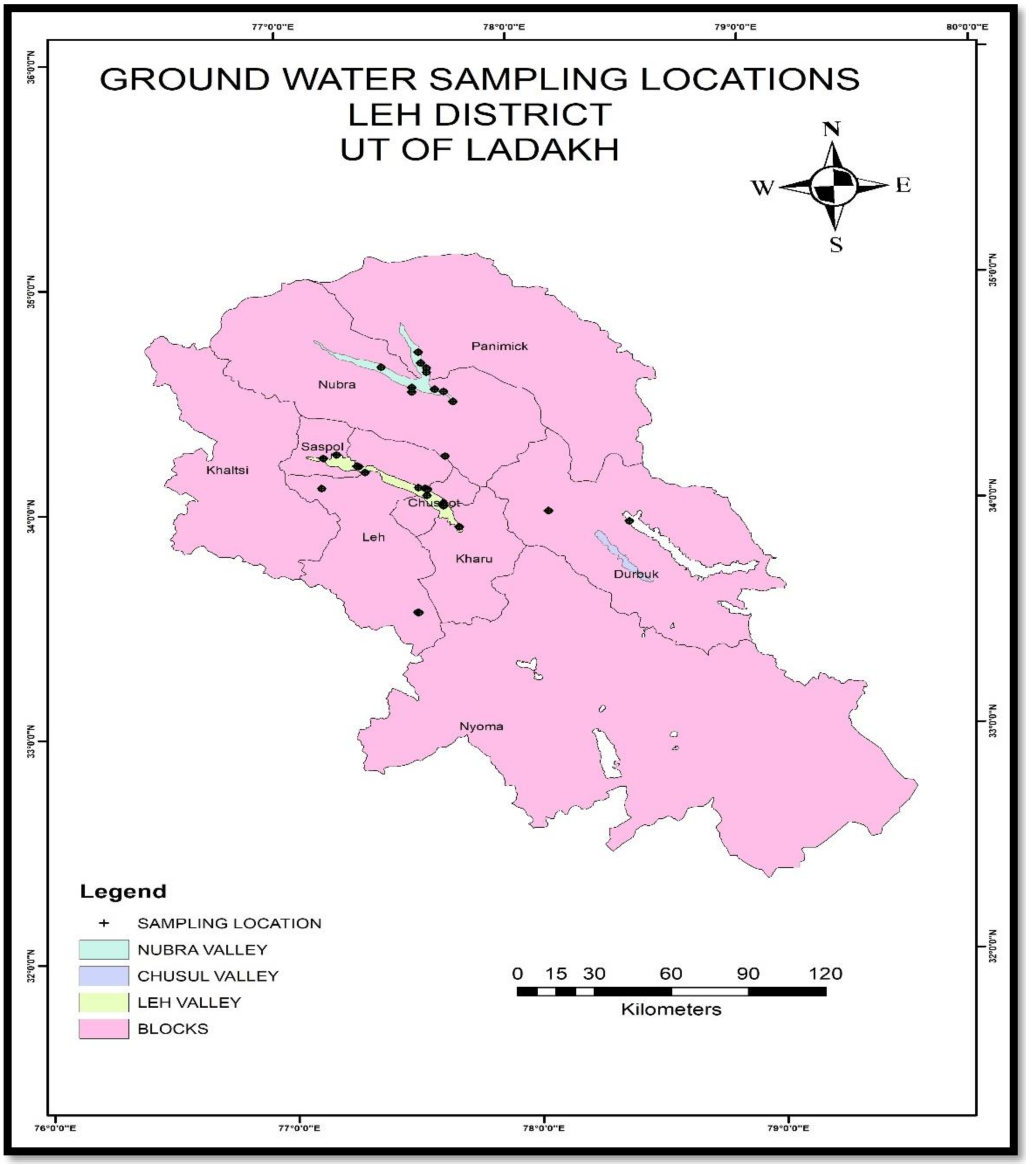

Figure 19 Ground water Sampling Locations in Leh District

2.6 GEOPHYSICS

The true disposition of Aquifer cannot be determined using present rigs as during the past exploratory drilling programs by CGWB as well by the private agencies, almost all the wells were drilled down to a depth not exceeding 100 meters. A hard-morainic boulder bed starts from a depth ranging from 60 to 100 mbgl depending upon the location along which the drilling is stopped, and further, the presence of a single unconfined aquifer whose bottom depth is not yet known makes the groundwater scenario more complicated. The basement rock encountered will be Ladakh granite and Karakoram granite, respectively whose true depths must be ascertained to determine the true thickness of the aquifer. Further, the presence of a deeper fractured aquifer which is concealed beneath the thick glacial sediments can also be ascertained.

The hydrogeophysical cross-section stretched over more than 70 km is along the Indus river valley in between Indus Suture Zone and Ladakh batholith. The NW-SE trending River Indus flows almost along the contact zone of southern Indus Suture Zone (ISZ) and the Laddakh-Gangdese Batholith towards the north. The folded chlorite and talc schist forms the major matrix rock of ISZ. It also includes highly dismembered and chaotically distributed rock – the 'ophiolitic mélange' (mixture of rocks). The thrust fault underlies the ISZ. Most of the VES are located along the Indus river valley between Saspul towards NW and Upshi towards SE. The hydrogeophysical cross-section (Figure 15) is based on the results of the VES conducted along the river valley. The elevation of VES sites varies considerably from 3556 m at VES 104 to 3023 m at VES 96. As observed from the cross-section, there are patches of areas with moderate resistivities (ranging from 66 ohm.m to about 200 ohm.m). They are shown as aquifer zones in the cross-section. In the entire cross-section the stretch of VES 97, 101 and 105 with a geoelectrical layer of resistivity 166-173 ohm.m in the depth ranges 16-110, 27-124, 39-117 m, respectively is expected to be most promising. Also, the patch between VES 110 and 115 is expected to hold a thick aquifer. At VES 90 and 115 localized patches of lesser resistivity 66-68 ohm.m are delineated up to 63 and 83 m depth respectively. Out of these, the layer 68 ohm.m resistivity at VES 90 is underlain by another layer of 285 ohm.m resistivity, which is a lesser value compared to 471 ohm.m at VES 115. Similar patches occur towards the NW end of the cross-section around VES 96, 114 and 118.

The hydro geophysical cross-section along the Indus River using most of the VES results manifests the possible presence of patches of moderately resistive rock that may form the aquifer. Besides, the qualitative analysis of fractured zones has revealed the possible presence of fractured zone aquifer in the area. The areas suitable for drilling are shown in figure 15. Based on VES inferred layer parameters and the fractured zone analysis, recommendations for drilling sites are given in Annexure-II.

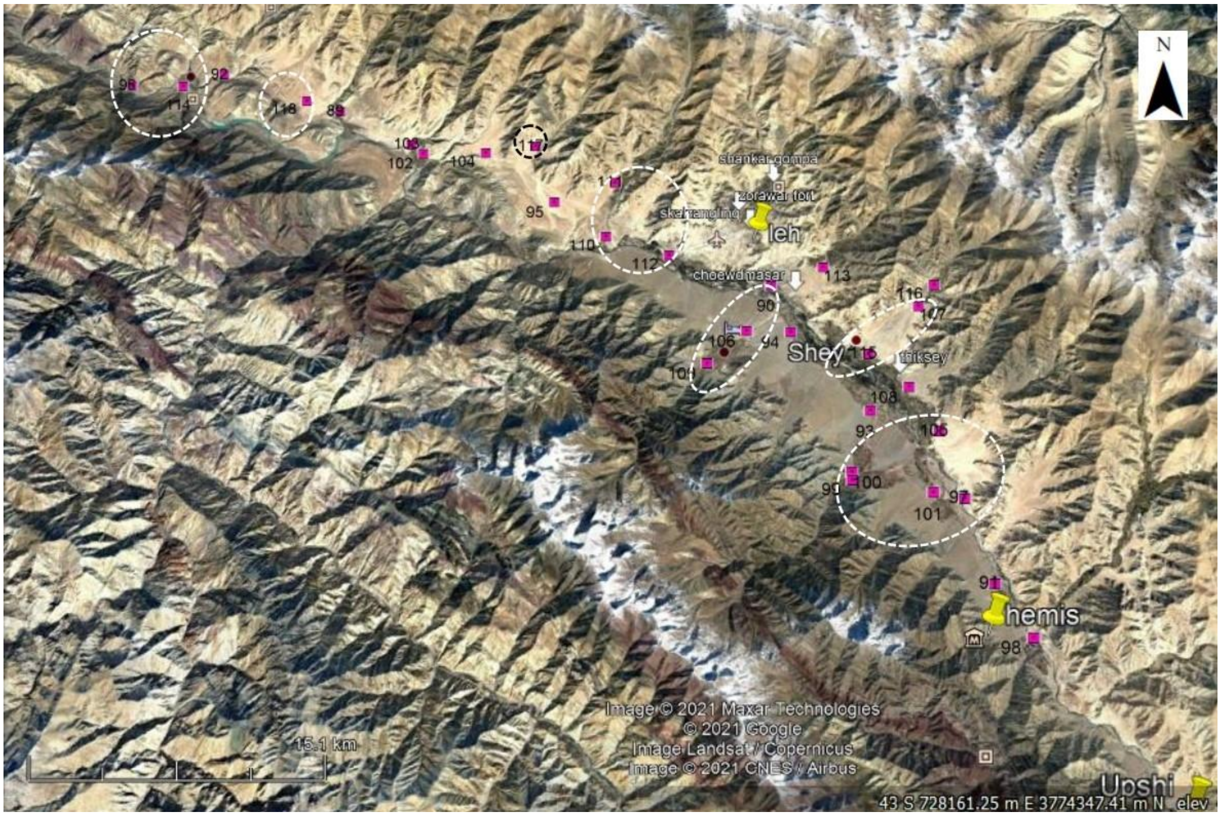

Figure 20 Vertical Electrical Sounding Locations

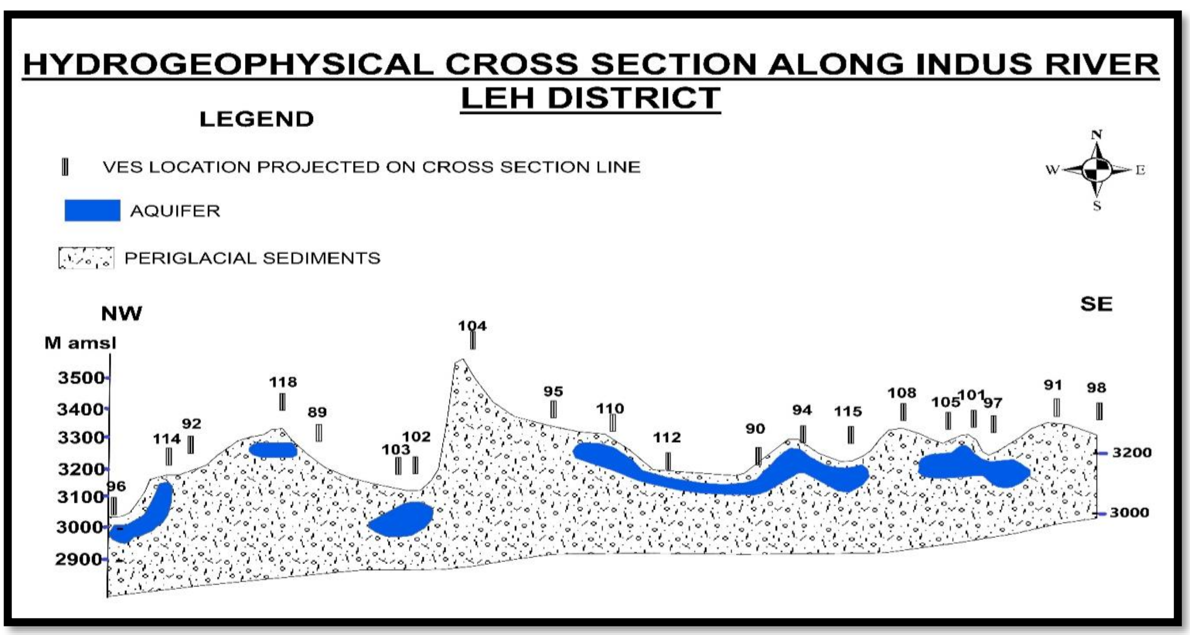

Figure 21 Geophysical Cross-section along Indus River

2.7 GROUNDWATER EXPLORATION IN AQUIFER MAPPING

The Central Ground Water Board has drilled 31 exploratory wells in Leh district, of which 8 exploratory wells were drilled in Nubra Valley, and 23 exploratory wells were drilled in Leh Valley, the details of which are summarized in table-7. The major lithology encountered was sand, gravel, pebble, boulders of granite mixed with little clay.(Figure-20)

Table 7 Details of Exploratory wells drilled in Leh district

S.No	Location	Depth drilled	Major Lithology	Zones encountered	Discharge lpm
1.	ITBP-I	62.50	Clay, sand, boulder of fluvio-glacial deposits	30.65-62.52	890
2.	ITBP-II	61.00	Clay, sand, boulder of fluvio-glacial deposits		604
3.	Zorawar Fort	70.00	Sand, Clay		775
4.	Sakara	54.00	Sand, Clay and boulders		905
5.	Shankar Gompa	73.00	Sand, Clay and boulders		636
6.	Skalzangling	71.50	Sand, Clay and boulders		197
7.	Trishul	53.00			
8.	Ditukmes/Pituk	65.00	Sand, Clay and boulders		1600
9.	16 BRTF,Leh	65.00	Sand, Clay and boulders		1173
10.	School of Buddhist philosophy (chublamsar)	56.00	Sand, Clay and boulders		550
11.	C.I.B.S	54.00			
12.	Air Force	58.00			
13.	ITBP-III	72.00			
14.	ITBP-IV	72.00			
15.	Project Himank	69.00			

16.	Thiksey, 753 BRTF	62.00	Sand, Clay and boulders	3-6.70, 6.70-19, 46.58-63	900
17.	Sakti,51 RCC	40.25	Sand, Clay and boulders	13-19, 22-31, 31-42	1250
18.	Patther Sahib	86.00	Clay, sand and boulders	63-66, 68-71, 73-76, 78-81,	
19.	Partapur-I	60.00	Sand and gravel	47-49	
20.	Partapur-II	49.00	Sand and gravel	35-40, 42-48	3068
21.	221-Transit Camp,	50.00	Sand and gravel	35-40	6947
22.	Siachen-I	43.50	Sand and gravel	5-12	3862
23.	Siachen-III	44.00	Sand and gravel	5-13	28465
24.	Siachen - III	10.00	Sand and gravel	10.13-11	
25.	Skampuk	49.63	Sand, gravel, pebble	35-40 , 42-47	1185
26.	Sasoma	44.50	sand, clay and gravel		
27.	ITBP 37th Bn Thicksey	68	Sand and gravel	59-65	90
28.	Milk Plant	78	Sand and gravel	40-77.50	150
29.	Changspa	251	Sand, gravel, pebble	165-251	120
30.	Skanpari	80	Clay, Sand, Boulders		
31.	ITBP-16th Bn Sabu	105	Sand and gravel	49-105	90

The major lithology encountered during the drilling was boulder, gravel pebble and sand of glacio-fluvial origin. The lithologies of a few Exploratory wells are as follows

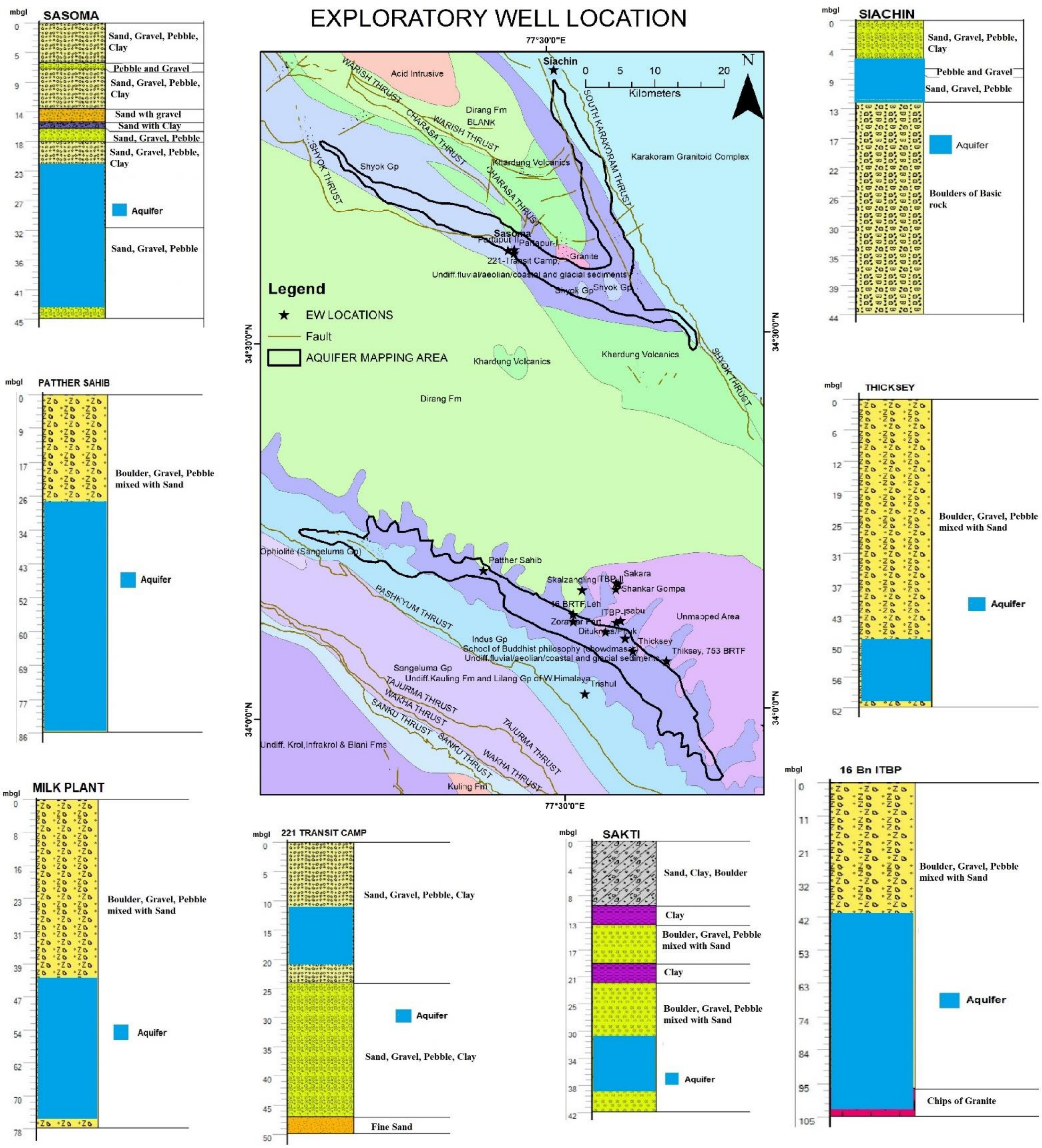

Figure 22 Lithologies of wells drilled along Leh valley and Nubra Valley

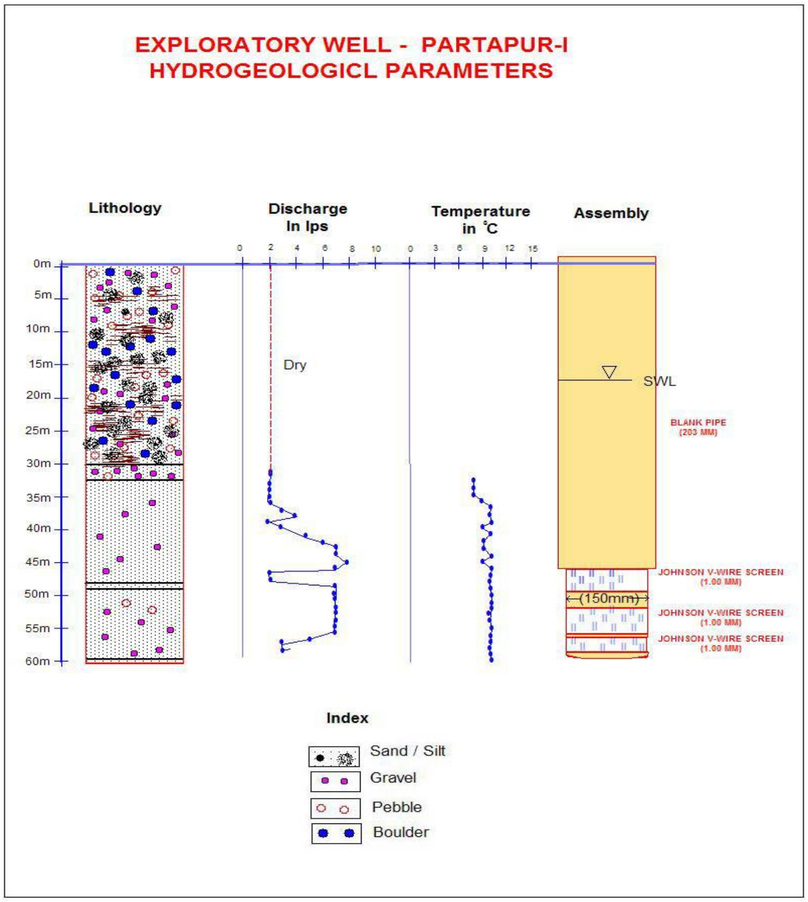

Figure 23 Lithology of exploratory well drilled at Partapur in Nubra Valley

3. NATURE OF AVAILABLE AQUIFERS

The district is underlain by the consolidated formation in the maximum part. Groundwater in these formations occurs in fissures and fractures developed due to repeated tectonic activity. Large scale groundwater development is not possible in consolidated formations but limited development of groundwater resources can be taken up. As the settlement pattern of people in this district mainly concentrated in the river valleys and few broad valleys formed due to the erosional activity of glaciers. The groundwater development in these areas is of utmost importance. The unconsolidated formations like alluvium, scree, and talus deposits present along the river valleys which plays a vital role in terms of occurrence and movement of groundwater. Groundwater resources in these formations can also be developed on a sustainable basis. The moraine formations consist of boulders and clastics in a matrix of gravel, sand, silt, and clay which from the aquifer. Depth to the water level in moraine formations is very deep which varies from 60 m bgl to 75 m bgl. The valley-fill deposits are mainly boulders and gravel mixed with silt and sand. This is mainly transported material lying unsorted in the recent river valleys. Groundwater occurs as unconfined conditions in valley-fill deposits. Depth to water is very shallow to as deep as 25 m bgl and is related to river water level.

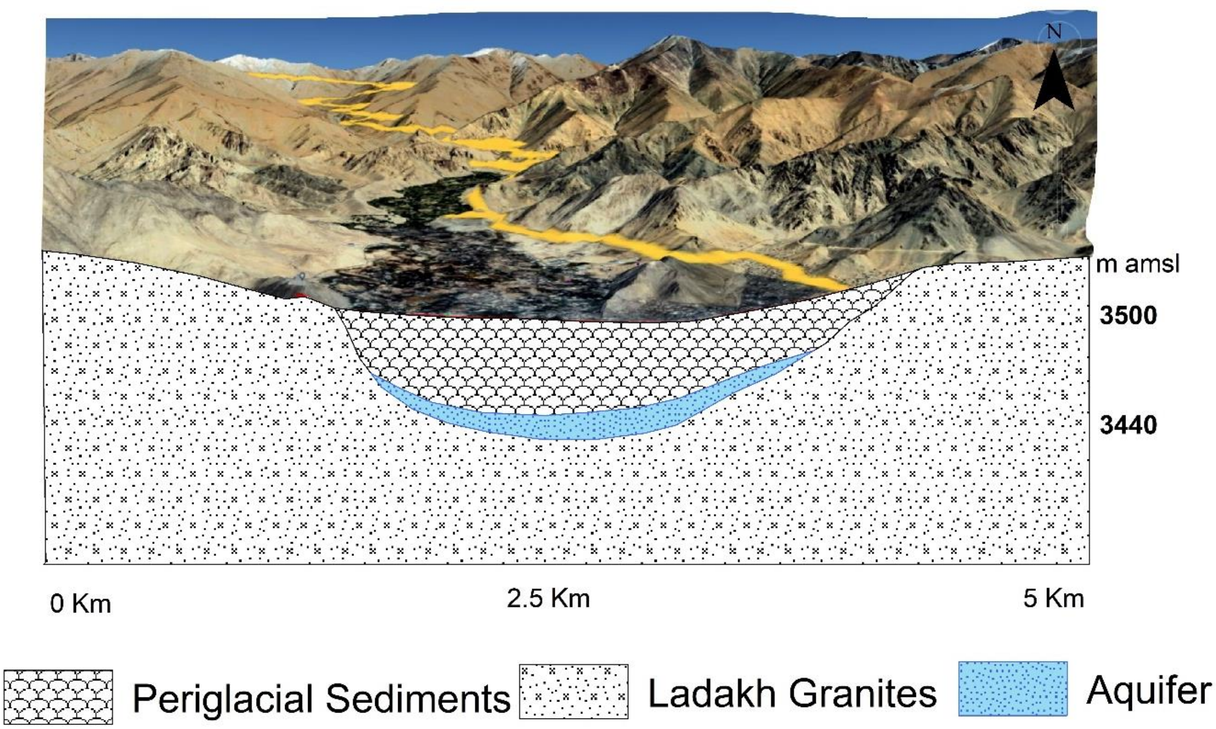

Figure 24 Lithological Cross-Section across Fort-road Leh Valley

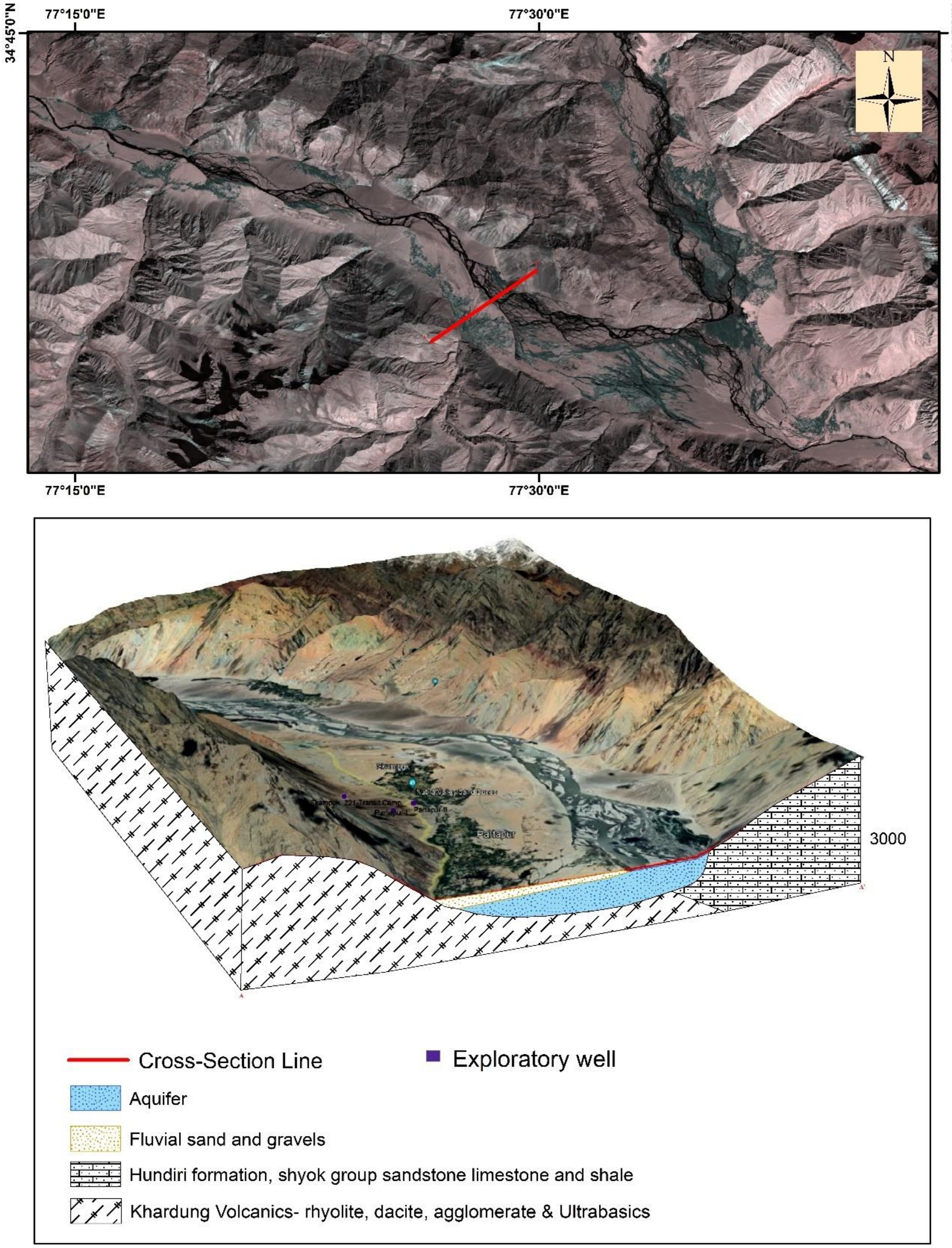

Figure 25 Lithological cross-section along Shyok river in Nubra Valley

Table 8: Aquifer Type, it's Quality and Suitability of Rigs

Formation	Prominent Lithology	Average Explored depth (mbgl)	Maximum depth drilled (mbgl)	Yield Potential (lpm)	Suitability for drinking and irrigation	Aquifer Type	Suitability of Rigs
Undifferentiated Quaternary	Alluvium, Moraine, Hill wash and Scree	50-105	111	90-120	Yes	Unconfined aquifer	DTH/ODEX
Indus Group	Conglomerate, sandstone, shale and siltstone					Un-explored	
Shyok group	Sandstone, limestone, shale with fossils					Un-explored	
Ladakh crystalline	Granite					Un-explored	

Leh plains are underlain by moraine deposits consisting of boulders, cobbles, pebbles embedded in an arenaceous matrix, and lake deposits comprising predominantly of clays, sandy clays, and silt. Varved clays overlie the sediments and silts of lacustrine origin again succeeded by moraine boulders and cobbles in the disintegrated, loose sandy matrix and alluvial deposits. The Nubra and Shyok valleys are underlain by Glacio-fluviatile deposits. These deposits are sand, gravel, and glacial boulders. Apart from Glacio-fluviatile deposits, sand dunes are also found along the southern side of the Shyok River near Disket and Hunder. Flood plain from north of Kalsar to Sammor comprises of fluvial sand, gravel, pebbles, and boulders. The porous formation along Nobra and Shyok River are also promising potential horizons for groundwater development.

Ground Water Exploration by CGWB is confined to Leh Plains and Nubra Valley. From 1973 to 1997, 16 exploratory wells have been drilled in the district. It is concluded that depth to the water level in the constructed wells ranges from 1.30 m bgl at Zorawar fort to 43.36 m bgl at ITBP-II. The yield obtained from these wells ranged from 197 lpm for 16.57 m drawdown at Skalzangling to 1600 lpm for a drawdown of 3.0 m at Pituk site. Groundwater exploration activities again resumed in the Leh district during 2005-06. 8 exploratory tube wells and 01 Observation well were constructed in Leh plains and Nubra Valley. The Depth of tube wells ranges from 43 m at Siachen to 84 m at Patter Sahib and the yield varies from 1000 lpm at Patter Sahib to 1200 lpm at Siachen Base-III. The transmissivity values range from 204 to 28465 m^2/day. In Nubra valley, PHE department has constructed a number of hand pumps for meeting water supply to the villagers. The depth of these hand pumps ranges between 21.336 m in Disket to 51.816 m in Disket Khemathong. The depth to water level ranges between 9.75m in Disket to 34.74m in Quarter Disket.

From figure 13, 14 it is evident that all of the tube wells drilled by CGWB are in the Quaternary Undifferentiated area which glacial aeolian and fluvial sediments of variable thickness whereas the Indus, Shyok, and Ladakh crystalline remain unexplored.

3.1 AQUIFER CHARACTERISTICS

The true aquifer thickness cannot be known through exploratory well data's as the maximum depth reached was 251 mbgl and till that depth, the zone continued.

The undifferentiated quaternary sediments in the Leh town Piedmont zone yields 90-905 lpm discharge, and drawdown ranges from 3 to 7 meters. Morainic alluvium, hill wash, and scree form the major aquifer of Leh valley. The aquifer system of Quaternary alluvium is mostly unconfined and only one single aquifer system prevails. The transmissivity of these formation ranges from 408 m^2/day to as high as 6947 m^2/day. The discharge along the Piedmont slope is usually less than 3 Lps; however these discharge increases on well-drilled along the channel alluvium. There Aquifer is discontinuous and is localized to Piedmont slope with perineal stream recharging the aquifer. The formation along the piedmont slope with no stream channel is usually dry as evident from the geophysical section and well drilled at Skanpari.

Formation	Prominent Lithology	Average Aquifer Thickness range (m)	Transmissivity m^2/day	Average Discharge (Lpm)	Quality
Undifferentiated Quaternary	Alluvium, Moraine, Hill wash and Scree	5-60 m	408-2376.34	90 - 905	Unconfined aquifer
Channel Alluvium	Sand, Gravel, Pebble, boulder	14-70 m	3068.67	1162-6947	Un-explored

3.2 LITHOLOGICAL DISPOSITION AND AQUIFER DISPOSITION

The lithological disposition and the aquifer disposition interpreted through the models, fence, and cross-sections prepared. The sections drawn for sub-surface formations and aquifers have vertical and horizontal scales in meters (Figure-24, 25).

The lithological and aquifer model of the complete aquifer mapping area depicts that the northern part is at a higher elevation and the depth of exploration is limited to 73 meters in this part the lithology from the bottom to the top remains more over the same that is boulder, gravel, pebble of granite and sand.

The fence diagram delineating the lithology and aquifer disposition is drawn between EW Sakara to EW Changpsa (Figure-26). The thickness of the aquifer increases downslope towards the Indus river. From the figure 27 it is evident that the elevation difference between the exploratory well is considerably very much.

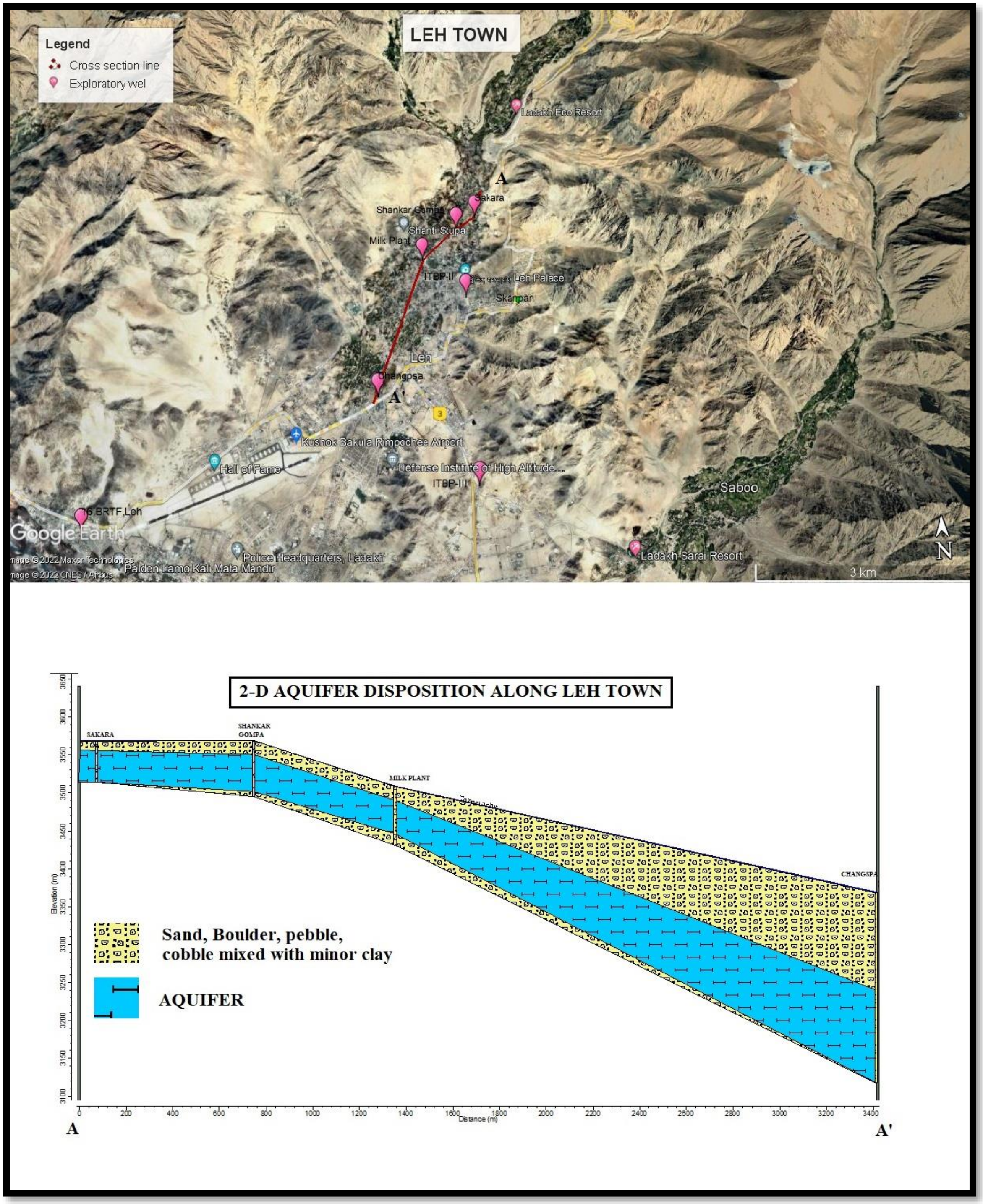

Figure 26 Aquifer disposition along Leh Town

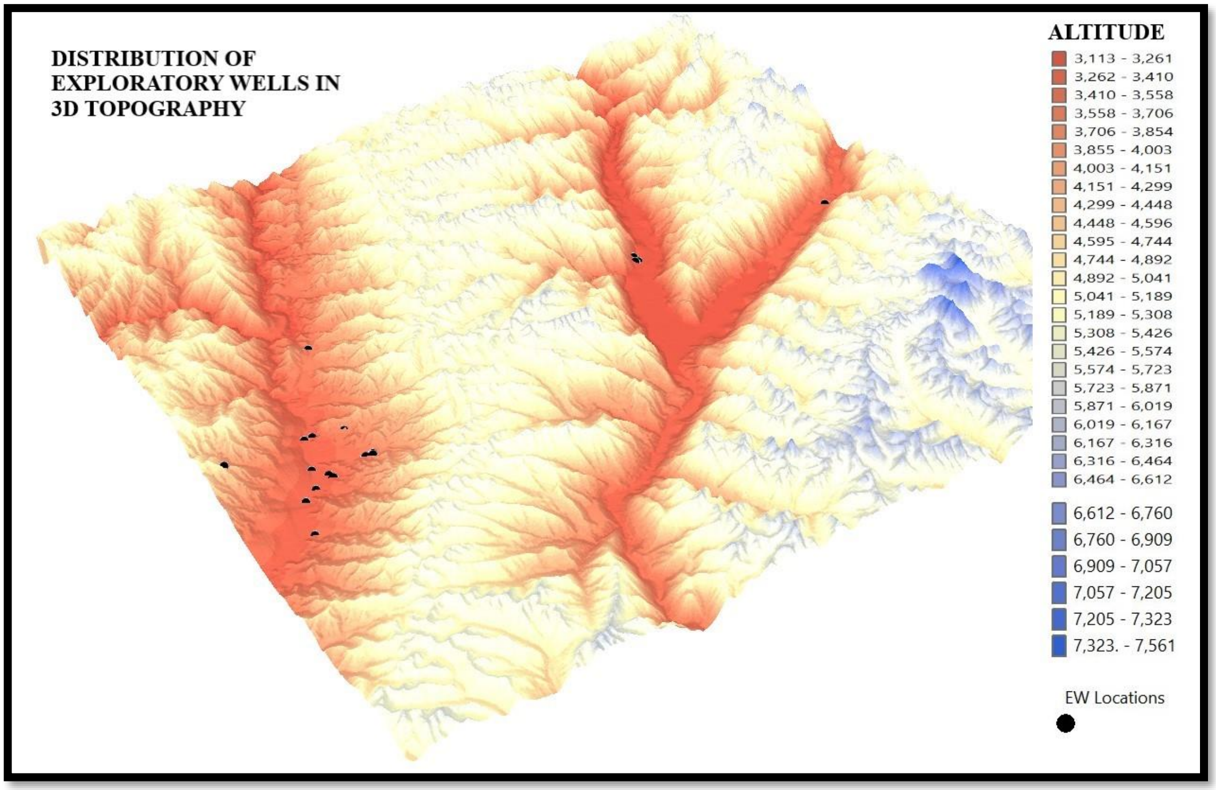

Figure 27 Distribution of EWs in a 3 D Topography

3.3 SPRING

Hydrogeological investigation during 2004-05, eighteen springs were inventoried. A perusal of the data reveals that the yields of these springs range from 1.5 lps (Yulkum) to 290 lps (Boudang). These springs normally are being used for domestic purposes but they also serve as sources of irrigation. The springs are the prominent seepage zone of the area and they receive their recharge from glaciers located at the higher altitude. These springs are present at the contact of valley-fill deposits and the older formations. They are also found along weak zones such as fractures, faults, and thrust zones. Hot water springs are located near Panamic and Changlumsar along thrust zones. Hot water springs are yielding 9 to 20 lps at nearly boiling water Temperature 95 ºC at the source, which infers that the groundwater is oozing from the deep-seated thrust zone. Figure 18 shows the distribution of both hot spring and depression springs in the Nubra valley area.

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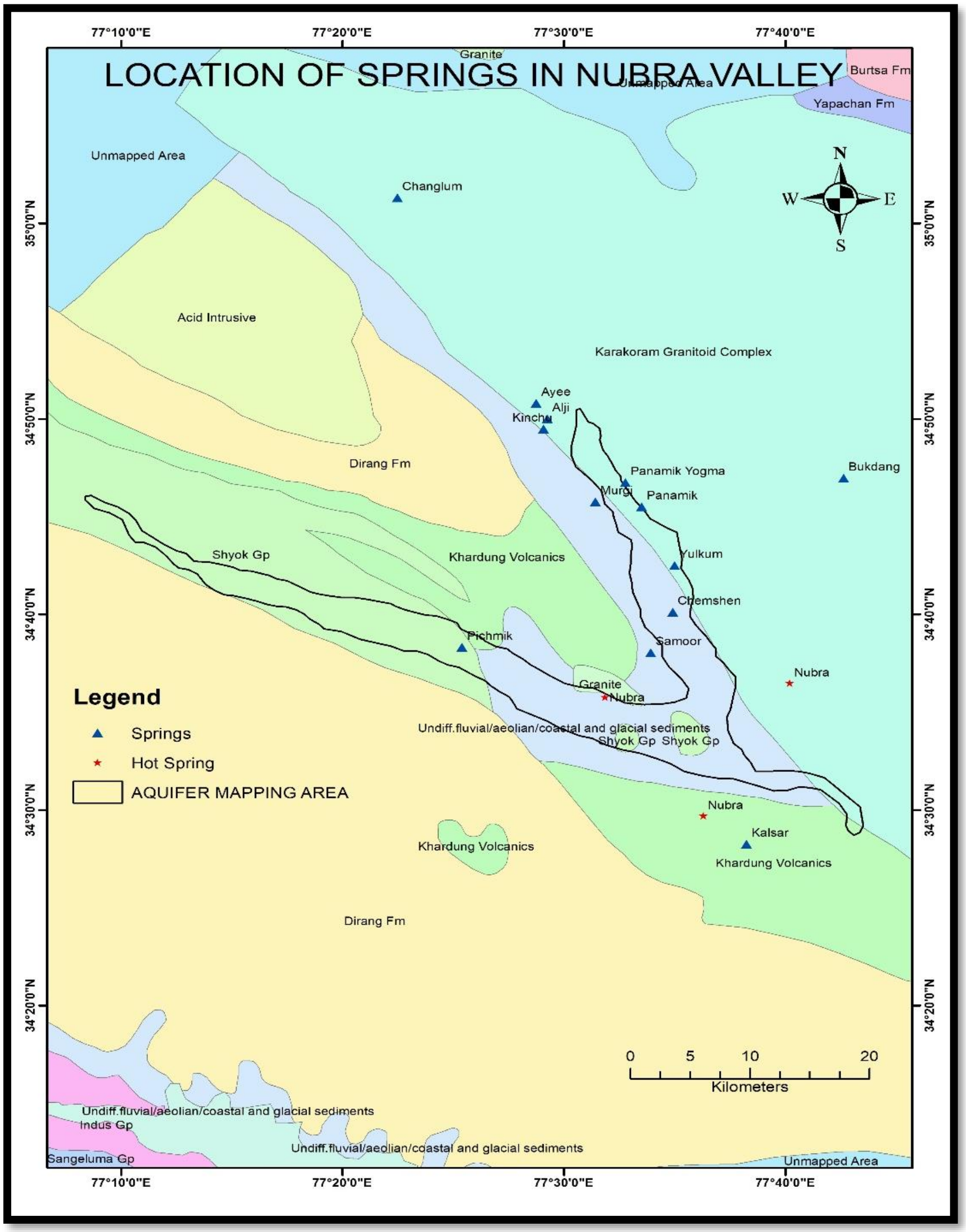

Figure 28 Spatial distribution of springs in various geological formation

3.4 GROUNDWATER RESOURCES

The quantitative estimation of various inputs to ground water resources and their temporal variation in space and time is imperative for a planned management and development of ground water resources. The resources in the surveyed area are computed on the basis of methodology recommended by the Ground Water Estimation Committee of Ministry of Water Resources, Govt. of India, 2015.

The entire aquifer mapping area, falls under command area and has been covered under ground water resource assessment. The estimation of ground water resource in the surveyed area is taken as on March 2020.

Methodology adopted

The primary source of recharge of groundwater in Ladakh district is snow melt and winter precipitation (snowfall and rainfall). Therefore, rainfall infiltration method has been used for estimating the resources. Rainfall recharge factor or Infiltration factor is a recharge parameter that indicates a quantum of water recharged to the groundwater system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The infiltration factor can be expressed as follows

IF = (Qi/Qa) X SY,
Where,
IF = Infiltration Factor
Qi = Quantum of water infiltrated over the test period in m
Qa = Quantum of water applied in m
SY = Specific Yield

Recharge of ground water involves several components and the rainfall being the major one. The other components are return irrigation flow from surface water and ground water.

Rainfall infiltration factor for alluvial formations is taken as 20%. The Return Flow Factor for recharge from surface water irrigation has been taken as 15-25 % for non-paddy crops and 50-60 % for paddy crops. In case of ground water irrigation, the return flow factor has been taken as 15-25 % for non-paddy crops. Canal seepage factor, for lined and unlined canals, has been taken as per GEC' 2015 norms. The recharge from other sources i.e. ponds and lakes have also been estimated based on the spread area of the water bodies.

DYNAMIC GROUND WATER RESOURCES (As on March 2020)

. The overall stage of ground water development in the NAQUIM area of Leh is 36.13 %, falls under safe category. The details are given in table-9. The Tube well census of the Town area of Leh is under progress. The assessment of 29 Sq Km area of Leh Town area will be accessed separately in the Groundwater resource estimation as on march 2022 after complete availability of extraction data.

Table 9 Dynamic Ground Water Resources of Leh district as on March 2020

S. No.	Assessment Unit/Distict	Command/non-Command/Total (Hac.)	Net Annual Groundwater Availability	Existing Gross Groundwater Draft for irrigation	Existing Gross Groundwater Draft for domestic and industrial water supply	Existing Gross Groundwater Draft for all uses (5+6)	Provision for domestic, and industrial requirement supply to 2025 years	Net Annual Groundwater Availability for future irrigation development (4-5-8)	Stage of Groundwater Development 7/4*100 (%)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Leh	71400	4698.86	89.86	1608.01	1697.87	1587.31	3,021.69	36.13

4. ISSUES

The major part of Leh is a mountainous area, and the groundwater is dipper in the piedmont zone and shallower near the valley portion.

Most of the major towns are located in this piedmont zone, and due to the narrow extent and steep slope, and high permeability of these zones, the groundwater holding capacity is less as the groundwater drains out in the Indus, Shyok, and Nubra River.

During the groundwater sampling, it was also observed that many hand pumps yielded silty water due to the improper development of wells.

Fluoride is present above permissible limits Chusul valley and Panamik, and Thrisha Spring

Recent Global Warming has decreased the extent of glaciers in the Himalayas, which were the primary contributors to surface and groundwater. Being in the rain shadow area, the precipitation received via rainfall is also very less.

Due to the increased number of tube wells in the pediment area of Leh town, people have reported a deepening of water level during peak seasons.

Besides, during the tourist seasons between March to September, the stress on the aquifer increases due to increased extraction of groundwater during this period.

5. GROUNDWATER MANAGEMENT STRATEGY

MANAGEMENT PLAN

5.1 MANAGEMENT OPTIONS - DEMAND SIDE

Conjunctive Use

The Valley portion of Leh possesses good groundwater potential. For efficient and sustainable agriculture in surface water-deficient areas, surface water and groundwater can be harnessed conjunctively to have a more or less drought-proof water management system. In the piedmont slopes, the perennial nalas should be used as a source of both domestic and industrial use and the groundwater piedmont area should only be used for drinking water.

The surface streams (locally called Yuras) must be managed efficiently and the dumping of effluents in this stream should be stopped.

Irrigation Strategies

Drought proofing can be achieved by promoting the use of drip & sprinkler irrigation system, with proper infrastructural support and government subsidies.

Solid Waste Disposal/Landfill site

Such a site should be decided in consultation with the Central Ground Water Board so that the quality of groundwater does not get affected.

In industrial areas, Effluent Treatment Plants of sufficient capacities must be installed and their working and waste disposal should be strictly monitored to protect the aquifer/water body from pollution.

Capacity Building

People should be made aware of water management practices, modern agricultural and irrigation techniques, changing climate, etc.

5.2 MANAGEMENT OPTIONS - SUPPLY SIDE

Protection of Aquifers

a- Banning of mining in the river bed.
b- Encroachment of flood zone should be stopped.
c- Banning disposal of effluents from domestic and industrial use to the streams.

Rejuvenation

a- Construction of check dams at suitable places in the river.
b- Sub-surface dyke across the river and nalas.

Uneven distribution of Aquifers

The inconsistency in the lateral and vertical extent of aquifers creates excess water availability in one area and scarcity in the other. The excess water should be supplied to water-scarce areas.

Scientific Approach for Exploration/Production

Construction of tube wells should be done on systematic and scientific lines. Scientifically specified distance should be maintained between tube wells to avoid interference of the wells. The well assembly of the should have proper slot size according to lithologies encountered.

Estimation of Aquifer parameters

Proper pump tests need to be carried out to arrive at the correct groundwater aquifer parameters of the tube wells and installation of the pumps of appropriate capacity.

The wells should be given proper recuperation time and the capacity of pumps should adhere to the recommended safe discharge.

Over Pumping/ Overdraft from Aquifer Ground Water

Over pumping from tube wells have to be stopped at all, as it is likely to damage not only the tube well but also the surrounding groundwater bearing formation. Overdraft from groundwater reservoir has to be avoided which may otherwise lead to disastrous consequences for the future development of sub-surface water.

Reclamation of water bodies and wetlands

The water bodies and wetlands should be protected and conserved and they should be restored to their original boundaries.

Groundwater development

Most of the district is concentrated in the valley portion which is drained by the Indus River and its tributaries. In the past, the development of groundwater was mainly through tube wells, wells along the Rivers, nallas. Some springs have played a major role in sustainable domestic and irrigational supplies. However, in recent years modern means of groundwater development have been employed. Public Health Engineering has been constructing a number of hand pumps and shallow to moderate deep tube wells for large-scale water supplies.

Snow harvesting & artificial recharge

Snow water harvesting is a technique of preservation of snow and delaying melting so that snow meltwater is available for a longer duration in a year. The selection of sites for snow harvesting depends on the isolation of an area, wind direction, wind velocity, and Relative Humidity. In the hilly areas, rooftop rainwater harvesting structures like storage tanks are recommended while in areas of low hill ranges check dams and snow water harvesting structures should be adopted. These structures were already constructed by local people on their own initiation and at some places government of Jammu and Kashmir has constructed few snow water harvesting structures.

Glacier serves as a source of fresh water that needs no further treatment and all the water contributed to the rivers is from glacial melt. Using Remote sensing analysis via Google Imagery the flow of a 1st order stream was analyzed from April 2019 to February 2020 from which it is evident that during April 2019 the water of

the stream was so less that it disappeared before reaching the Indus river and as the temperature starts increasing from mid-June onwards the water from the stream reaches the Indus and maintains its flow till October and from the mid-October as the temperature decreases the water freezes. The water from this stream can be utilized judiciously in the summer months.

Figure 29 Ice stupa (Artificial Glacier) in Ladakh

Image Source: India Water Portal

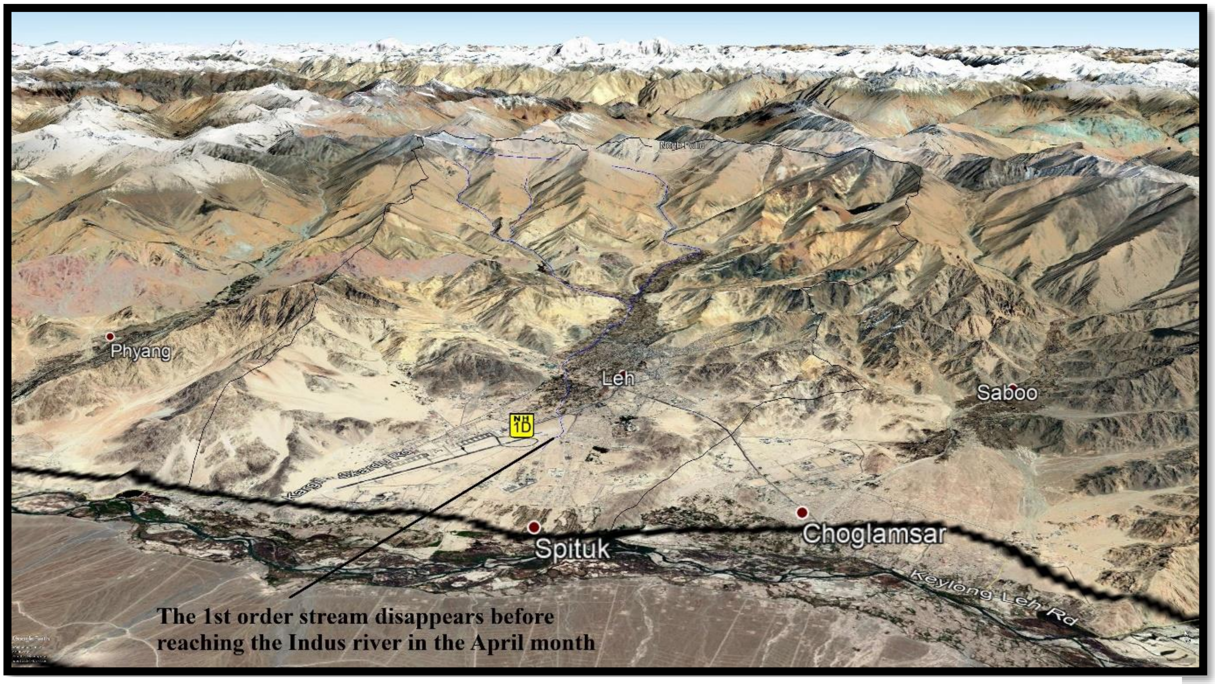

Figure 31 Land Sat/Copernicus google image of the Phyang Watershed depicting the status of stream flow during the month of April 2019

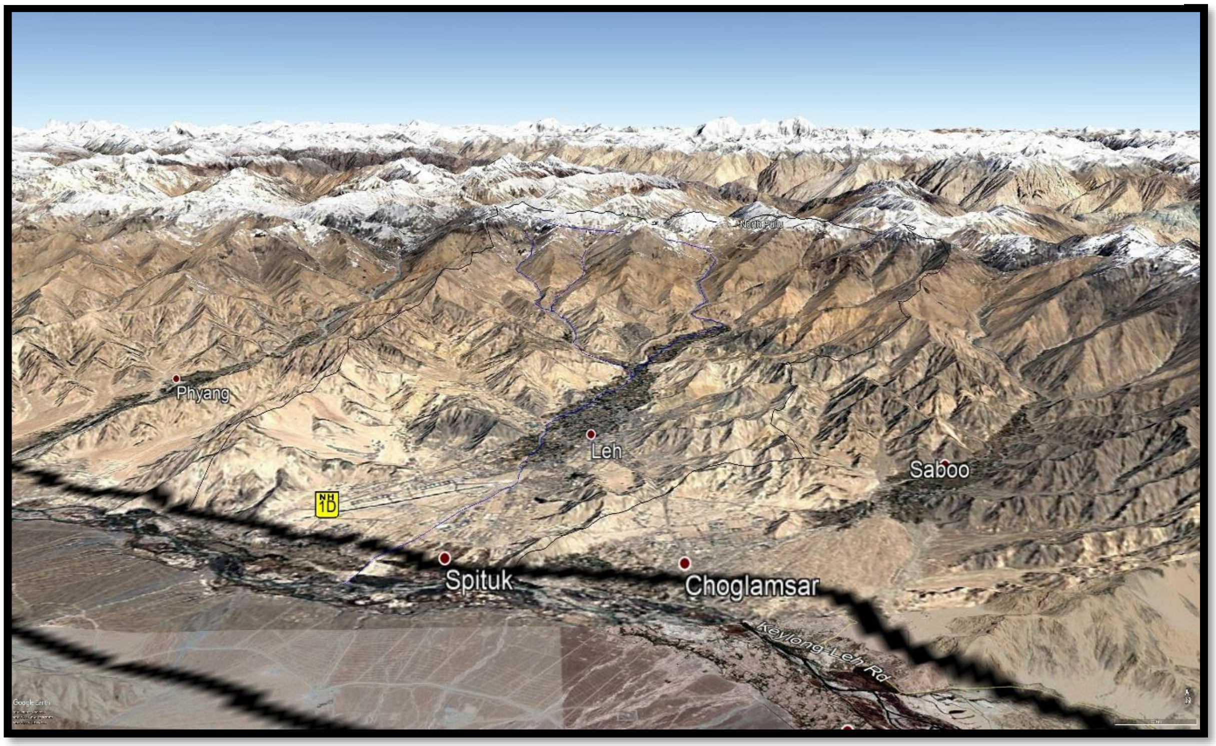

Figure 30 Land Sat/Copernicus google image of the Phyang Watershed depicting the status of stream flow during the month of July 2019

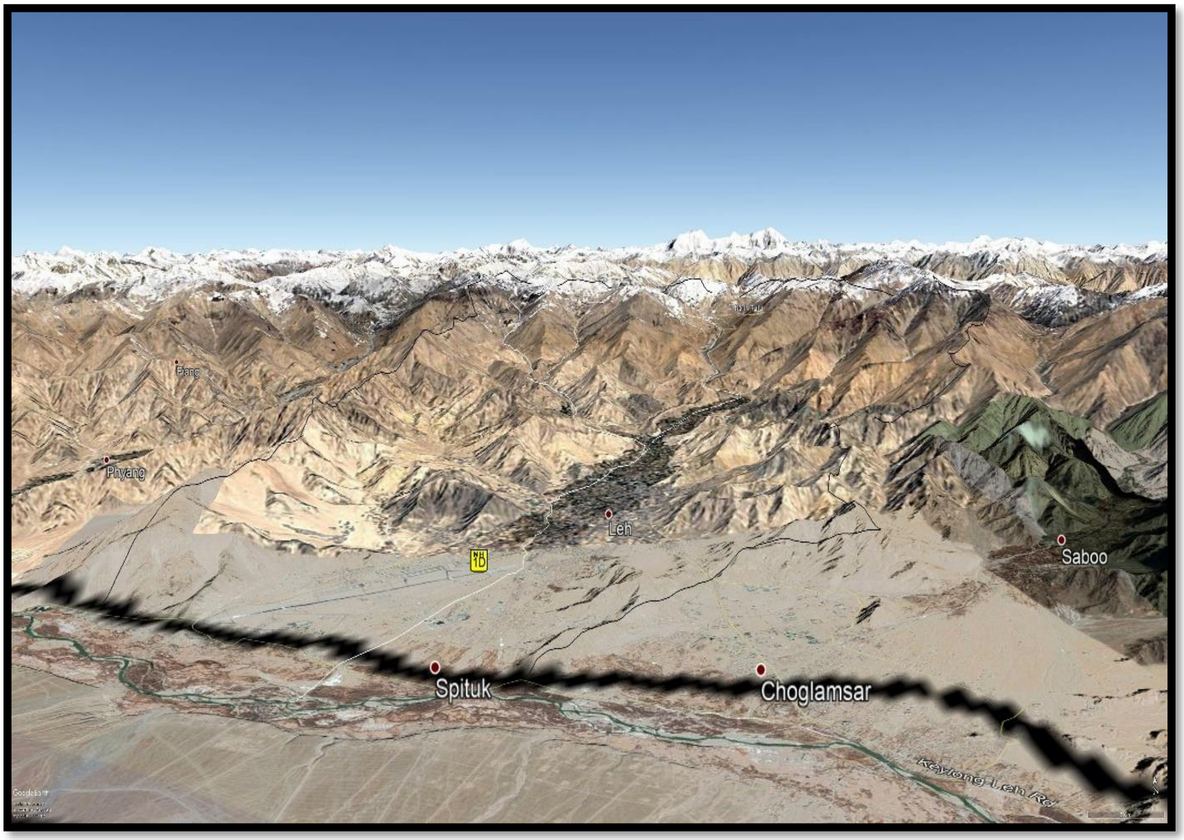

Figure 32 Land Sat/Copernicus google image of the Phyang Watershed depicting the status of stream flow during the month of February 2020

RECOMMENDATIONS

- The town area of Leh is an isolated unit of aquifer system covering an area of 28 Sq Km area. Recent studies along this piedmont slope has revealed that there are more than 1400 to 1700 unaccounted private tube-well drawing 1.60 MLD of water in this very small stretch of land (Source- Report on water supply and usage in highest town of Leh published by BORDA). This tube-wells mainly belongs under infrastructure category and there is no data of unit draft available for this tube-wells leading to improper assessment of resources further leading to over-exploitation of resources. The Pubic health department, Leh district has reported deepening of groundwater levels. Therefore it is recommended that the construction of new tube-wells along the Town area should be strictly prohibited until proper auditing of the tube-well is fully completed.

- In Valley areas, groundwater resources can be developed by constructing infiltration galleries/Percolation wells and dug wells. Shallow tube wells can also be constructed by deploying the percussion or DTH rigs.

- In the Piedmont areas, stream water should be used to cater to domestic as well as agricultural use. The channels should be kept clean.

- In hilly terrain, springs and perennial nallas are the major sources of water. These springs shall be developed based on modern scientific knowledge and they can be to be protected.

- Tube wells of 100 to 120 m depth are recommended to be constructed for water supply in terraces underlain by moraine formations. Hand pumps of 70 to 80 m depth are also recommended in small hamlets to meet the water supply requirements.

- Piezometers with automatic water level recorder with telemetry must be installed at every quadrangle of the aquifer mapping area as the area is devoid of dug wells to conduct manual water level monitoring.

- Irrigation channels carrying water from higher reaches need to be maintained properly and if required, they may be cemented so that the water can be safely transported to greater distances. Along the channels, small ponds can be constructed at suitable locations so that water can be stored in these shallow ponds which can also act as recharge structures for terraces deposits.

- Monitoring of springs both for discharge and quality shall be taken up regularly. Scientific studies shall be taken up in this district to study the source area and recharge the characters of springs.

- Traditional resources like springs need to be revived, developed & protected on scientific lines for various uses. All the springs shall be enumerated and listed properly and data shall be properly maintained. The discharge of such springs can be sustained by the construction of small check dams or subsurface dykes across the nallas/tributaries in the downstream at favorable locations.

- Small ponds/tanks can be utilized for recharging groundwater. These structures can be constructed for harvesting water and utilized for both recharging and meeting the domestic needs.

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Annexure 1 *Ground Water Quality Analysis of Leh District*

Sr. No.	Location	pH	EC (µs/cm) at 25^0 C	TDS	CO3 (mg/l)	HCO_3 (mg/l)	Total Alkalinity	Cl (mg/l)	Total Hardness as CaCO3 (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NO3 (mg/l)	F (mg/l)	SO4 mg/l	PO4 (mg/l)	U (µg/l)
1	Tirith Village Hand Pump	8.75	220	132	6.51	113	103	7	98	22	11	5.6	7.8	3.5	0	15.67	ND	1.5918
2	Sumoor Taxi Stand	8.56	180	108	6.51	139	125	7	98	17	13	6.0	5.6	3.12	0	13.64	ND	6.26466
3	Pinchmik	8.37	240	144	6.51	139	125	7	98	26	8	19.0	5.5	3.16	0.37	28	ND	15.2786
4	Youlkam	8.46	180	108	6.51	86	81	7	109	17	16	6.9	3.2	4.2	0.498	18.4	ND	23.9929
5	Tsati Handpump	8.50	280	168	6.51	113	103	27	109	26	11	26.3	4.6	4.1	1.33	37	ND	2.9622
6	Skampuk	8.38	150	90	6.51	113	103	7	76	22	5	3.6	2.3	3.6	1.042	8.4	ND	1.34736
7	Hotel Sand Dune Diskit	8.39	200	120	6.51	126	114	88	141	35	13	5.6	2.9	5.05	0.252	16.7	ND	0.38283
8	Diskit H.P opposite Kumzes Dolma General Store.	8.42	200	120	6.51	99	92	14	98	26	8	9.2	3.2	8.49	1.038	20.2	ND	2.48862
9	H.P near Hotel Siachin Sign board	8.30	210	126	0.00	53	43	27	119	26	13	7.3	2.6	4.2	0.244	27.45	ND	1.47818
10	H.P Lakjung	8.58	310	186	6.51	152	136	27	141	22	21	22.9	6.6	3.02	0.213	19.44	ND	8.1851
11	H.P Shyok river near Tisati Bridge	8.45	360	216	6.51	126	114	41	130	30	13	41	5.2	3.9	0.487	52.4	ND	5.1439
12	H.P Nubra River	8.48	240	144	6.51	126	114	7	119	22	16	14	6.5	3.66	0.718	30.68	ND	13.9227
13	H.P Sachule	7.43	90	54	0.00	66	54	7	65	13	8	3	2.5	3.83	0.178	9.05	ND	ND
14	H.P, P.H.E Tubewell, Chublamsar	8.30	180	108	0.00	119	98	7	98	26	8	5	3.6	4.2	0.161	14.66	ND	0.9871
15	H.P Shey	8.53	240	144	6.51	126	114	20	98	17	13	28	3.5	4.34	0.248	25.22	ND	5.97263

16	H.P Karoo	8.52	290	174	6.51	113	103	34	119	26	13	18.3	3.7	20.58	0.198	37.88	ND	3.77978
17	H.P Ranbirpur	8.66	290	174	6.51	113	103	20	130	26	16	27.2	4.2	3.37	0.37	40.22	ND	4.1534
18	H.P Thicksey	8.72	290	174	6.51	99	92	27	152	30	18	29.0	3.2	3.9	0.411	38.44	ND	6.82629
19	Saspul H.P-I, Infront of Hotel Duke Restaurant.	8.58	380	228	6.51	86	81	14	76	35	0	38.0	2.9	11.73	0.246	103.2	ND	4.23497
20	Saspul H.P-2, Saspul city	8.50	480	288	6.51	73	71	48	109	30	8	51.0	3.8	4.09	0.432	157.4	ND	ND
21	Spring Sample from Leh	8.67	280	168	6.51	113	103	20	109	35	5	26.2	2.4	6.01	0.54	25.76	ND	6.72205
22	Bagzo H.P 1	8.66	210	126	6.51	126	114	14	98	22	11	8.6	3.3	2.87	0.47	27.43	ND	0.41939
23	Bagzo H.P 2	9.00	330	198	13.02	185	174	14	141	13	26	51.0	4.0	3.099	0.908	26.9	ND	0.8854
24	Nimo	8.69	210	126	6.51	126	114	7	130	30	13	5.7	3.3	4.8	1.115	13.77	ND	0.40905
25	Stakmo	8.62	190	114	6.51	99	92	7	130	30	13	3.7	4.0	4.17	0.298	18.51	ND	1.08168
26	ChushotH.P	8.65	200	120	6.51	99	92	7	109	26	11	7	1.9	5.91	0.629	30.6	ND	0.514
27	Palam H.P	8.65	200	120	6.51	113	103	7	87	17	11	8.8	1.9	4.66	0.289	20.69	ND	1.1026

Annexure 2 Groundwater quality analysis for Irrigation

Location	Na%	SAR	RSC	Mg Ratio	Permeability Index	CR	SSP
Tirith Village Hand Pump	21.5	0.3	0.1	44.4	26.7	0.3	42.146
Sumoor Taxi Stand	16.1	0.4	0.5	55.5	29.2	0.3	18.25028
Pinchmik	16.5	1.2	0.5	33.3	85.1	0.4	13.2482
Youlkam	10.2	0.4	-0.5	60.0	33.0	0.4	11.41259
Tsati Handpump	15.0	1.6	-0.1	40.0	117.2	1.1	12.30931
Skampuk	6.7	0.3	0.5	28.6	17.5	0.3	6.227447
Hotel Sand Dune Diskit	9.0	0.3	-0.5	38.5	26.4	2.5	5.918519
Diskit H.P opposite	9.7	0.6	-0.1	33.3	42.0	0.6	7.818892

Kumzes Dolma General Store.							
H.P near Hotel Siachin Sign board	8.4	0.4	-1.5		33.8	1.3	6.893574
H.P Lakjung	20.8	1.2	-0.1	61.5	103.7	0.9	19.45405
H.P Shyok river near Tisati Bridge	18.1	2.2	-0.3	41.7	182.4	1.6	13.55721
H.P Nubra River	19.3	0.8	-0.1	54.5	64.5	0.4	18.01632
H.P Sachule	7.4	0.2	-0.2	50.0	13.7	0.3	10.76261
H.P, P.H.E Tubewell, Chublamsar	10.4	0.3	0.0	33.3	23.6	0.3	8.249475
H.P Shey	12.6	1.7	0.3	55.5	125.9	0.8	13.92283
H.P Karoo	12.1	1.0	-0.3	45.4	82.3	1.3	9.939906
H.P Ranbirpur	14.5	1.5	-0.5	50.0	121.6	0.9	12.02556
H.P Thicksey	12.3	1.4	-1.2	50.0	129.3	1.1	9.511225
Saspul H.P-I, Infront of Hotel Duke Restaurant.	10.8	2.5	-0.1		166.9	1.5	7.652359
Saspul H.P-2, Saspul city	14.9	3.0	-0.8	30.0	224.7	3.4	11.58285
Spring Sample from Leh	8.9	1.5	-0.1	20.0	115.8	0.8	6.310327
Bagzo H.P 1	10.1	0.5	0.3	44.4	39.9	0.6	9.479093

Bagzo H.P 2	17.0	2.6	0.7	76.9	230.1	0.5	22.42315
Nimo	10.1	0.3	-0.3	41.7	27.0	0.3	7.221274
Stakmo	11.7	0.2	-0.8	41.7	18.1	0.4	8.243783
ChushotH.P	6.4	0.4	-0.3	40.0	33.8	0.5	5.283689
Palam H.P	6.5	0.6	0.3	50.0	41.2	0.4	7.280287

Annexure 3 VES Interpretation, Leh district

VES No.	Location	Probable Aquifer			Recommendations for Drilling	Remarks
		Depth (m)		Resistivity (ohm.m)		
		From	To			
1	Bazgo	2	24	21	Dug Well or shallow well	The layer up to 24 m depth is predominant in clay. Dug well can be made.
2	Chaklamgr	17	63	68	70 m	The layer resistivity of 68 ohm.m in the depth range 17-63 m is favourable to form aquifer. The underlying layer of 285 ohm.m may also hold aquifer zones. The minimum depth of drilling is 70 m. It can be increased to 100 m
3	Chango	3	22	26	Dug well or shallow well	The layer up to 22 m depth is of sand mixed with in clay. Dug well can be made.
4	Chhulungche	No depth zone with favourable resistivity				No recommendation for drilling
5	Chuchot Gongama	No depth zone with favourable resistivity				No recommendation for drilling

6	Chusot	11	107	300	100 m	The resistivity of the layer in the depth range 11-107 m is 300 ohm.m. As such the resistivity value is high. It may form aquifer zone, because the resistivities of the overlying and underlying layers are much higher (1300 to more than 2800 ohm.m)
7	Taru	No depth zone with favourable resistivity				No recommendation for drilling
8	Lardo	18	73	209	80 m	The resistivity of the layer in the depth range 18-73 m is 209 ohm.m. As such the resistivity value is high. It may form aquifer zone, because the
						resistivities of the overlying and underlying layers are much higher (608 to more than 1200 ohm.m)
9	Mane	16	110	171	110 m	The depth range 16-110 m may form good aquifer zone
10	Marchilang	4	20	88	Dug well preferred	The layer of 88 ohm.m resistivity may near surface aquifer zone. The underlying layer of 248 ohm.m resistivity in the depth range 20-55 m can also for aquifer. It has not been considered because it is reflected in the VES curve in the rising segment of the VES curve and in the transitional resistivity zone.
11	Matha-2	1	20	52	100 m minimum	Though the layer of 109 ohm.m resistivity forms a part of the rising segment of the VES curve, i.e., in transitional
		20	86	109		

		86	To depth			resistivity zone, the actual values being moderate (109 ohm.m) and the resistivity of the layer underlying it being only 211 ohm.m the site is recommended
12	Matho	10	69	121	100 m	The layer resistivity of the aquifer zone and the layer underlying it being in the favourable range BH can be drilled up to 100 m depth
		69	To depth	193		
13	Miruche	27	124	173	125 m	The resistivity of the layer overlying the aquifer zone is high and extends up to 27 m depth. Though the resistivity of the aquifer zone is high (173 ohm.m), it has been considered because it is reflected in the VES curve as a low, overlain and underlain by highly resistive layers.l
14	Nimu	38	To depth	288	50 m	The layer resistivity of 288 ohm.m for the aquifer zone is approximate.
15	Phey	66	To depth	355	80-100 m	The bottom layer delineated has a resistivity of 355 ohm.m. The resistivity value is quite high but being in last layer delineated and overlain by layers of higher resistivity it is considered (LOW PRIORITY)y
16	--	2	12	53	Dug well	The resistivity of the bottom layer is 400 ohm.m (approx.,).
17	Lungila	39	117	166	120 m	The aquifer layer is reflected as low in the curve.

18	Stok	5	48	230	50 m	Though the resistivity of the aquifer zone is high (230 ohm.m), it has been considered because it is reflected in the VES curve as a low, overlain and underlain by highly resistive layers.l
19	SW of Stakmo	27	143	152	150 m (Maximum)	The aquifer zone resistivity is 152 ohm.m in the depth range 27-143 m
20	Sumdo	No depth zone with favourable resistivity				
21	Stok	26	129	165	130 m	The aquifer zone resistivity is 165 ohm.m
22	Phe	23	107	316	120 m	The aquifer zone resistivity is 316 ohm.m . It is much higher than the conventional range of resistivity for the aquifer zone.
23	Phyang	12	93	279	100 m	The aquifer zone resistivity is 279 ohm.m. . It is much higher than the conventional range of resistivity for the aquifer zone. It is considered because reflected in the VES curve as low
24	Pitok	12	50	241	50 m (Maximum)	The aquifer zone resistivity is 279 ohm.m. . It is much higher than the conventional range of resistivity for the aquifer zone. It is considered because reflected in the VES curve as low. Curve is distorted. LOW PRIORITY
25	Sabu	No depth zone with favourable resistivity				
26	Saspola	5	41	155	50 m	The aquifer zone resistivity is 155 ohm.m
27	Shey	9	83	66	90 m	The aquifer zone resistivity is 66 ohm.m favourable

28	Stakmo	No depth zone with favourable resistivity				
29	Taru	12	139	219		The aquifer zone resistivity is 219 ohm.m
30	Umlung Yogma	44	89	221		The aquifer zone resistivity is 221 ohm.m. The overlying layers of 199- 345 ohm.m up to 44 m depth also may form a part of the aquifer