



2020-2021 COMPREHENSIVE WATER AUDIT OF LEH

PHE WATER SUPPLY SYSTEM

Report on water supply, demand, loss, quality, people's opinion & identifying opportunities for better management practice



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Liveable Leh Project - The overall objective of the project is to strengthen capacities of the local government, the Ladakh Autonomous Hill Development Council (LAHDC) to make Leh, its prominent capital city and surrounding areas more environment friendly and a symbol of resilient and sustainable urban development.

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With support from WatSan Team, LEDeG

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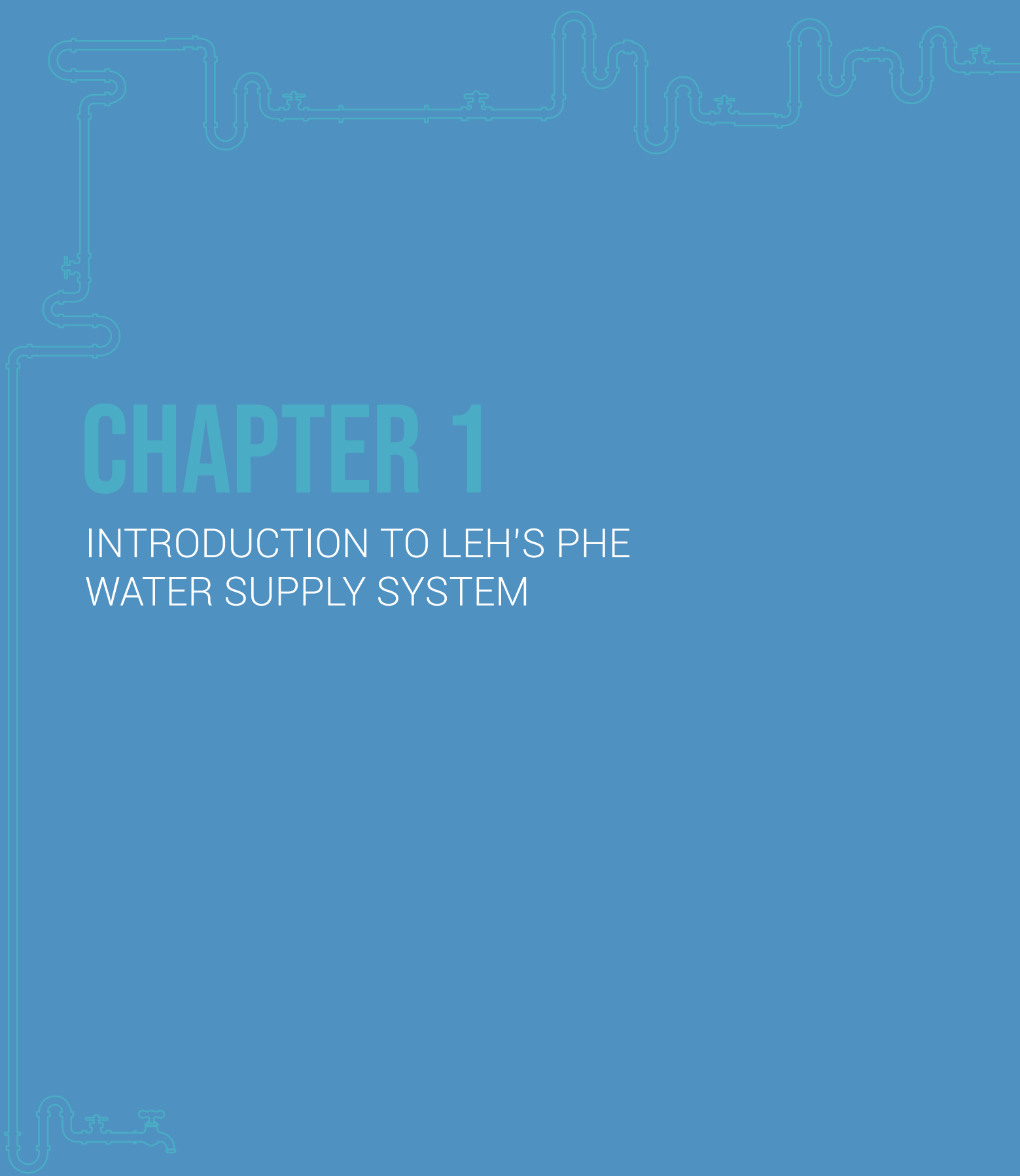
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CHAPTER 1

INTRODUCTION TO LEH'S PHE WATER SUPPLY SYSTEM

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INTRODUCTION TO LEH'S PHE WATER SUPPLY SYSTEM

In Leh, drinking water is supplied to its population through Public Stand Posts (PSP), Functional House Tap Connections (FHTC) and Water Tankers (WT) by the Public Health and Engineering Department Leh (PHED). As per the data obtained from PHED, currently, there are around 269 PSP and 4,188 FHTC. However, an increase in the demand for drinking water in recent years has shifted focus away from these sources and has created a dependence on private bore wells.

The PHED, which is responsible for supplying water to Leh, does so through a network of pipelines that is distributed throughout the town. These pipelines make up two major water distribution systems.

1. Old water distribution system supplies water primarily through the public stand posts (PSP). This water distribution system has been developed through numerous augmentations over the years. The details of the laying of the pipelines are shown in the figure below.

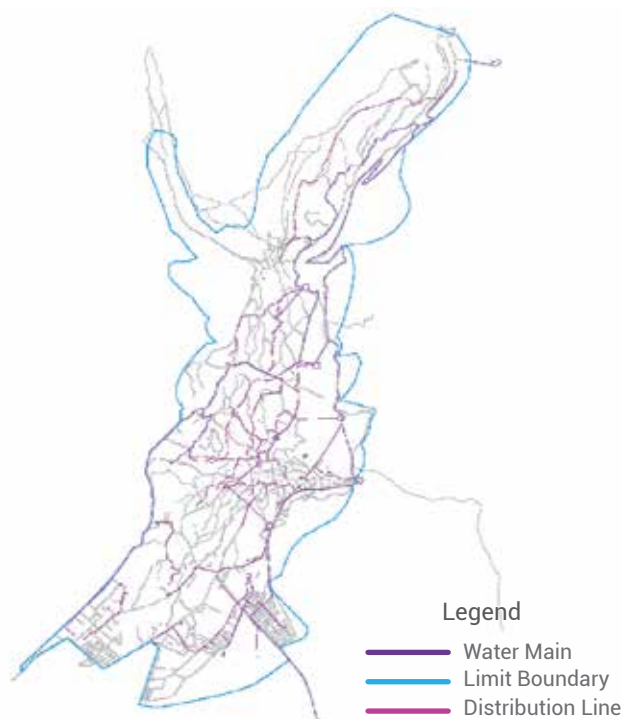
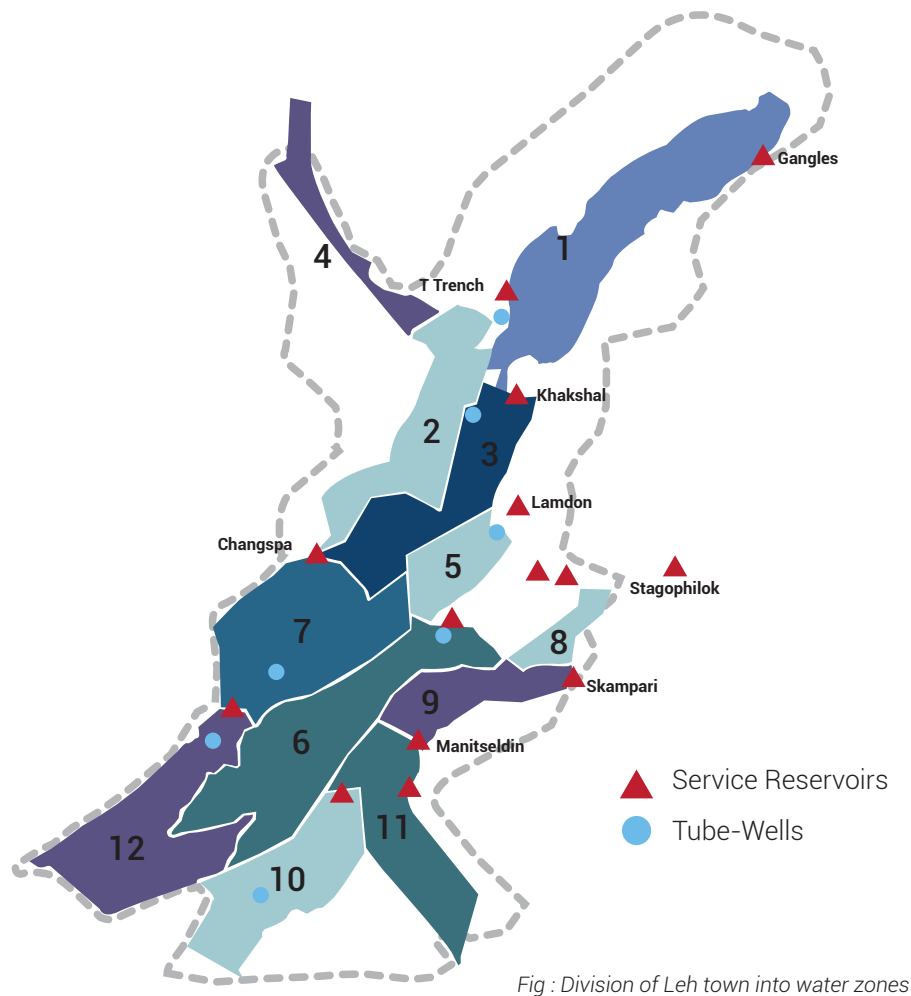


Fig : Network of old distribution line

2. New water distribution system: Initiated by the Ladakh Autonomous Hill Development Council, Leh (LAHDC, Leh) in 2008 and developed under the Urban Infrastructure Development Scheme (UIDSSMT), this Rs. 70.48 crore project is meant to supply 12.77 Million Litres Per Day (MLD) of water to a projected population of 82,275 people by 2042. To achieve this, Leh town was divided into 12 PHED zones, which was done on the basis of capacity of service reservoirs, permissible ground level of the road, the projected population density of Leh and features like natural drains etc. The zoning system also ensured equal distribution of water at the consumer end in each zone. The division of the town into zones was based on different physical features, existing reservoirs and population estimation of the zones.

These details are depicted in the figure below::



The work to lay 20 km of rising main pipes ranging from 80 mm to 400 mm, to supply water from the infiltration tank to the service reservoirs is still in progress. This is also true for the installation of 128 km of distribution network using pipes varying in size from 80 to 250 mm. Around 80% of the work has been completed so far. This means, an intermittent supply is currently functional.

As of now, water is supplied for two to four hours daily through FHTC and PSP. Water tankers are still used widely, especially during winters. Apart from this, four service reservoirs of various capacities and a series of new pump houses have also been constructed. The existing service reservoirs will be joined together with the newly-built service reservoirs to form a looping system.

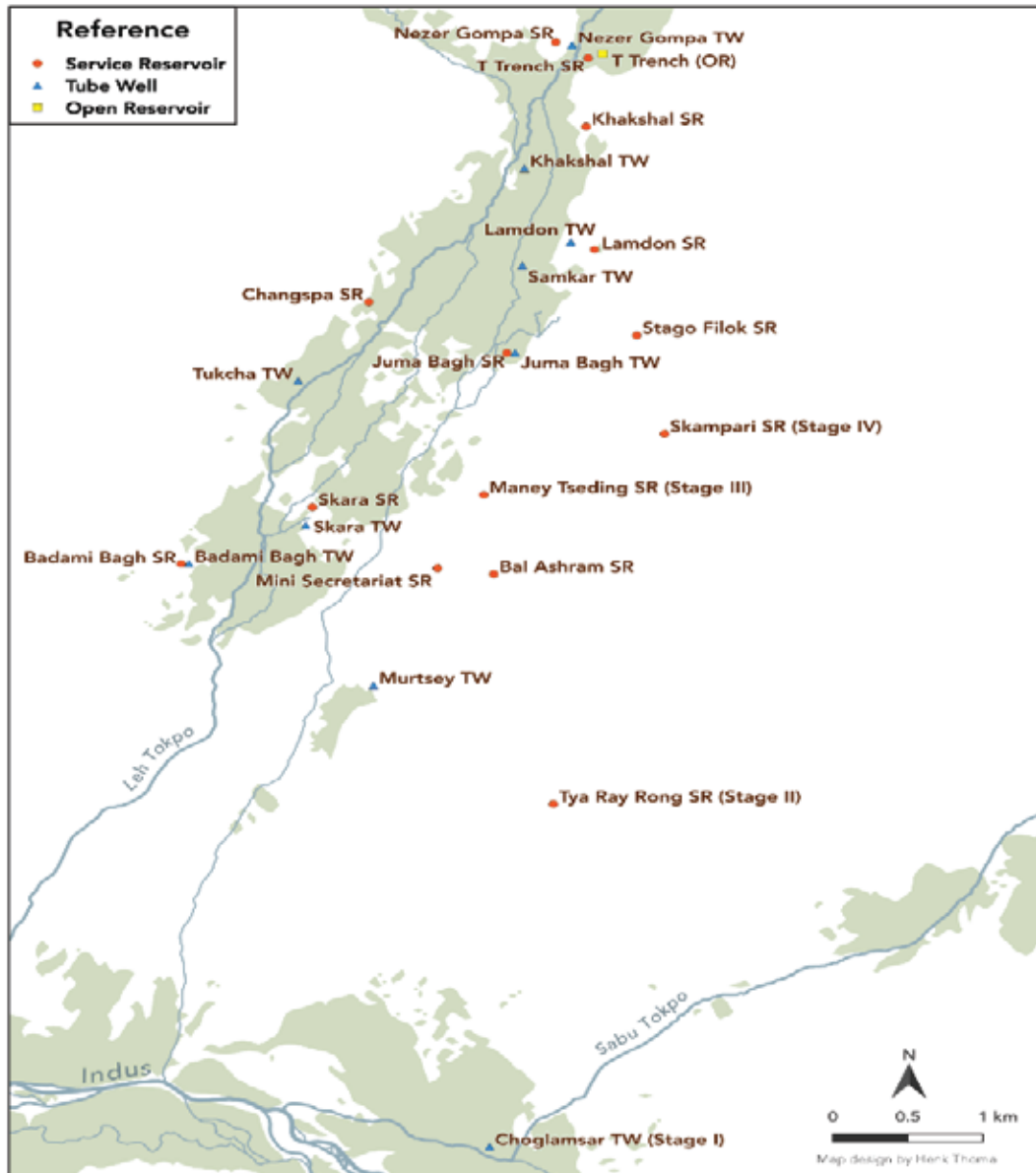


Fig : Locations of PHE Service Reservoirs and Tube Wells in Leh

Conversations with officials at PHED revealed that the delay in the completion of the project is a matter of great concern for them. Over the years, they have faced numerous challenges including land acquisition to drill new pump houses and construct new service reservoirs. Objections have also been raised by residents in areas where the new pipeline were to be installed. Finally, the COVID-19 pandemic further stalled this work.

CHAPTER 2

OBJECTIVE AND METHODOLOGY

Objective of the Study:

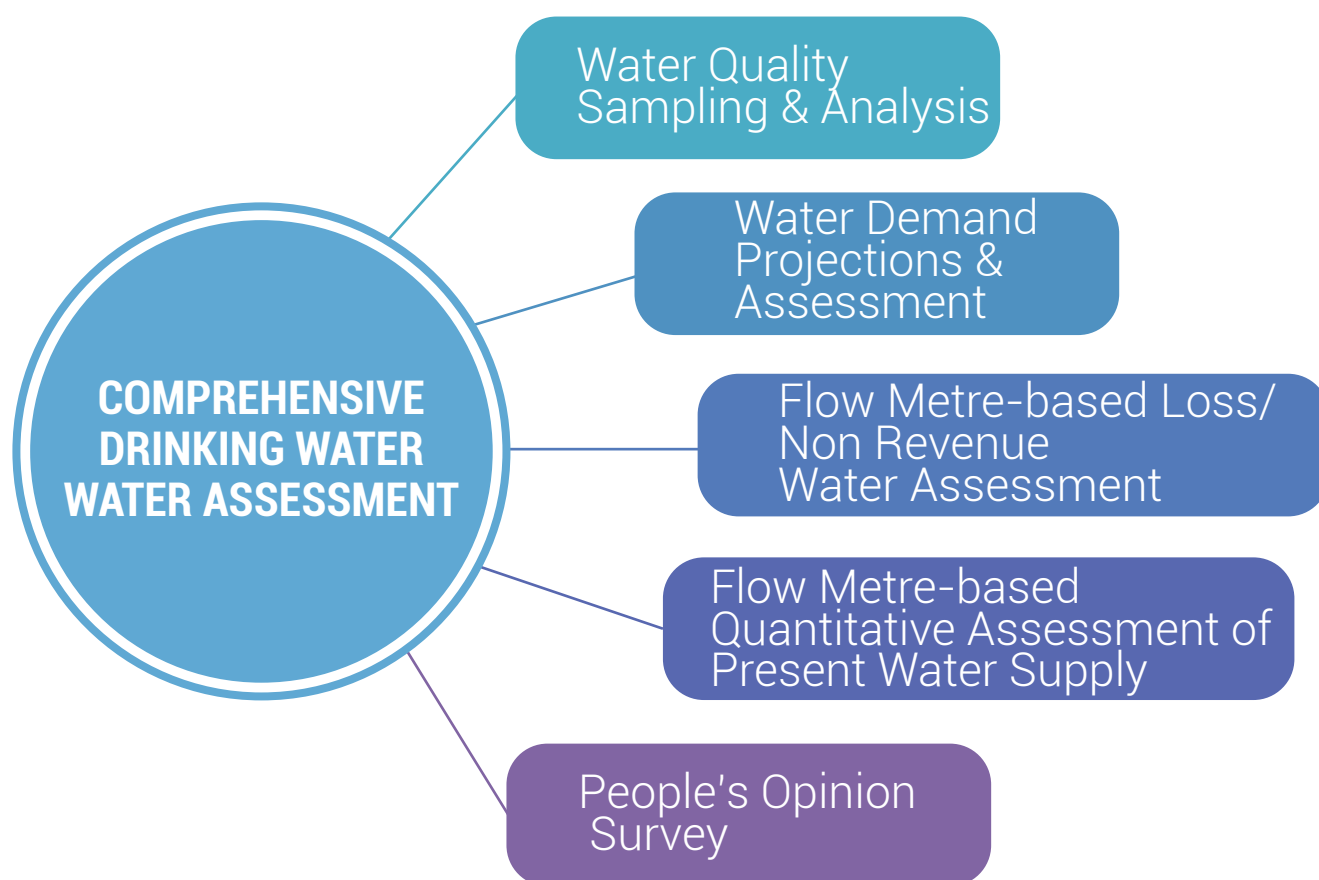
The water supply system in Leh town is operated by the Public Health and Engineering Department (PHED). A water audit of the entire system has never been done. Common practice calls for an annual or bi-annual auditing exercise to detect infrastructural issues, leakages, etc. and smoothen the operation of the supply network .

Therefore the main objective of this study was to conduct a comprehensive Water Audit of Leh Town's PHE water supply system: to evaluate water use (supply, demand, loss), water quality and identify opportunities for improve management practices.

Audit Methodology :

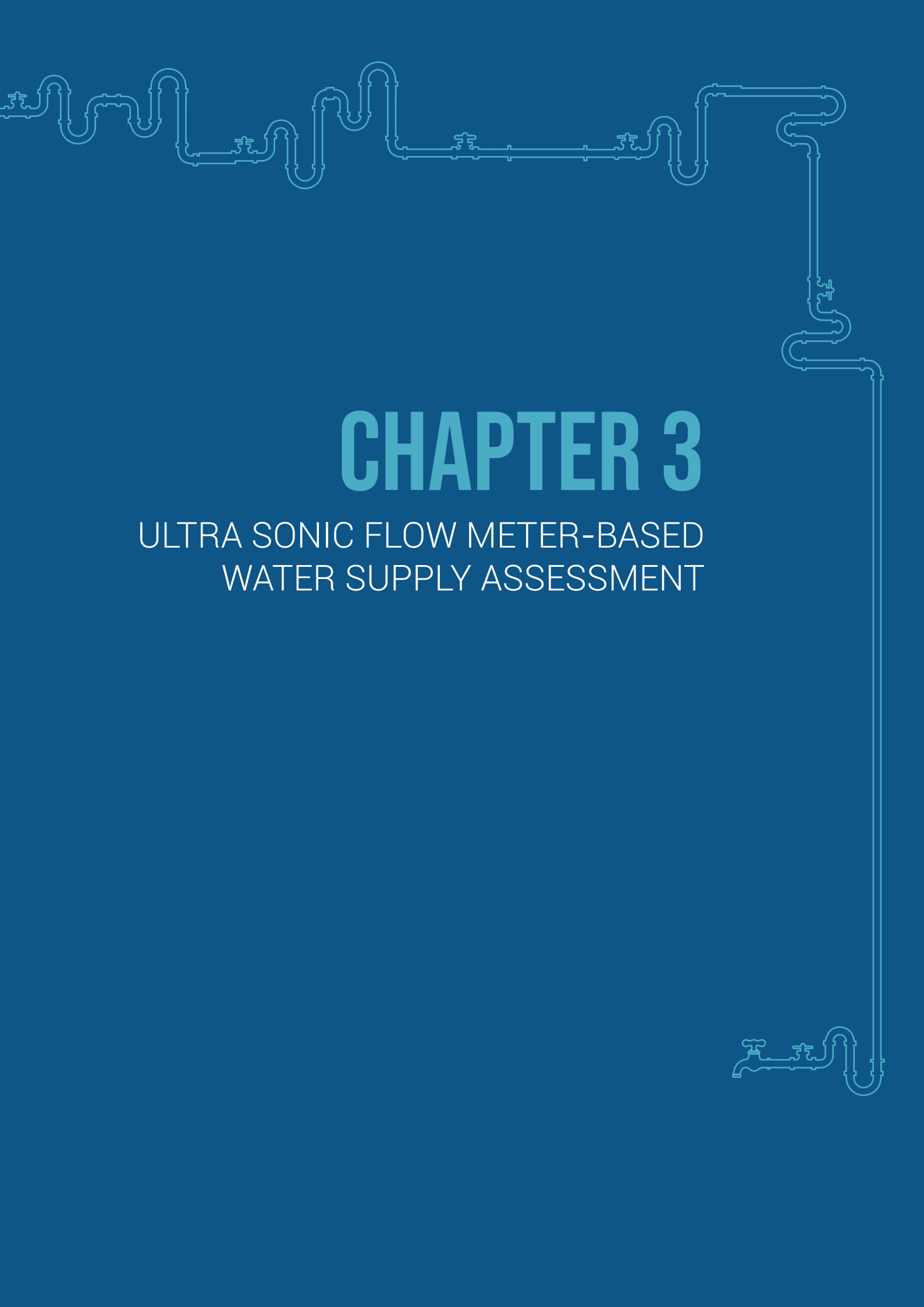
A comprehensive water audit methodology was conceived to check water supply, demand, loss and quality of potable water in Leh to develop technical and managerial solutions to improve management practices and provide recommendations to the Public Health Engineering Department, Leh.

1. Ultrasonic Flow Metre-based readings were taken to quantify the system's capacity to supply water, assess loss and project a demand forecast.
2. Field testing kits from the Tamil Nadu Water Supply and Drainage Board (TWAD) were used for preliminary water quality analysis. This was followed by laboratory analysis. Two rounds of 9 samples from crucial service reservoirs and one major spring source i.e. T-Trench, were sent to a NABL-accredited laboratory in New Delhi for further analysis. The water samples were tested for various parameters in keeping with the standardised methodology proposed by APHA (2005)
3. A comprehensive household survey using stratified random sampling was also carried out throughout the town; with special focus on the largest water zone (10) in town to understand people's perspective and issues. This included structured interviews with water experts in Leh, community leaders and important stakeholders.



Limitation(s) of the Study :

- The biggest challenge for this project was the COVID-19 pandemic which led to restrictions in intra-state travel including local movements. This resulted in many changes in the project timeline and the overall objective.
- In order to truly assess loss, water has to be running within the distribution pipeline at a required minimum pressure. Since Leh town has an intermittent water supply system where residents get water either for two hours in the morning (summer) or two hours in the evening (winter), a true assessment of loss of the network became complicated. Housing Colony is the only ward in the town where water is supplied to residents directly from a pump house and hence was the only place suitable to calculate loss using flow metres.



CHAPTER 3

ULTRA SONIC FLOW METER-BASED WATER SUPPLY ASSESSMENT

CHAPTER 3

ULTRA SONIC FLOW METRE-BASED WATER SUPPLY ASSESSMENT

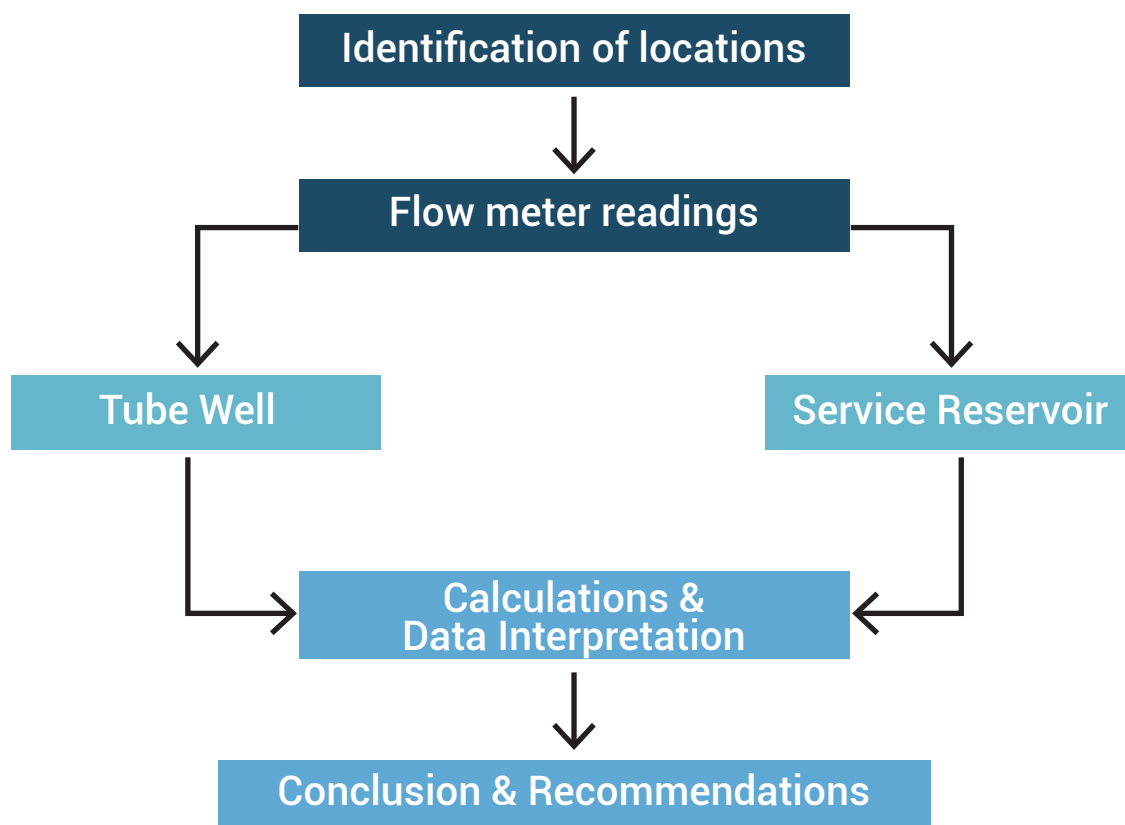
Water pressure, volume, flow and loss need to be regularly monitored to run the system efficiently. This information is also important for budget planning, infrastructure planning, loss assessment and maintenance, facilitation of decision-making, right execution and improvement in resource management. Monitoring and surveillance procedures need to be followed for quantitative assessment to develop a database in a scientific manner.

So far, no work on quantitative assessment through flow metre analysis has ever been in Leh town. All the data on PHE water supply quantity are based on best approximates after consultation with all stakeholders. This quantitative assessment through ultrasonic flow metre will assist in estimating the actual on-ground supply situation.

For this exercise we have:

- a. Measured instantaneous readings and extrapolated the results based on the number of running hours of the supply system based on information provided by PHE, Leh officials.
- b. Considered the standard schedule of water supply from PHED as the actual operating conditions on the ground.

To assess water supply, portable sensor-based ultrasonic flow metre readings were taken from all the service reservoirs and tube wells currently operated by PHE, Leh. Each service reservoir has more than one outlet to supply water to different areas across the 12 zones. This analysis was done for all these outlets, and the amount of water provided was recorded and included in the MLD.



Service Reservoirs and their supply capacity

S. No.	Name of service reservoir	Capacity in lac gallon per day	SR capacity in liters per day	MLD	Remarks
1	Gyamtsa	1.5	687,000	0.69	Not operational during survey for PHED study
2	T Trench	0.50	229,000	0.23	
3	Khakshal	1.5	687,000	0.69	
4	Nezer Gompa	0.50	229,000	0.23	
5	Lamdon	1.5	687,000	0.69	
6	Juma Bagh	0.50	229,000	0.23	
7	Stago Filok	0.50	229,000	0.23	
8	Changspa	1.0	458,000	0.46	
9	Skampari	1.5	687,000	0.69	
10	Mini Secretariat	1.0	458,000	0.46	
11	Badami Bagh	0.50	229,000	0.23	
12	Skara	0.50	229,000	0.23	
13	Bal Ashram	1.5	687,000	0.69	
14	Maney Tselding	1.0	458,000	0.46	
TOTAL			6,183,000	6.18	

A detailed work plan was developed in collaboration with PHED officials and taking into consideration factors such as distance between each service reservoir and their working hours. IISD finalised the schedule (dates and time) of audits at all SRs in advance and informed all stakeholders in advance. SR operators were requested to be present during the flow meter reading at those locations. It was necessary to take the measurements during the actual working hours of the SR. On the scheduled date, the IISD team along with the flow metre expert and two representatives from LEDeG started work around 6 am. Flow metre measurement at each SR was taken for all outlets. In two areas, it was observed that water is supplied directly through Tube Wells (TW) using water tankers (WT). These tube wells (used for filling WT) were also identified and their flow metre measurements were also taken.

Additional details like the number of WT re-filling from each TW, the size and the area it caters to were also noted for further analysis. The flow metre measurements were noted, and data interpretation was carried out. Volumetric assessment of each service reservoir was determined and documented.

Field survey execution implementation - Flow Metre-based data generation

Flow metre tests were conducted to calculate the exact quantity of water being supplied in Leh town, where 13 reservoirs and two tube wells (with direct supply) supply water to 12 zones through PSP, FHCT and water tankers. All the service reservoirs have multiple outlets, releasing water on a schedule to different locations for a period ranging from two to four hours each day. This duration is dependent on the population size of an area and the size of the service reservoir. A total of 40 readings were taken from the service reservoirs and tube wells currently supplying water. During the process, GPS coordinates were also noted down.





Total Water Supply Quantitative Assessment from Primary Survey

Sensor-based ultrasonic flow metres were used in field surveys to measure water flow rate at all supply points for Leh town. The measurements were done at all outlets of:

- 13 operational service reservoirs
- Two tubewells which are directly used to fill tankers
- One Direct supply for Housing Colony (from Stage 2 of Indus lift scheme)
- One Tube Well direct supply to mainline (Khakshal)





The following formula was used for the calculation of SR wise daily water supply -

Per day quantity supply per SR = Flow rate (measured) x hours of operation (provided by PHED)

Total quantity supplied by SRs = sum of all SR flows

S No.	Service Reservoir	Water Supplied to Area	No of hours	Measured flow (m ³ /h)	Litres/Supply Hr	Litres/ Day*	MLD
1	Juma Bagh	Sheynam, Tukcha	3	38.2	38,200	114,600	0.115
2	Juma Bagh	Zangsti, Upper Sheynam	1	32.2	32,200	32,200	0.032
3	Changspa	Skara Yokma	2	38.1	38,100	76,200	0.076
4	Changspa	Sangto, Changspa	2	37.1	37,100	74,200	0.074
5	Changspa	Tukcha	2	33.5	33,500	67,000	0.067
6	Skara	Skara	2	23.1	23,100	46,200	0.046
7	Skara	Skalzangling	2	20.1	20,100	40,200	0.040
8	Badami Bagh	SkaraYogma	2.5	20.7	20,700	51,750	0.052
9	Badami Bagh	Industries	2.5	19.7	19,700	49,250	0.049
10	Badami Bagh	Skara Middle	2.5	18.7	18,700	46,750	0.047
11	Badami Bagh	Councilor Quarter	2.5	15.3	15,300	38,250	0.038
12	Bal Ashram	Murtseri	3	36.2	36,250	108,750	0.109
13	Bal Ashram	Norguasling	3	52.4	52,400	157,200	0.157

14	Nezer Gompa	Gompa	2	61.3	61,300	122,600	0.123
15	T Trench	Khakshal	24	27.4	27,400	657,600	0.658
16	Mini Secretariat	Skalzangling	4	17.9	17,900	71,600	0.072
17	Mini Secretariat	Ibex Coliny	4	28.7	28,700	114,800	0.115
18	Mini Secretariat	Murtsey	2	25.9	25,900	51,800	0.052
19	Mini Secretariat	Targyal Ling	4	13.62	13,620	54,480	0.054
20	Lamdon	Tukcha	2.5	111.1	111,100	277,750	0.278
21	Lamdon	Lower Karzoo	2.5	80.14	80,140	200,350	0.200
22	Lamdon	Maney Tselding	2.5	3.56	3,560	8,900	0.009
23	Lamdon	Chubui	2.5	18.56	18,560	46,400	0.046
24	Skampari	Main Market	2	28.6	28,600	57,200	0.057
25	Skampari	Stalam	2	41.2	41,230	82,460	0.082
26	Skampari	Skampari	2	41.2	41,200	82,400	0.082
27	Skampari	Old Road, Maney Tselding	2	41.2	41,200	82,400	0.082
28	StagoFilok	Shey Line	3	3.93	3,930	11,790	0.012
29	StagoFilok	Upper Skampari	3	3.24	3,240	9720	0.010
30	StagoFilok	Stalam	3	2.24	2,240	6720	0.007
31	StagoFilok	Maney Tselding	3	1.97	1,970	5910	0.006
32	Maney Tselding	Housing Colony	2.3	36.6	36,600	84,180	0.084
33	Maney Tselding	Sheynam	2.3	57.9	57,900	133,170	0.133
34	Maney Tselding	Maney Tselding	2.3	30.7	30,700	70,610	0.071
35	Maney Tselding	Bus Stand	2.3	23.8	23,800	54,740	0.055

36	Khakshal TW (Direct Supply from TW)	Yurtung, Shastang	2	48.3	48,300	96,600	0.097
37	Khakshal	Khakshal, Yurtung, Changspa & upper Changspa	2	41.2	41,200	82,400	0.082
38	Housing Colony Direct from Stage II	Housing Colony	3	167.7	167,700	503,600	0.53
Total						3,899,730	3.89

Each of these SRs is briefly discussed below :

1. Juma Bagh: The 5,000-gallon Juma Bagh SR is located near Grand Himalaya Hotel at an elevation of 3,542m above msl. It supplies water to Sheynam, Tukcha and Zangsti area. During its daily operational timing, it releases 146,800 litres of water. This accounts for a total of 0.147 MLD.

2. Changspa : The 100,000-gallon Changspa SR is located below Shanti Stupa at an elevation of 3,541m above msl. It supplies water to Skara Yokma, Sangto, Changspa and Tukcha area. During the daily operational timing, it releases 217,400 litres of water. This accounts for a total of 0.217 MLD

3. Skara : The 50,000-gallon Skara SR is located near Sheynam Hall at an elevation of 3,441m above msl. It supplies water to Skara and Skalzangling area. During its daily operational timing, it releases 86,400 liters of water. This accounts for a total of 0.086 MLD.

4. Badami Bagh : The 50,000-gallon Badami Bagh SR is located near the Councilors' Quarters at an elevation of 3,397m above msl. It supplies water to Skara Yokma, Industrial Area, Skara Middle and the Councilors' Quarters. During its daily operational timing, it releases 186,000 litres of water. This accounts for a total of 0.186 MLD.

5. Bal Ashram : The 150,000-gallon Bsl Ashram SR is located near Bal Ashram at an elevation of 3,435m above msl. It supplies water to Murtsey and Norgyasling area. During its daily operational timing, it releases 265,950 litres of water. This accounts for a total of 0.266 MLD.

6. Nezer Gompa : The 50,000-gallon Nezer Gompa SR, which is located near Nezer Gompa, sits at an elevation of 3760 meters. It supplies water to Gompa area. During its daily operational timing, 122,600 liters of water is released. This accounts for a total of 0.123 MLD.

7. T-Trench : The 100,000 T-Trench SR is located near Nezer Gompa at an elevation of 3,760m above msl. It supplies water to Khakshal. During its daily operational timing, it releases 657600 litres of water. This accounts for a total of 0.658 MLD.

8. Mini Secretariat : The 50,000-gallon Mini Secretariat SR is located near Government's Boys Higher Secondary School at an elevation of 3,425m above msl. It supplies water to Skalzangling, Ibex Colony, Murtsey and Targyas-ling area. During its daily operational timing, it releases 292,680 litres of water. This accounts for a total of 0.293 MLD.

9. Lamdon : The 150,000-gallon Lamdon SR is located inside the Lamdon School Campus at an elevation of 3,425m above msl. It supplies water to Tukcha, Lower Karzoo, Maney Tselding and Chubi area. During its daily operational timing, it releases 533,400 litres of water. This accounts for a total of 0.533 MLD.

10. Skampari : The 150,000-gallon Skampari SR (Stage IV) is located in Upper Skampari at an elevation of 3,560m above msl. It supplies water to the Main Market and Stalam area. During its daily operational timing, it releases 304,460 litres of water. This accounts for a total of 0.303 MLD.

11. Stago Philog : The 50,000-gallon Stago Philog SR is located below Tsemo at an elevation of 3,630m msl. It supplies water to Shey Line (*a neighbourhood in skampari*), Upper Skampari, Stalam and Maney Tselding area. During the three hours of daily operational timing, it releases 34,140 litres of water. This accounts for a total of 0.006 MLD.

12. Maney Tselding : The 100,000-gallon Maney Tselding SR (Stage III) is located near New Bus Stand at an elevation of 3,604m msl. It supplies water to parts of Housing Colony, Sheynam, Maney Tselding and New Bus Stand area. During its daily operational timing, it releases 342,700 litres of water. This accounts for a total of 0.343 MLD.

13. Khakshal SR : Khakshal receives water from the SR and directly from TW. It provides water to parts of Khakshal. During its daily operational timing from both SR and TW, it supplies 179,000 litres of water, which accounts for 0.179 MLD.

14. Housing Colony from Stage II : The Housing Colony area water is released directly from Stage II at Tyari Rong. During its daily operational timing, it supplies 0.503MLD.

Tube well flow rate measurement and calculation

Only two tube wells were considered for volumetric assessment which is used for supplying to the tankers.

Water tankers are a main mode of water transport in many areas where PHED is not able to supply potable water through pipelines. Two tube wells are used for re-filling these tankers, which are of 9000 liters capacity each. Sankar TW re-fills multiple water tankers totaling 30 times a day which is supplied to nearby areas and Murtsey TW re-fills multiple water tankers (of other departments as well) totaling 40 times which supplies to nearby areas. Therefore, from the tube wells mentioned above, water tankers have filled a total of 70 times per day.

Formula =9000ltr (Tanker capacity) x 70(Total no of tanker refills per day)=630,000 liters per day = 0.63 MLD

Quantitative assessment by Ultra Sonic Flow Meter at 2 TW.

S. No.	Tube Well	Supply Mode	No of times tankers refill/day	Tanker capacity	Litres/day	MLD
1	Sankar TW	Water Tanker	30	9,000	270,000	0.270
2	Murtsey TW	Water Tanker	40	9,000	360,000	0.360
Total					630,000	0.630

Sankar Tube well : Sankar Tube well is located at Sankar road and solely used to fill water tankers. Daily, multiple water tankers re-fill on an average of 30 times. The capacity of each tanker is 9,000 litres. It thus supplies a total of 270,000 litres of water, which amounts to 0.270 MLD.

Murtsey Tube well: Apart from supplying water to Mini Secretariat, Murtsey TW is also used to re-fill water tankers that have a capacity of 9,000 litres on an average of 40 times each day to supply water to different parts of Leh town. It supplies a total of 360,000 litres of water, which amounts to 0.360 MLD. If we assume 26.27% of distribution loss (based on our measurements captured in the next chapter of this audit), we have calculated that 3.34MLD of water reaches consumers in Leh town.

Actual supply estimation and analysis

Based on this audit, from the SRs a total of	3.89 MLD
And two TW accounting for	0.63 MLD
A total of	= 4.52 MLD

is supplied.

Taking in account of **26.27%** of **loss** in distribution line (based on our measurements captured in the next chapter of this audit), **3.34MLD** is the quantity of water which reaches the consumer in Leh town.

CPHEEO standards:

The Central Public Health and Environmental Engineering Organisation (CPHEEO) (1999) developed a manual on water supply and treatment. Based on the standards they have set, around 135 LPCD is required for a projected population of 54,553, which amounts to 7.49 MLD. Whereas by standards set by CPHEEO of 180 LPCD, for a daily projected tourist population of 4,602, a total of 0.83MLD is required. Thus the total requirement comes to 8.32MLD.

Through the flow metre analysis, it was deduced that the service reservoirs and water tankers account for a total potable water supply of 3.34MLD. This leaves a shortage of 4.98MLD in Leh town, based on CPHEEO's recommended per capita water supply.

Actual demand:

Considering the actual demand of 80 LPCD (based on our household survey) for locals and 100 LPCD for daily projected tourist population for a projected general population of 54,553 and daily projected tourist population of 4,602. Thus, a total of 4.44MLD and 0.46 MLD of potable water are required respectively, amounting to a total actual demand of 4.90MLD. Thus, the actual deficiency is 1.56MLD. It is noteworthy that our demand projections do not include commercial and other public requirements, which would further add to the deficit.

There a large number of bore wells in town, which was estimated to be 611 according to PHED data and around 1,500 to 2,000 according to LEDeG data. These possibly provide an alternative source to the residents of Leh town.

A thorough demand side study, including all possible demands from different stakeholders could be conducted for better estimation of demand. At the same time, supply management should be strengthened to reduce the current deficit.

Conclusion

A volumetric assessment was conducted in Leh town for the first time to evaluate actual water supply using sensor-based ultra-sonic flow metres. Meticulous planning and careful selection of measurement points were made along with local experts and PHED department.

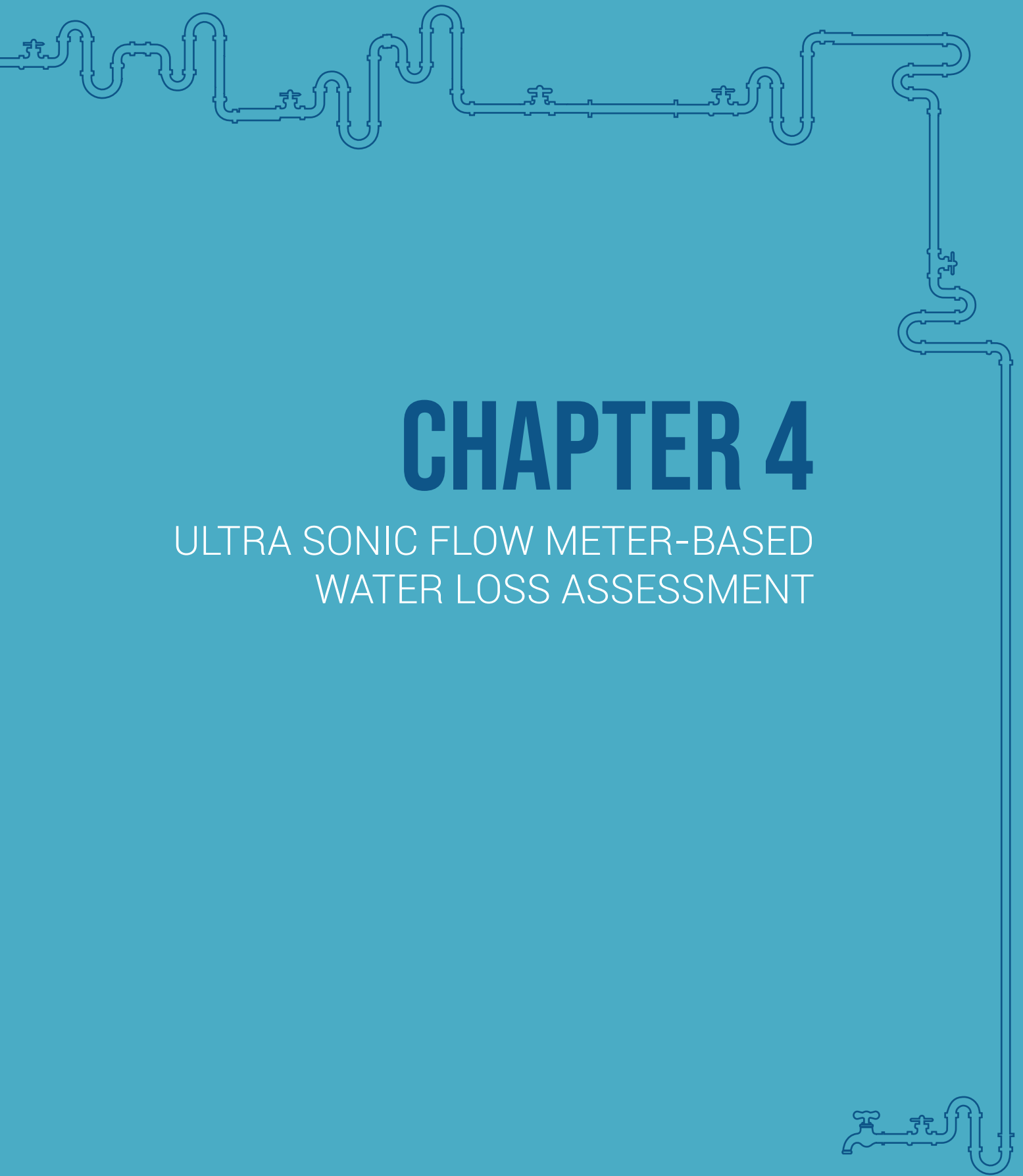
In the present water audit of Leh town carried out by IISD, the total potable water supplied by the PHED was estimated to be 3.34 MLD after taking into account 26.27% real loss as per our measurements.

There is a supply deficit ranging from 1.56 to 4.98 MLD depending on per capita demand consideration from IISD's household survey and CPHEEO recommended maximum demand for domestic consumption respectively. This does not include any other commercial or public services demand.

There is scope to improve supply through existing infrastructure. However, an internal gap analysis should be conducted to identify challenges and possible solutions. In the medium term, the present condition of water supplied could be improved if the new water distribution supply scheme is completed on a priority basis.

PHED estimations and its comparison with data from the Water Audit Exercise

Quantitative assessment of water supply by the PHED department is based on assumptions and estimates. According to PHED estimations mentioned in the Water Status Report 2019, water supply for Leh town was estimated to be 3.60 MLD whereas the IISD audit suggests current water supply accounts for 3.34 MLD. A difference of $\pm 10\%$ is observed, which is reasonable and validates the actual supply.



CHAPTER 4

ULTRA SONIC FLOW METER-BASED WATER LOSS ASSESSMENT

CHAPTER 4

ULTRA SONIC FLOW METRE-BASED WATER LOSS ASSESSMENT

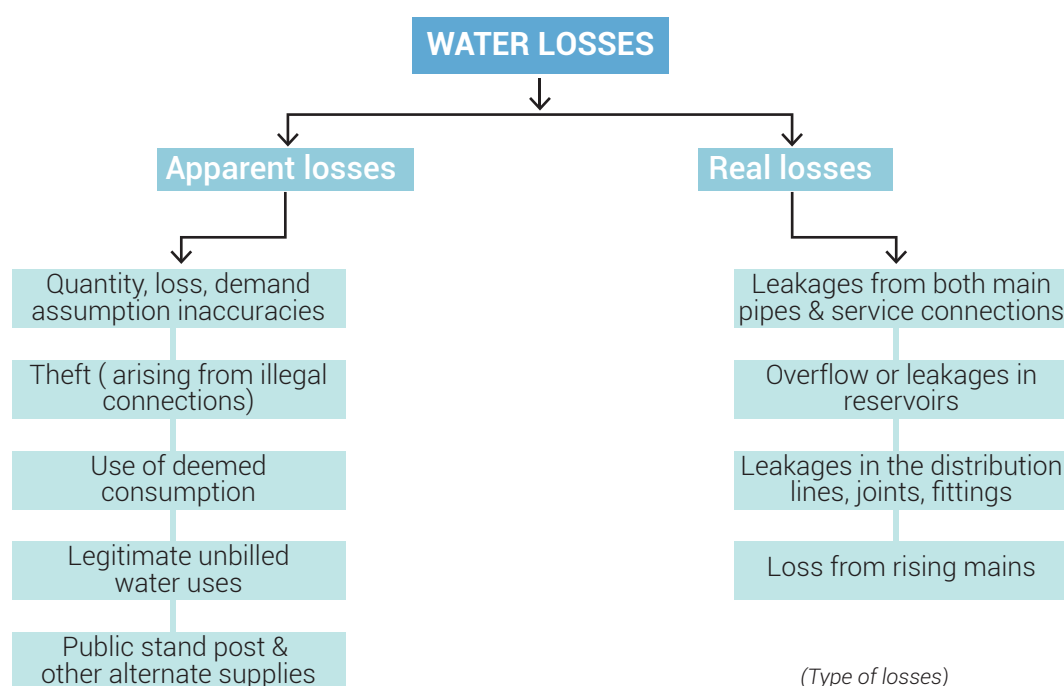
Introduction:

Water loss is an essential indicator of the efficiency of a system. In the domestic water sector, loss due to leakage in the mains, service pipes and valves are common. A survey conducted by the Centre for Science and Environment in 71 cities, suggests 25 to 40% of water is generally lost during distribution in most cities (Narain, 2012a) while an audit by ADB estimates the loss at 27% (ADB, 2007). By reducing these leakages, water loss can be reduced to 10-15% of the total supply.

The objective of the loss estimation is to minimise wastage and improve revenue generation from water supply. The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to conduct necessary repairs as quickly as possible. Procedures for identifying, reporting, repairing and accounting for all visible leaks should be taken.

According to the International Water Association (IWA), loss of water can be defined in two ways.

- 1. Real (or physical or technical) loss** : represents all types of actual water losses including leakages from transmission mains, storage facilities, distribution mains, service connections, overflow of reservoirs or leakages in reservoirs. They are mainly caused by low operation and maintenance and poor quality of underground materials or assets.
- 2. Apparent (commercial or non-technical) loss** : Apparent loss could be due to water theft, metre inaccuracies, poor data holdings, public stand post losses etc.



Rationalization:

Loss of water is not defined by leakage alone but also by water quantity that does not generate revenue. Some water loss in any system is inevitable but remedial measures are warranted when this happens in excess. Therefore, an accurate diagnosis of the losses and development of water balance provides us with a realistic understanding of the present performance level of the service. This in turn, can help us arrive at optimum solutions to improve actual water supply quantity and revenue.

Lack of proper metres on mains and distribution network leaves a significant information void resulting in estimation of water supply, leakages and delivery by assumption-based indirect methods. This audit attempts to measure the actual water flow data at strategic points to understand the existing water supply, demand situation deficit and estimate possible losses.

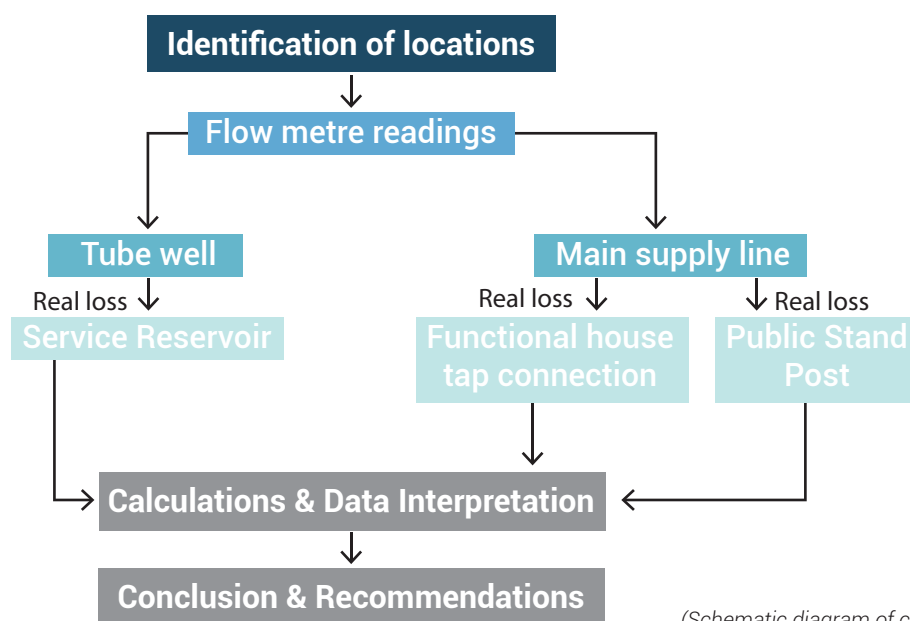
Limitations of the loss assessment exercise:

The audit focuses on the supply and demand of water at Leh town with the boundary condition of limiting the analysis to the domestic market. It does not consider commercial demand, office demand or demand of public services. Some of the other limiting factors for this audit are:

1. Service reservoir main supply lines are underground and so our team could not identify points to measure real loss from these supply lines. Since 70%+ of the water of the town flows through this network first, this could have some impact on the findings.
2. This audit does not consider the impact of private bore wells (household or commercial) on the town's water demands since there are no reliable estimates for the number of bore wells and the quantity of water extracted from them.
3. A pilot audit for 600 households to evaluate distribution line loss was extrapolated to a larger population to estimate demand and real losses for the new supply system.

The measurement survey was done under the guidance of flow metre expert, Rajiv Kumar, Director of Aqua Jet Electronic Instruments Private Ltd using methodology used for loss estimations:

Careful identification of locations for measurement was made, keeping in mind the objective of the audit while working with the physical constraints of availability of pipelines over ground with consistent pressure and information about the lines supply locations. Actual loss measurements were carried out at places where real loss is possible as seen in the flow diagram. All the information was compiled and carefully examined to draw interpretations and conclusions.



(Schematic diagram of calculation of loss)

Planning and Execution

For real loss analysis, detailed discussions with PHED officials were held at PHE Office in Leh. Pre-approval from the Executive Engineer was sought to carry out the work. A preliminary site visit was done by the IISD team to document details of working hours and distance from the TW. It was observed that the TWs were functioning throughout the day and in some locations even in late-night to wee hours of the morning. Keeping in view of this information, a detailed plan was made in collaboration with PHED officials.

Two readings were taken for each SR; first in the main line near the TW and the second one at the inlet to the SR. The difference in both was calculated keeping in mind the head loss. The result was calculated as the real loss in the system. In this manner, 26 different readings were taken, at all working SR and TW supplying water to the town. Stage I, II, III and IV of the Indus Lift Scheme were also included in this exercise. It was not possible to calculate the real loss of the entire town due to reasons already mentioned in the 'limitations' sections. The only exception in this regard was the Housing Colony area. We were able to assess losses accurately in the Housing Colony area due to several reasons, including:

- i) The pipeline size at the consumer end was uniform in all households and public stand posts, which is not true for the rest of the town.
- ii) Water supply in Housing Colony is released in the pipelines directly from Indus Lift Stage II pump house, resulting in a steady pressure being maintained throughout the supply time, which is essential to measure loss.

Upon detailed consultations with the PHED, it was decided that household readings would be taken based on the difference in altitude among households. The area was divided into three parts depending on their altitude. Data for the number of connections/households in these areas was obtained from PHED officials. On the said date, the IISD team and two representatives from LEDeG and two officials from PHED with the concerned line-person of the area started the work around 7am. The first reading was taken at the main valve, and the remaining readings were taken in the FHTCs and PSPs of the area, which was pre-identified. The readings were noted down and analysed :

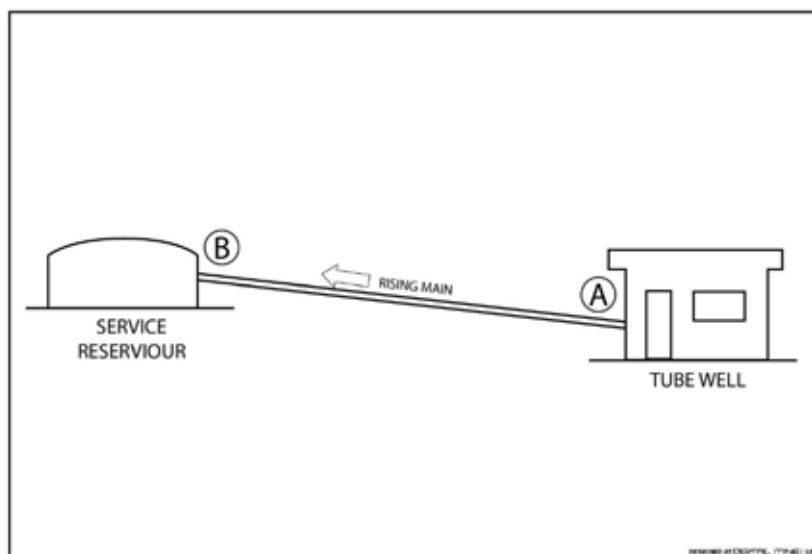
Real (physical) loss evaluation

Measurements were done keeping in mind different types of real losses applicable to Leh town. Each of these losses are discussed in detail below.

1.Real loss in rising mains

To calculate real loss, flow metre readings were taken at the rising main. Rising main refers to the pipeline that connects the tube well to the service reservoir. For this, a first flow metre reading was taken near the tube well (A), and a second reading was taken at the service reservoir inlet (B), in the rising main.

$$\text{Loss per location (MLD)} = (\text{Flow rate in m}^3/\text{hr at TW} - \text{Flow rate in m}^3/\text{hr at SR}) \times (1 - \text{Head loss \%}) \times \text{hours of operations (hrs/Day)} / 1000 \text{ m}^3/\text{ML}$$





Head loss – Head loss refers to the total pressure losses sustained by the fluid as it flows from the suction point to the discharge point. Head loss is caused when the liquid loses momentum as it flows, which depends on the viscosity of the fluid, pipe diameter, pipe length and accessories such as valves and elbows within the pipework. For this study, we assumed an average of 20% head loss, which is the standard followed by the PHE department.

Therefore, a Head Loss of total of 0.24MLD was measured as shown in the following table.

Table : Difference in Flow at TW and SR at different locations

S. No	Location	Reading at TW (m ³ /h)	Reading at SR (m ³ /h)	Difference in Flow (m ³ /h)	Distance between TW & SR (Meters)	Difference in altitude (Meters)	Counting Head Loss with altitude of motor by 20%	Difference in Liters/Hour(after head loss)	No of Hours TW Hours of Operation(Hrs)	Difference in litres for operationalHours	Difference in LPS	Difference in MLD
1	Juma Bagh	33.51	33.51	0	10	0	0	0	10	0	0.00	0
2	Lamdon from Lamdon TW	19.48	18.6	0.88	300	9	0.7	700	15	10500	0.19	0.0105
3	Lamdon from T Trench	10.4	9.95	0.45	800	-98	0.36	360	24	8640	0.10	0.00864
4	Skara	36.15	31	5.15	200	10	4.12	4120	2	8240	1.14	0.00824
5	Badami Bagh	18.82	18.82	0	15	0	0	0	2.5	0	0.00	0
6	Tukcha	38.36	37.9	0.46	800	52	0.37	370	12	4440	0.10	0.00444
7	Nezer Gompa	23.94	20.6	3.34	400	48	2.68	2680	5	13400	0.74	0.0134
8	Stage II to Balashram	135.12	134.3	0.82	2500	-9	0.66	660	4	2640	0.18	0.00264
9	Stage II to Maney Tselding	113.5	105.15	8.35	3000	32	6.68	6680	13	86840	1.86	0.08684
10	Murtsey	56.5	51.98	4.52	1200	56	3.62	3620	10	36200	1.01	0.0362
11	Stage III to Skampari	48.29	46.48	1.81	1500	128	1.45	1450	10	14500	0.40	0.0145
12	Khakshal	48.4	39.3	9.1	800	48	7.28	7280	5	36400	2.02	0.0364
13	Stage I toll* (Pump A and B)	A - 84.44B - 77.69	Not Available									0.0185
Total										240,283	7.74	0.24

*Stage - I houses two water pumps (A & B) which supply water to Stage II, the readings for stage I was done but the reading at Stage II was not possible as the rising main pipelines were 8 to 10 feet underground and permission to dig was denied. For this SR, we have considered an average loss calculated from other 12 SR.

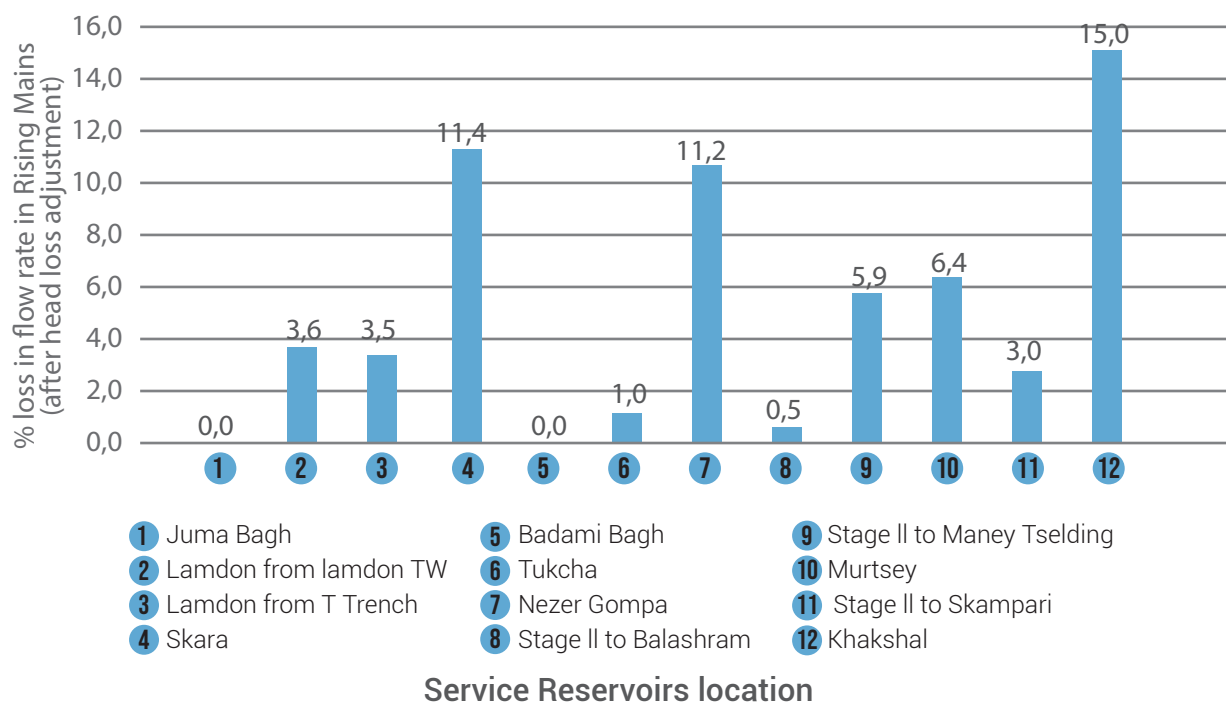


Fig : Loss percentage in Rising Mains

The assessment indicates that some of the rising mains lines, particularly in Skara, Nezer Gompa and Khakshal have very high loss in the range of 10 to 15%. Similarly, rising main lines at Lamdon, T Trench, Stage II to Maney Tselding, Murtsey and Stage III to Skampari also have a moderate loss of around 3 to 6%. Ideally, these losses should be less than 1%. Immediate repair and maintenance is required to stop these losses.

The calculated real loss for each tube well is discussed below.

I. Juma Bagh : The Juma Bagh tube well is located near Hotel Grand Himalaya at an altitude of 3,542m above msl. The distance between the tube well and the service reservoir is only 10m. Therefore, no loss was recorded here.

II. Lamdon : Lamdon actually has three sources of water: Lamdon TW, T-Trench and Gyalung Spring. One of them, (Gyalung) was not operational when this exercise was conducted and we focussed on the other two sources of water. The distance between Lamdon tube well and the service reservoir is 300m and the difference in their elevation is 9m. Here, we recorded a total loss of 880 litres per hour.

T-Trench to Lamdon : T-Trench is a source of spring water. This water is released in the Lamdon service reservoir 24/7 through gravity. The distance between the two is 800m. A total loss of 450 litres per hour was recorded here.

III. Skara : The Skara service reservoir is located near Sheynam Community Hall, at an altitude of 3,431m. The distance between the tube well and the service reservoir is 200m and the difference in their elevation is 10m. A total loss of 5,150 litres per hour was recorded here.

IV. Badami Bagh : The Badami Bagh tube well is located near the Councillor Quarters at an altitude of 3,397m above msl. The distance between the tube well and the service reservoir is 15m and no loss was recorded between them.

V. Tukcha : The Tukcha tube well is located on Lower Tukcha road, at an altitude of 3,489m. The distance between the tube well and the service reservoir is 800m and the difference in their elevation is 52m. A total loss of 460 litres per hour was recorded here.

VI. Nezer Gompa : The Nezer Gompa tube well is located at the base of Nezer Gompa hill at an altitude of 3,712m above msl. The distance between the tube well and the service reservoir is 400m and the difference in their elevation is 48m. A total loss of 3,340 litres per hour was recorded here.

VII. Stage I (Choglamsar) to Stage II (Tya ri rong) : Stage I which is located on the Choglamsar to Spituk road on the bank of the Indus river. Two different pump houses, namely A & B operate 15 hours a day to lift water to stage two. A new SR has been constructed in the vicinity but is not functional yet. Loss could not be calculated at Stage II as the rising main pipelines are eight to 10 feet underground and PHED refused to permit any digging. For this SR, we have assumed an average of the losses calculated for the other 12 SRs.

VIII. Stage II (Tya ri rong) to Stage III (Maney Tselding) : Stage II is located at Tya ri-rong at an altitude of 3,444m above msl. The distance between the two is 3,000m and the difference in their elevation is 32m. A total loss of 8,350 litres per hour was recorded here.

IX. Stage II to Bal Ashram : Stage II is located at Tya ri-rong, at an altitude of 3,444m above msl. The distance between the two is 2,500m and the difference in their elevation is 9m. A total loss of 820 litres per hour was recorded here.

X. Stage III (Maney Tselding) to Stage IV (Skampari) : Stage III is located at Maney Tselding at an altitude of 3,476m above msl. The distance between the two is 1,500m and the difference in their elevation is 128m. A total loss of 1,810 litres per hour was recorded here.

XI. Murtsey : The Murtsey tube well is located near the Murtsey Community Hall, at an altitude of 3,369m above msl. The distance between the tube well and the service reservoir is 1,200m and the difference in their elevation is 56m. A total loss of 4,520 litres per hour was recorded here.

XII. Khakshal : The Khakshal tube well is located on the Khakshal road at an altitude of 3,640m above msl. The distance between the tube well and the service reservoir is 800m and the difference in their elevation is 48m. A total loss of 9,100 litres per hour was recorded here. This is the highest water loss we recorded during this audit.

2. Real loss in Households

Calculating real loss for the entire town of Leh was not possible due to constraints such as:

- **Limited-time period for the audit :** Time was a major constraint as measuring the real loss of a town of this size is a time-consuming task.
- **Non-availability of water metres at consumer end-** Water metres are of high importance for calculating real loss, if water metres are available then, reading at consumer end can be noted from them.
- **Intermittent supply :** The intermittent supply of water makes it difficult to cover even a single zone in a day. Taking readings on different days in the same line will give false results as among other factors, the flow depends on the amount of water present in the service reservoir.
- **Pressure :** There are no pressure valves installed, which makes it challenging to maintain a steady pressure.
- **Irregularly-sized pipes at consumer end:** Consumer end pipeline size varied from home to home. The size of the pipe varied from 0.50, 1.00 to 1.50 inch.
- **Altitude :** In addition, there is a vast difference in altitude from the service reservoir to the consumer end.

In this context, we picked Housing Colony area of Zone 11 for this pilot audit. The area is divided into three mohallas: A, B and C. It also contains government quarters and the area behind Maney Ringmo. Two factors played a key role in selecting this area. First, the pipeline size at the consumer end was uniform in all households and public stand posts. In all, there are 600 FHTC and PSP connections in this area according to the data obtained from PHED. Secondly, water is released in the pipelines directly from stage II, which ensures that there is a steady pressure throughout the supply time.

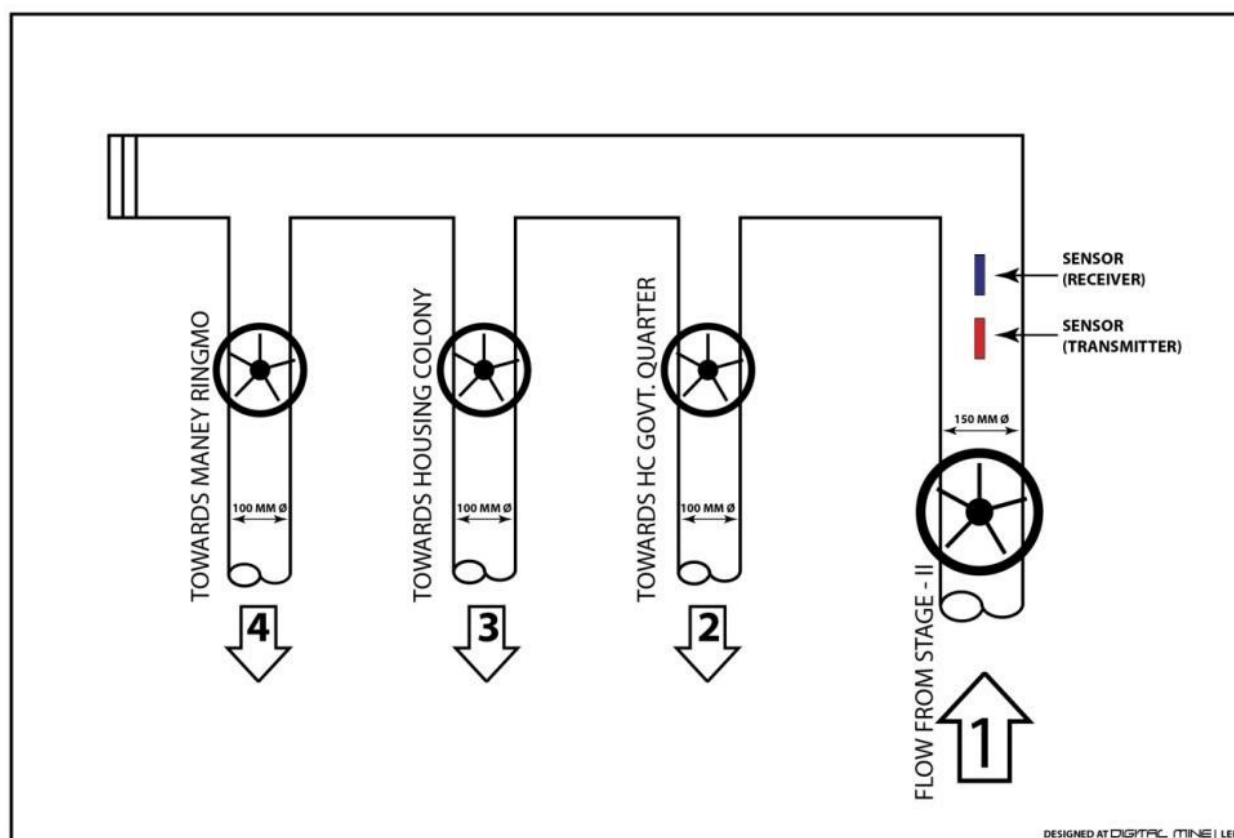


Fig : Diagram of Chamber at Housing colony

To calculate real loss, the initial reading was taken at the chamber that controls the supply of water to the area, which is located near the Animal Husbandry office. The chamber is operated daily by a lineman, who supplies water from 7 a.m. to 10 a.m. The second set of readings were taken at households and public stand posts at different altitudes to check the difference in flow, as locations with higher elevations were believed to have less flow rate. The details are provided in the tables below.

To calculate real loss, the area was divided into three parts based on how they differed in terms of their altitude difference in relation to the main valve. The first had an altitude difference of 0 to 15m lower than the main chamber, the second was 16 to 30m lower, and the third was over 30m lower than the main chamber. This was done since the areas with higher elevation receive water for a shorter period of water supply unless the residents in part 3 fill water and shut their taps. The required pressure required to supply water to the elevated areas does not form till the other two parts finish filling water.

Initial reading at Chamber, Near Animal Husbandry Office from where Water supply to Housing Colony, is controlled

S No :	Location	Altitude (Metres)	Measured Flow m ³ /h (Average)	Litres/hr	LPS
1	Housing Colony Chamber	3,423	167.71	1,67,715	46.6

Formulations:

Water supply at the main line

Main water supply to housing Colony (m^3/day) = *Measured flow (m^3/h) x operating hours (hrs/day)*

Flow at valve (main) = *Average of two readings taken* = $(194.23 \text{ m}^3/\text{h} + 141.2 \text{ m}^3/\text{h})/2 = 167.71$

No. of hours Water was supplied = **3 hours (7 a.m. to 10 a.m.)**

Flow per day (3 hours operations) = **$167.71 \times 3 = 503.13 \text{ m}^3/\text{d}$**

Water received at Mohalla level

Water supplied to each mohalla (m^3/day) = *Measured flow (m^3/hr) x duration of water supply (hrs/day) x number of households*

Total water supplied to Housing Colony (Zone 11) = *sum of water supply at all Mohallas.*

S No	Altitude Range (Metres)	Measured flow (m^3/h)	Duration of water supply (hrs/day)	Household consumption (m^3/d)	No of House-holds	Total water supplied (m^3/d)
1	0-15	0.26	2	0.504	310	156.24
2	16-30	0.30	2.5	0.75	190	136.80
3	>30	0.36	3	1.08	100	108.00
Total					600	401.04

Table : Readings taken from different households & Public Stand Posts

Calculation of Real loss in the Housing Colony of Zone 11:

Difference = **$503.13 - 401.04 = 102.09 \text{ m}^3/\text{d} = 0.102 \text{MLD}$**

From the above results, it was observed that a total of **0.102MLD** of water was lost daily from the pilot loss study of 600 FHTC households.

We extrapolated the results to the total **4,188 FHTC** households using the unitary method,

Hence,

Total loss = **$\text{loss for } 600 \text{ FHTC} / 600 \times 4188 = 0.0826 / 600 \times 4188 = 0.71 \text{MLD}$** .

Therefore, Real Loss of 0.71MLD is estimated from distribution lines to FHTC connections across Leh town.

Real Loss calculation in PSP and Water Tankers (WT)

PSP and WT result in overflow and spillage, respectively. Although both PSP and WT are non-revenue supply, they have both real and apparent loss aspects. The physical losses are calculated in this section, and the balance amount of water supplied would reflect as apparent loss since it does not generate any revenue.

A total of nine readings were taken from different parts of Leh town, which has been listed in the table below.

The flow rate was measured in these readings.

S No	Location	Flow (M ³ /h)
1	Lamdon (PSP)	0.18
2	Gompa (PSP)	0.10
3	Chhutey Rantak (PSP)	0.17
4	Devi Too (PSP)	0.16
5	Old Road (PSP)	0.18
6	New Sheynam Road (PSP)	0.10
7	Housing Colony, Liker Labrang (PSP)	0.18
8	Housing Colony (PSP)	0.16
9	Industrial Area (PSP)	0.19
	Total	0.16

Table : Flow rate measurements from different Public Stand Posts

- a) If we take an average of 0.16 M³/h, the total recorded number of functional PSPs in Leh as 269, and assume that each PSP is running for an average of five hours daily (PSPs typically run for four hours according to PHED guidelines with several PSPs running for six to 12 hours and a few that run for 24 hours. Therefore an average value of five hours is assumed for all PSPs.
- b) Based on ground observation, about 60% of the total water being supplied is used by the general population, and 40% is wasted on account of direct draining of flowing water while changing cans and users as well as free-flowing PSPs with no users during certain times.

Average Flow 0.16 M³/h

No of Recorded PSP's= 269

Average no of Hours PSP's working = 5

Total supply of water from the PSP's= **269 x 0.16 x 5 hours = 215.2 m³ per day**

Real loss from PSPs @ 40% = **40% x 215.2 m³/day = 86, 08 m³/day = 0.086 MLD**

Based on expert observation and on-site evaluation, 25% wastage was estimated for Water Tankers (WT).

Total WT supply = **0.63 MLD**

Water loss = Total supply x % loss = **0.63 x 0.25 = 0.189 MLD**

Table : No of FHTC and PSPs in Leh town till July 2020

S. No	Name of Zone	Area Under Zone	PSP	FHTC
1	Zone I	Gangles, Horzey, Digur, Spurka	08	13
2	Zone II	T Trench,	17	130
3	Zone III	Khakshal, Sankar ,Yurtung, Upper Changspa, Changspa , Tukcha	11	197
4	Zone IV	Gompa Village	03	76
5	Zone V	Lamdon, Sankar, Khakshal, Karzoo, Chhubi, Eidgah, Tukcha, Malpak,	53	265
6	Zone VI A	Old Leh, Stalam, Kharyok, Maneykhang, Main Bazar, New Shar lane, Fort road	0	591
7	Zone VI B	Fort Road, Upper Sheynam, Malpak, Old Road	11	154
8	Zone VII	Changspa, Upper Tukcha, Main Tukcha, Lower Tukcha	0	265
9	Zone VIII	Skampari, Leh Palace area, Pologround area, Kidar lane, Maney tselding	24	48
10	Zone IX	Skampari, Katmochey, Pologround, Old road	23	454
11	Zone X	Targyasling, Skalzangling, Murtsey, Ibex	57	1353
12	Zone XI	Nimoling, Government Quarters, Housing Colony	28	513
13	Zone XII	Old Skara, Lower Skara, Kartse, VIP Dak Banglow, Industrial area	34	129
			269	4188
PSP: Public Stand Post. FHTC: Functional House Tap Connection				

Cumulative real loss:

Based on all above measurements and calculations, the table below compiles the real loss in the system:

S No.	Real Loss types	Quantity
1	Rising Mains loss	0.24 MLD
2	FHTC distribution to HouseHold	0.71 MLD
3	Public Stand Post (PSP)	0.086 MLD
4	Water Tanker (WT)	0.158 MLD
5	Main transmission lines - SR to distribution/service lines	Not Available*
	TOTAL	0.644 MLD

*Measurement was not possible at receiving end for SRs since supply lines are underground. Therefore, the impact of this category is not reflected in our results.

Apparent Loss (Non-technical/commercial loss)

Apparent loss indicates loss due to illegal or unregistered connections, defective metres, wastage by consumers, flat rate consumption, public stand posts, open or faulty taps, etc.

Non-revenue water is defined as the difference between the amount of water put into the distribution system and the amount of water billed to consumers (ADB 2010). The calculation of non-revenue water was done using PHED data on total number of FHTC and PSP connections and revenue generated in the financial year 2019-2020 (March 2019 to March 2020).

Of the 4,188 FHTC connections, revenue was generated only from 245 connections. This implies that the remaining 3,943 connections do not generate any revenue. This accounts for an annual loss of Rs. 95,22,345 to the PHED calculated from the nonpayment of bills.

- No of Functional House Hold Tap Connections = 4,188
- No of Connections generating revenue = 245
- Flat rate water pricing = Rs 2415/ year.
- No of connections not generating revenue = 3943
- Total loss in revenue due to nonpayment of bills= $3943 \times 2415 = \text{Rs } 95,22,345$.

Amount collected from water connections

S No	Financial Year	Amount Charged Per Year	Total Amount Collected	Total Connections Paying for Water
1	2019-2020	Rs 2,415	Rs 5,85,053	245

Apparent loss in Public Stand Post:

As calculated earlier, total PSP water flow = 215.2 M3/d for 269 PSPs

60% of the supplied water is utilised by people and does not generate any revenue. This thus counts as apparent loss.

Apparent loss for PSPs = $0.215 \text{ MLD} \times 60\% = 0.129 \text{ MLD}$

Apparent loss in Water Tankers:

As calculated earlier, total water tanker supply = 0.63 M3/d

75% of the supplied water is utilised by people and does not generate any revenue and thus counts as apparent loss.

Apparent loss for WTs = $0.63 \text{ MLD} \times 75\% = 0.47 \text{ MLD}$

Cumulative Apparent Loss:

Based on the calculations above, the table below lists the real loss in the system,

S No.	Apparent Losses	Quantity
1	PSP supply	0.129 MLD
2	WT Supply	0.47 MLD
3	Illegal connections	Cannot be measured or estimated
	TOTAL	0.601 MLD

Steps taken by PHED to reduce apparent loss:

Other than inspections at the consumer end by the PHED, there have been no studies of water loss involving flow metres in Leh. PHED conducts periodical inspections to check the illegal installation of motor pumps on the mainline and double connections. Officials from the Municipal Committee, Leh and the police accompany PHED officials during these raids. The IISD-Leh team joined them on one such inspection to understand the process.



Water Balancing of Leh Town

The level of water losses can be determined by conducting a water audit. The International Water Association's water balance is an approach applied worldwide to determine and analyse water loss. A water balance is based on measurements or estimations of water produced, imported, exported, used and lost in water distribution systems up to the point of customer consumption. However, in Leh where water metres are not in place and supply is intermittent, there is a considerable amount of water loss. At the same time, the flat-rate tariff system adopted does not cover all the water used. Therefore, actual consumption and wastage should be quantified separately or estimated in the context of the utility's water reduction measures and the calculation of revenue water. We carried out a water balancing exercise for Leh town was done in this context to determine the revenue and non-revenue water of Leh town.

All the water supplied from PHED is sourced from Tube wells (TW) through three different channels namely Service Reservoirs (SR), Water Tankers (WT) and in Housing Colony, directly from Stage II pump house.

A total of 4.53 MLD of Water is supplied daily. Out of 4.53 MLD total supply in Leh town, 1.19MLD was lost due to real losses, and 0.6 MLD is lost as an apparent loss.

Through the water balancing exercise, we found that 2.74MLD is the authorised consumption after deduction of real and apparent loss. Authorised consumption primarily reflects household water supply of a total of 4,188 FHTC households out of which only 245 are paying for water while the remaining 3,943 are not paying anything. This adds to the non-revenue water. We assumed that all households have similar consumption patterns and divided authorised consumption proportionately based on the number of paying and non-paying households.

Paid consumption = $2.74 \text{ MLD} / 4,188 \times 245 = 0.16 \text{ MLD}$

Unpaid consumption = $2.74 \text{ MLD} / 4,188 \times 3,943 = 2.58 \text{ MLD}$

Tube-well (Source)	SERVICE RESERVOIR (SR)	SUPPLY INPUT 4.53 MLD	Authorised consumption 2.74 MLD	Billed consumption (245 FHTC) - 0.16 MLD	REVENUE WATER
	3.373 MLD			Unbilled consumption (3943 FHTC) - 2.58 MLD	NON - REVENUE WATER
	WATER TANKER (WT)		Apparent loss	Public Stand Post (PSP) - 0.129 MLD	
			0.60 MLD	Water Tankers (WT) - 0.47 MLD	
	0.69 MLD		Real Loss 1.19MM MLD	Household transmission loss (measured) - 0.71 MLD	
	TUBE WELL (TW) DIRECT SUPPLY			TW to SR transmission loss (measured) - 0.24 MLD	
				WT transmission loss - 0.158 MLD	
				PSP usage point loss (observed) = 0.086 MLD	
	0.517 MLD				

Table : Water balance diagram for Leh town based on IWA methodology

The following inferences can be drawn water balance diagram :

1. Only 3.5% of the total water supply input is revenue water and the remaining 96.5% water is non-Revenue water.
2. Currently, real loss accounts for around 26.27% of the total water supply. This is expected to increase further when real losses from the main service reservoir supply lines are considered. During the real loss measurements, visible damage was observed at rising mains at Nezer Gompa, Skara and Khakshal resulting in 10% to 15% losses. High water loss was also measured in rising main lines at Lamdon, T-Trench, Stage II to Maney Tselding, Murtsey and Stage III to Skampari, ranging from 5% to 10% losses. Proper repair and maintenance is recommended at these points. Comparatively, there are higher transmission losses in the household distribution system. An internal study by PHED should be carried out to identify leakages and initiate a corrective action plan.
3. There is an apparent loss of 13% where the supply is provided but monetisation of these losses is not possible in the current scenario. PSP and WTs clearly fall in this category. With the adoption and expansion of the New Supply System, piped and metred supply could be adopted for these supply sources as well. Other sources of apparent loss could be present including but not limited to illegal connections.
4. There is an authorised consumption of 60.5% supplied through pipelines. However, at the moment a majority of the people with these connections are still not paying a fee for water.

Observations and recommendations:

- Appropriate measures should be undertaken immediately to enable field conditions that will facilitate monitoring and surveillance to undertake flow and loss related audits in the near future.
- 24x7 Supply: PHED must establish a proper monitoring system and MIS. Initially, they can procure 30 to 50 Portable Sensor-based Ultrasonic Flow Metres on a priority basis, train the linemen and other relevant manpower to calibrate and operate these instruments on the field and generate reliable data. This will help generate estimate for total supply, loss and leakages.
- In the long term; PHED must explore the possibility of installing automated systems in Leh. Even the installation of software-based digital flow metres at strategic locations of the present water supply-piped network can generate relevant information round-the-clock, which can then be used to calculate non revenue water or losses. This will enable PHED to develop a more informed 'plan' to revamp the system.
- Households survey suggests that residents of Leh town are willing to pay for their consumption against metering, if their quality and quantity needs are addressed properly. In order to understand their consumption level, PHED needs to opt for an integrated metring system, involving each household.
- The department should also conduct a; willingness to pay' study for households, to arrive at an appropriate water pricing and tariff structure for the town.

The following are recommendations to reduce non-revenue water (NRW):

- a) Detect leaks acoustically and fix them: Detection and fixing of leakages is of utmost importance. An electronic acoustic method can be adopted to detect leakages.
- b) Managing distribution system pressure: Pressure reducing valves and variable speed pumps can be used to manage pressure in the distribution system while minimising line losses. This would also address the household pressure problem and improve efficiency of the existing supply system.
- c) Adoption of metre-based billing: Metre-based billing would ensure responsible behaviour of water consumption. Integrated metre system as suggested above would also improve revenue generation and provide rational information regarding water supply and demand.

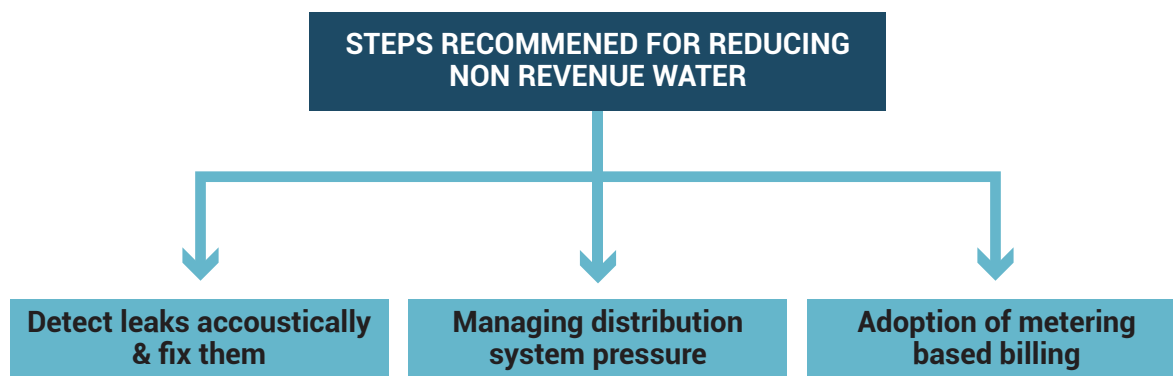
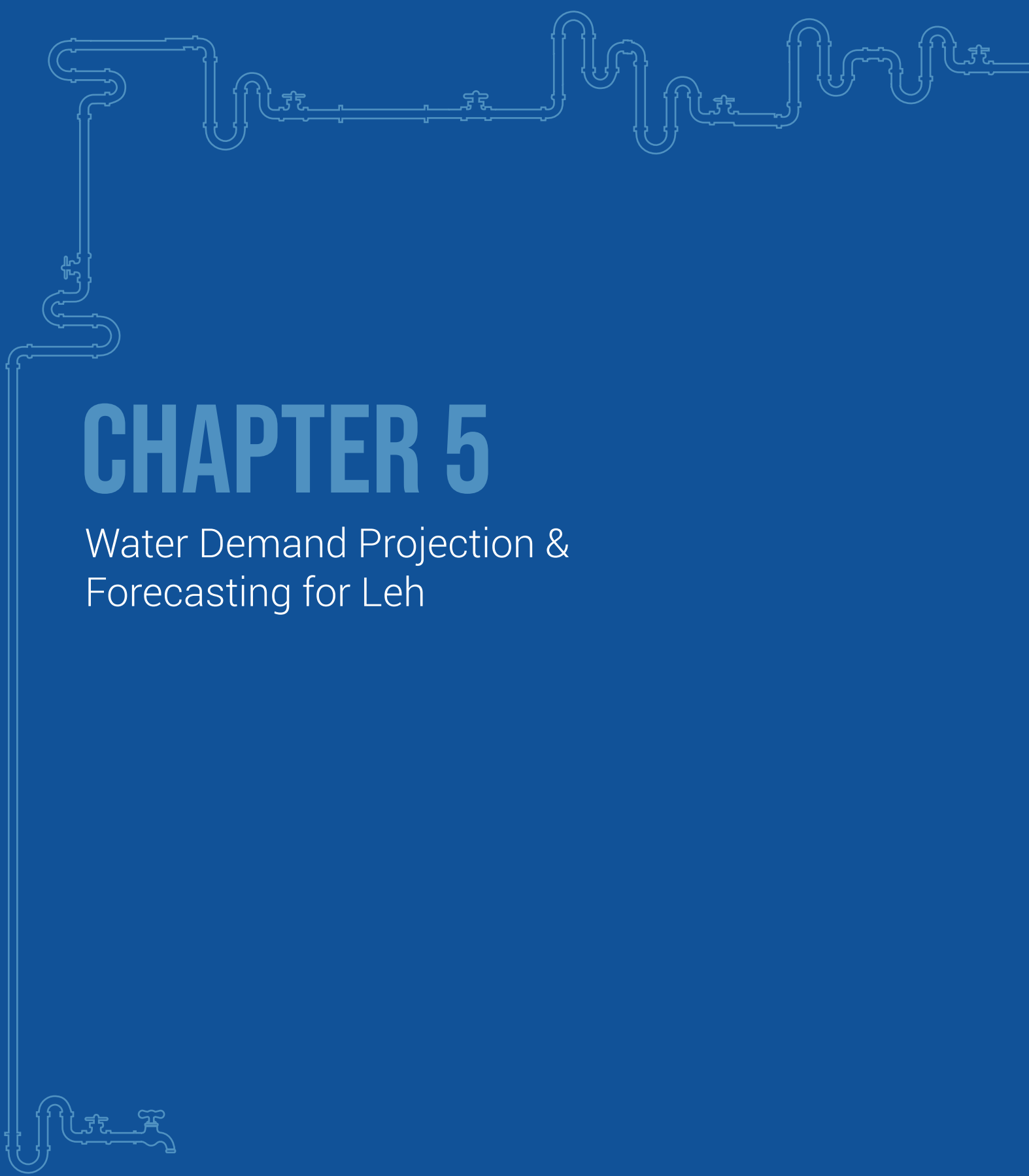


Fig : Steps recommended to reduce non-revenue water



CHAPTER 5

Water Demand Projection & Forecasting for Leh

CHAPTER 5

WATER DEMAND PROJECTION & FORECASTING FOR LEH

Introduction:

Increasing water demand is linked to population growth, economic development and changing consumption patterns. By 2030, India's water demand will exceed supply significantly, indicating severe water scarcity in the country. The importance of projecting water usage has to be understood and brought to the notice of the government/administration.

In Ladakh, where a boom in the tourism industry is taking a toll on the region's most precious resource; water. Groundwater bears the more direct impact of this change. In the 1980s, there were 24 hotels in Ladakh, and today there are 1,098 as per the Department of Tourism (UT Ladakh). Some 60 to 70 % of all hotels and guesthouses in Ladakh are concentrated in Leh town. The increasing number of guesthouses and hotels means more water intensive flush toilets and bathrooms. In addition, even local residents are rapidly moving away from dry toilets to flush toilets, which increases the pressure on Leh's water sources. The rapid increase in the population of the town due to urban migration in search of jobs and livelihoods is exerting significant stress on the water resources of Leh town.

The concept of per capita water is often used for comparing water usage over time or among groups of people that use public water supplies. Generally, per capita means the average amount of water each person in a particular area uses on a daily basis. Water availability per person is dependent on the population of the area. According to the Central Public Health and Environmental Engineering Organisation's (CPHEEO) (1999) 'Manual on Water Supply and Treatment, New Delhi' around 135 LPCD is the recommended benchmark for urban water supply for residents.

Per Capita Supply:

Factors affecting per capita consumption are:

- a) Size of town: Population plays a vital role. The population includes the number of hospitals, schools, offices, tourists etc.
- b) Characteristics of population and standard of living: The availability of a sewer system plays an essential role as towns with a sewer system require more water
- c) Climatic conditions: Areas with a colder climate require less water.
- d) Metres: Wastage of water is less if water metres are present.

Present and future demand Forecasting of potable water requirements in Leh town

Water demand forecasting is an essential factor in planning infrastructure development and estimation of budget, evaluation of constraints and development of plans. This study focuses on domestic water demand estimation in the present and forecasting for the next 20 years till 2041.

Present demand estimation

Leh is a unique town that remained a low priority for the government. In 2019, Ladakh has granted Union Territory (UT) status. There is a lack of reliable information, including but not limited to the latest population and number of households in Leh town. The latest government information available is from the 2011 census and next census data is due in 2021 or later. Therefore, this report tries to estimate the population based on available information and by using the following methodology.

Methodology

Water demand in Leh depends on the local resident population as well as the number of visiting tourists.

Formulae:

Total daily Water Demand= *Average daily resident population × Average per capita per day water demand for residents + Average daily tourist population × Average per capita per day water demand for tourists*

Average daily resident population – This has been estimated based on available village-wise 2011 census data, which has been divided into 12 PHED zones.

Decadal Growth of Population (Percentage %)-Leh District	
1901-11	12.45
1911-21	1.31
1921-31	4.78
1931-41	5.33
1941-51	8.30
1951-61	8.11
1961-71	18.56
1971-81	31.78
1981-91	31.91
1991-01	29.97
2001-11	13.86
Average	15.12

Table - Decadal Growth of Population (Percentage) – Leh District

Based on 110 years (1901-2011) population data (District Statistical Handbook, 2018-19), a decadal organic growth rate of 15.2% was calculated, which amounts to 1.52% per year. However, application of this growth rate implies a lower population projection as it does not account for the influx of tourists and migrant workers in this decade (2011-2020). Based on our understanding of local population trends, some zones have remained mostly unaffected by migrants, while others have seen exponential growth due to tourism and urban migration. Therefore, we applied different growth rates for these zones as listed in the following table :

Zones	Decadal growth estimate	Basis
Zone 1, 2, 3, 4, 8 and 12	15.2%	110 years (1901-2011) District Statistical Handbook 2018-19 population data
Zone 5, 6, 7, 9, 10 and 11	90.8%	Household growth between census 2011 data and actual water connections data from PHED 2019 for Zone 10. Zone 10 is taken as the basis since PHED has very comprehensive household-level links and operations in this zone. Work is still in progress in other zones. This growth rate was uniformly adopted for different zones exhibiting similar behaviour.

Based on the above information, the table below presents a zone-wise projected population of Leh town:

Projected population of Leh town till 2020

Zone	Household (2011 census)	Population (2011 census)	Growth %*	Projected Household 2020	Projected Population 2020
1	66	306	15.2%	76	352
2	48	272	15.2%	55	313
3	554	3,267	15.2%	638	3,761
4	45	227	15.2%	52	261
5	398	5,497	90.8%	759	10,488
6	550	3,917	90.8%	1,049	7,474
7	213	1,055	90.8%	406	2,013
8	48	216	15.2%	55	249
9	919	9,683	90.8%	1,753	18,475
10	709	3,190.5	90.8%	1,353	5,152
11	441	1,945	90.8%	841	3,711
12	434	2,001	15.2%	500	2,304
Total				7,539	55,488

Average daily tourists – Annual tourist data is available from the Department of Tourism (UT Ladakh) till August 2020. We have estimated the average daily population-based on two factors:

- a) New tourists per day:** To estimate daily demand, we need the number of tourists staying in Leh town each day. We have considered tourist inflow for six months (15th April to 15th October) from the annual data to calculate the average daily rate of tourists visiting the town.
- b) The number of days of stay per tourist:** The available data covers the number of individual tourists visiting the town but does not cover the number of days spent in Leh. Based on our local expert's suggestion, we have assumed that people visit Leh town for five to six days on an average out of which they spend three days in the Leh town and use the remaining three days to explore areas nearby. Therefore, we have assumed three days of stay per tourist for our calculation.

Average per capita demand for residents and tourists - According to the standard set by CPHEEO, for communities/towns with a population ranging between 20,000 to 1, 00,000; together with flushing system for excreta disposal, 135 LPCD has to be met by public water supply system. In the same way, the quantity recommended for tourists is 180 LPCD.

From the PHED as well as household survey, 80 LPCD has been derived as the actual demand for residents and 100 litres for tourists from the Water Status Report (BORDA, 2019)

Present water demand estimation

S No	Classification	Population (average daily)	CPHEEO recommendation			Actual Demand		
			Maximum water supply levels (LPCD)	Total liters/day required	Total MLD required	Actual water supply levels (LPCD)	Total liters/day required	Total ML/d required
1	Local residents of Leh town	55,488	135	$55488 \times 135 = 7,490,880$	7.49	80	$55488 \times 80 = 4,439,040$	4.44
2.i	Tourist (Business as Usual)	4602	180	$4602 \times 180 = 828,360$	0.83	100	$4602 \times 100 = 460,200$	0.46
2.ii	Tourist (Actual situation with Covid-19)	102	180	$102 \times 180 = 18,360$	0.02	100	$102 \times 100 = 10,200$	0.01
Total (Business as usual scenario)			8.32			4.90		
Total (Actual situation with Covid-19)			7.51			4.45		

Table : Present (2020) water demand estimation of Leh town

Future water demand forecasting for next 20 years:

This report also tries to project annual water demand for the general population for the next 20 years till 2041. We have used the geometric method for this estimation with the 2020 population as the baseline for residents and 2019 as the baseline for tourists.

Local population growth – We have considered the organic growth of local resident population at the long term average of 1.52% per year as discussed earlier. An additional 2% growth rate has been taken into account for expected accelerated growth through urban migration following the recent allocation of Union Territory status to Ladakh and other significant developments.

However, we have applied the additional growth factor from 2026 onwards to account for subdued tourism and work opportunities due to the impact of COVID-19. The projected population till 2041 was estimated to be 104,076, and the water requirement for general population till 2041 was estimated to be 14.05MLD. Since Ladakh is a semi-arid region local residents are accustomed to low - moderate water consumption by using traditional practices. Local agencies can promote traditional techniques and other sustainable water use practices for local residents as well as tourists to shift to a more sustainable water demand and management regime.

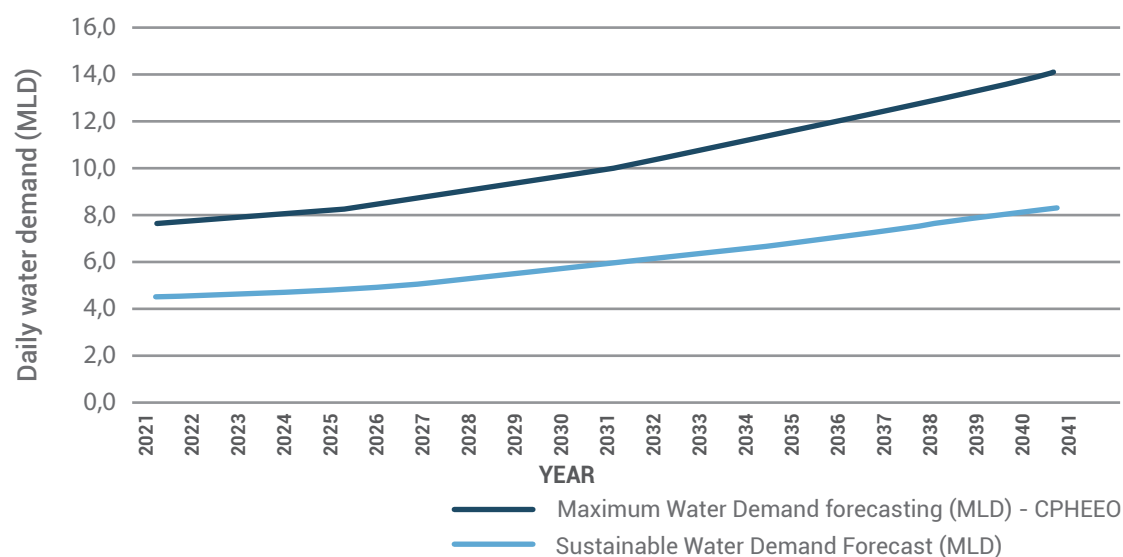


Fig : Projected population and water demand for local residents between 2021 and 2041

Projected population and water demand for local residents between 2021 and 2041

S. No	Year	Projected Population	MLD Requirement (CPHEEO)	MLD Requirement (Sustainable pathway)
1	2020	55,488	7.49	4.44
2	2021	56,332	7.60	4.51
3	2022	57,188	7.72	4.58
4	2023	58,057	7.84	4.64
5	2024	58,940	7.96	4.72
6	2025	59,836	8.08	4.79
7	2026	61,942	8.36	4.96
8	2027	64,122	8.66	5.13
9	2028	66,379	8.96	5.31
10	2029	68,716	9.28	5.50
11	2030	71,135	9.60	5.69
12	2031	73,639	9.94	5.89
13	2032	76,231	10.29	6.10

14	2033	78,914	10.65	6.31
15	2034	81,692	11.03	6.54
16	2035	84,567	11.42	6.77
17	2036	87,544	11.82	7.00
18	2037	90,626	12.23	7.25
19	2028	93,816	12.67	7.51
20	2039	97,118	13.11	7.77
21	2040	100,537	13.57	8.04
22	2041	104,076	14.05	8.33

Comparison of population growth projection vs Tetra Tech DPR

We evaluated our growth projections against a DPR by Tetra Tech for PHED, Leh produced in 2008 under Urban Infrastructure Development Scheme (UIDSSMT). In the DPR for the new water supply system, a population projection, including the floating population of tourists, was made by taking the average of the following methods: arithmetic, geometrical, incremental, state urban average and graphical.

Table 7.6: Comparison of IISD local resident population projections with PHED estimates

Population projection	2041 Projections by IISD	2041 Projections by Tetra Tech	Percentage change	Comparison remarks
Local residents	104,076	80,592	+29.13%	Considering the new designation of UT and major development plans in the region, a slighter higher growth due to urban migration can be expected.

Tourist: Projected population and water demand 2021-2041

The tourist population was estimated based on the geometric method. With regard to water demand estimation, like present-day scenario, we considered peak tourist season from 15th April to 15th October after reviewing monthly tourist inflow data. We assumed an average stay of three days per tourist in Leh town.

Growth projections:

We evaluated different methods and periods to estimate the growth rate. We analysed the annual tourism data since 1974-2019 for 10 year, 20 year and 45 year periods and found an incremental (geometric) growth of 20%, 28% and 27% respectively, which is astonishing. However, if we applied these growth rates for our forecast, the city could expect more than six million tourists per year by 2042, which is way above the town's capacity to manage and would put unsustainable pressure on its natural resources and ecology. Thus, we considered various push and pull factors listed below to identify a reasonable growth rate for the town.

Table : Push and pull factors for tourist growth Leh town

Push factors	Pull factors
Designation of UT status	COVID-19 and its impact on tourism
Developments like educational universities etc.	Town's sustainable carrying capacity of people
Better connectivity and road infrastructure	Ongoing border escalation
Tourism promotion and development of modern facilities	

Covid-19 impact on the industry:

Tourist visits dropped by 97.8% between 2019 and 2020 due to COVID-19-related lockdown and travel restrictions. The effect might have long-term impacts for the global and national travel industry. So, we have estimated that the tourism industry will recover to the 2019 level only by 2025 in a phased manner (refer remarks in table below).

Growth projections (2026 onwards):

Considering all the above factors and in consultation with experts, we have decided to use an initial growth rate of 20% (based on data for the last decade as earlier growth rates were relatively lower) for the period 2026-2030. However, we expect the growth to plateau after five years of high growth to 15% between 2031-2035 periods. Furthermore, the number of visitors might be restricted to protect the environment, ecology and local communities lowering the growth rate to 10% for the years between 2036 and 2040.

The maximum water demand for tourists till 2041 was estimated at 7.01MLD. However, sustainable water use practices could be promoted to incoming tourists and implemented with the support of the local community and businesses. Sustainable demand for tourist population till 2041 was estimated at around 3.89 MLD.

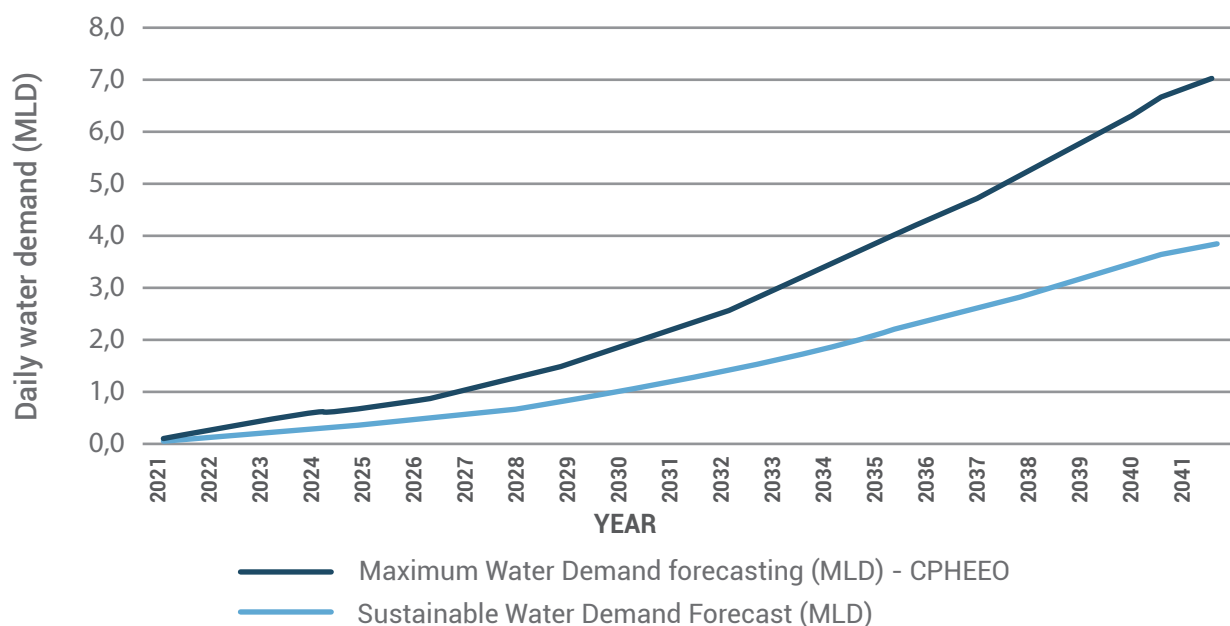


Fig - Projected annual water demand for Tourists in Leh Town (2021-2041)

Projected population and water demand for tourists between 2021 and 2041

S No	Year	Projected Tourist Population (annually)	Total person-days stay per year	Total person-days stay per day	Maximum demand in MLD	Sustainable demand in MLD	Remarks
1	2019	279,937					Base year - Actual data from MoT
2	2020	6,181					Actual data from MoT till 24th august 2020
3	2021	69,984	209,953	1,150	0.21	0.12	Tourists at 25% of 2019 levels
4	2022	125,972	377,915	2,071	0.37	0.21	Tourists at 45% of 2019 levels

S No	Year	Projected Tourist Population (annually)	Total person-days stay per year	Total person-days stay per day	Maximum demand in MLD	Sustainable demand in MLD	Remarks
5	2023	181,959	545,877	2991	0.54	0.30	Tourists at 65% of 2019 levels
6	2024	237,946	713,839	3911	0.70	0.39	Tourists at 85% of 2019 levels
7	2025	279,937	839,811	4602	0.83	0.46	Tourists matching 2019 levels
8	2026	335,924	1,007,773	5522	0.99	0.55	Annual Growth – 20%
9	2027	403,109	1,209,328	6626	1.19	0.66	Annual Growth – 20%
10	2028	483,731	1,451,193	7952	1.43	0.80	Annual Growth – 20%
11	2029	580,477	1,741,432	9542	1.72	0.95	Annual Growth – 20%
12	2030	696,573	2,089,719	11451	2.06	1.15	Annual Growth – 20%
13	2031	801,059	2,403,176	13168	2.37	1.32	Annual Growth – 15%
14	2032	921,218	2,763,653	15143	2.73	1.51	Annual Growth – 15%
15	2033	1,059,400	3,178,201	17415	3.13	1.74	Annual Growth – 15%
16	2034	1,218,310	3,654,931	20027	3.60	2.00	Annual Growth – 15%
17	2035	1,401,057	4,203,170	23031	4.15	2.30	Annual Growth – 15%
18	2036	1,541,162	4,623,487	25334	4.56	2.53	Annual Growth – 10%
19	2037	1,695,279	5,085,836	27868	5.02	2.79	Annual Growth – 10%
20	2038	1,864,807	5,594,420	30654	5.52	3.07	Annual Growth – 10%
21	2039	2,051,287	6,153,862	33720	6.07	3.37	Annual Growth – 10%
22	2040	2,256,416	6,769,248	37092	6.68	3.71	Annual Growth – 10%
23	2041	2,369,237	7,107,710	38946	7.01	3.89	Annual Growth – 5%

Comparison of population growth projections against Tetra Tech DPR

Table : Comparison of Tourists population projections with PHED estimates

Population Projection	2042 Projections by IISD	2042 Projections by Tetra Tech	Percentage change	Comparison remarks
Tourists	38,946	11,363	+242.7%	Estimations for DPR were done in 2008. However, tourist numbers have skyrocketed in the decade from 2009 to 2019 due to the success of Hindi films shot in Ladakh, promotional efforts by local agencies and access to information through Internet/social media/ etc. We expect much higher growth in tourist population in line with the last 45 years track, which recorded an average growth of 27%.

Total water demand for Leh Town for the period 2021 to 2041:

Based on the above projections, the total water demand for Leh town has been projected in the graph and table below. It is worth noting that promoting water-efficient traditional practices could help reduce the demand by up to 42%, making the Leh more sustainable and resilient. Separate studies are needed to evaluate the maximum carrying capacity and maximum water supply capacity of the town to develop a road-map.

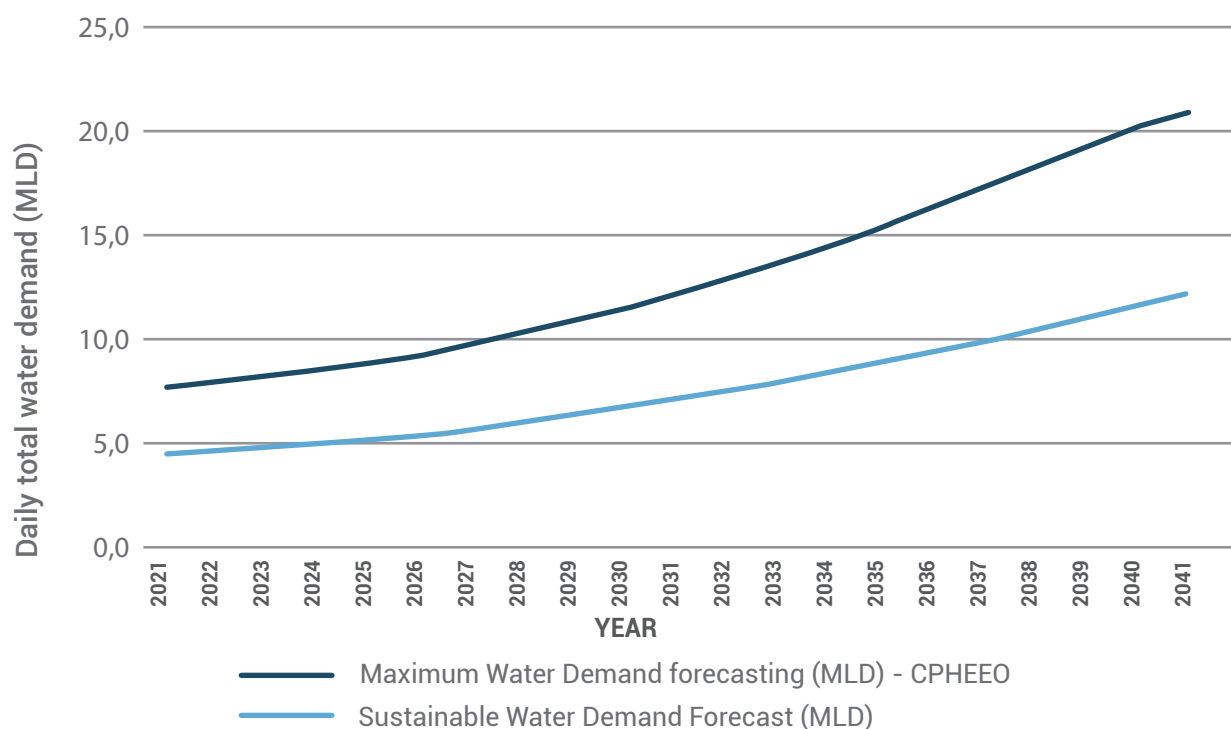


Fig: Projected total annual water demand in Leh town (2021-2041)

Projected total water demand for Leh town between (2021-2041)

Year	Maximum Water Demand forecasting (MLD) - CPHEEO			Sustainable Water Demand Forecast (MLD)		
	Local Residents	Tourists	Total	Local Residents	Tourists	Total
2021	7.6	0.2	7.8	4.5	0.1	4.6
2022	7.7	0.4	8.1	4.6	0.2	4.8
2023	7.8	0.5	8.4	4.6	0.3	4.9
2024	8.0	0.7	8.7	4.7	0.4	5.1
2025	8.1	0.8	8.9	4.8	0.5	5.2
2026	8.4	1.0	9.4	5.0	0.6	5.5
2027	8.7	1.2	9.8	5.1	0.7	5.8
2028	9.0	1.4	10.4	5.3	0.8	6.1
2029	9.3	1.7	11.0	5.5	1.0	6.5
2030	9.6	2.1	11.7	5.7	1.1	6.8
2031	9.9	2.4	12.3	5.9	1.3	7.2
2032	10.3	2.7	13.0	6.1	1.5	7.6
2033	10.7	3.1	13.8	6.3	1.7	8.1
2034	11.0	3.6	14.6	6.5	2.0	8.5
2035	11.4	4.1	15.6	6.8	2.3	9.1
2036	11.8	4.6	16.4	7.0	2.5	9.5
2037	12.2	5.0	17.3	7.3	2.8	10.0
2028	12.7	5.5	18.2	7.5	3.1	10.6
2039	13.1	6.1	19.2	7.8	3.4	11.1
2040	13.6	6.7	20.2	8.0	3.7	11.8
2041	14.1	7.0	21.1	8.3	3.9	12.2

Comparison of local resident's water demand projections against Tetra Tech DPR

In the Tetra Tech DPR for the new water supply system, a population projection including the floating population of tourists was made by taking the average of the following methods: Arithmetic, Geometrical, Incremental, State urban average and Graphical. According to those projections, in 2041 water requirement will be 10.88 MLD. The table below compares the DPR projections against maximum projections made by IISD as well as 'sustainable demand projections.'

Comparison of projections of daily water demand in 2041 with PHED

Max. water demand projection by IISD – (as per CPHEEO)	Max. water demand projection by DPR – (as per CPHEEO)	Percentage difference (for CPHEEO)	Water demand projections by IISD – Sustainable demand	Comparison remarks
21.10 MLD	10.88 MLD	+93.9%	12.2 MLD	Our estimates for tourist numbers are higher than the DPR as the tourism industry in Ladakh has witnessed dramatic growth over the last decade. Furthermore, we have considered 180 LPCD as per CPHEEO recommendation for tourists (hotel bed category) compared to 135 LPCD considered in the DPR. Even with the higher estimates for resident and tourist population, we can still come close to the DPR projected values if sustainable practices and prudent water management strategies are adopted.

Conclusions and recommendations

A detailed exercise has been carried out to arrive at year-wise future water demand projections for Leh town over the next 20 years while accounting various push and pull factors including the recent impact of COVID-19 to estimate the growth of actual population, including tourists.

For growth projection of local population, Team-IISD considered 110-year average growth rate. This was supplemented with the expected increase in urban migration due to factors such as:

- a) Recent increase in visiting tourists generating livelihood opportunities
- b) Newly declared Union Territory (UT) status, and
- c) Various major development projects initiated (or planned) recently by the government.

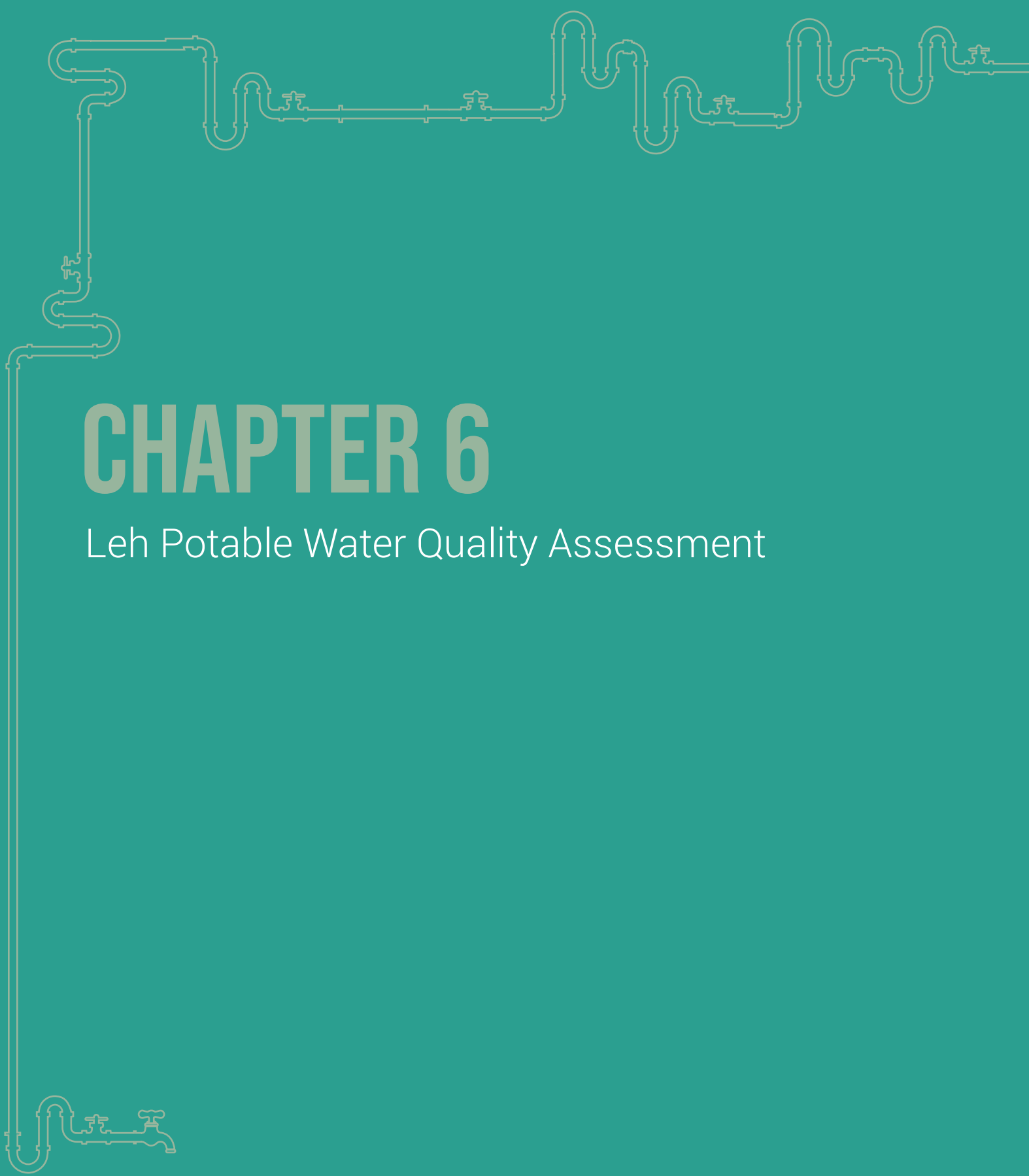
For tourist growth, we accounted for the impact of COVID-19 and considered a slower growth in the region till 2025. Afterwards, the area is expected to witness a higher growth rate till 2030 and then gradually plateau by 2041 based on the carrying capacity of the town and possible restrictions to preserve local culture and ecology among other factors.

This exercise presents two future scenarios:

- 1) Business as Usual scenario based on CPHEEO demand projections and
- 2) Sustainable water demand scenario.

Improving standard of living and economic development is likely to give a boost to the region, especially with being given UT status. Leh is the main administrative town in the region and its per capita consumption is likely to increase from the present 80 litres to 135 litres in the near future, especially with proposed 24x7 water connection to every household. However, the town is already facing water supply-demand deficit of more than 1MLD and depletion of groundwater due to 100% dependence on groundwater extraction by PHED and private bore wells.

To meet the projected future demand, concerned agencies should plan for the required infrastructure, while at the same time, develop a water management action plan in a phased manner. It should take into account maximum available water resources, alternate sources of water, and ways to promote sustainable consumption by all stakeholders, which could help reduce the demand by 42%, using CPHEEO maximum recommended demand as baseline. However, it is recommended to restrict the water demand by promotion and adoption of Ladakhi traditional practices and efficient water usage by local residents and tourists. It would help improve the management of the town's water resources and optimise its infrastructure and budgetary resources while still maintaining its ecological integrity.



CHAPTER 6

Leh Potable Water Quality Assessment

CHAPTER 6

LEH POTABLE WATER QUALITY ASSESSMENT

Water Quality Analysis

Water quality testing is a tool that can be used to help identify safe drinking water – whether at source, within a piped distribution system, or at the consumer's end. Water testing plays an important role in monitoring the correct operation of water supply systems, verifying the safety of drinking water, investigating disease outbreaks, and validating processes and preventative measures (Bain et al., 2012). Water quality analyses enable assessments of the current state of quality of water and its variability in space and time.

Drinking water quality assessment by Team- IISD

In the past one decade many researchers have tried to study the quality of drinking water that is being made available to the people of Leh. According to secondary data collected from various publications, news articles, websites and related portals, most studies reported that some water sample parameters fell within as well as higher than the desirable or permissible limit in certain locations, with respect to the prescribed BIS standards. We decided to corroborate these findings and perceptions by conducting a systematic and thoroughly tested scientific methodology.

Laboratory analyses and field testing kits (FTK) are the two main testing methods used by government and NGOs. The standard laboratory methods currently used in the context of routine testing have many limitations, especially when applied in remote and difficult areas such as Leh due to geographical constraints, scarcity of resources and time. In situations where cost or logistics prevent use of advanced testing methods, the use of field-testing kit allows rapid assessment of water quality giving reliable on-site results. Leh does not have an NABL-accredited water testing laboratory facility as of now. Hence, FTKs were used in the preliminary round of testing. In addition, we managed to send two batches of nine samples each to an NABL-accredited laboratory in New Delhi for further analyses.

Method adopted:

S No.	Method adopted	Sample Locations	Batches	Parameters
1	Water Testing Kit	37 sampling locations in Leh town	Four batches with eight to nine samples in each	16 physical, chemical and H25 vile test
2	Laboratory Testing	8 service reservoirs + T-Trench	Two batches of nine samples each	16 physical, chemical, E. Coli and total coliform count test

Water sampling and analysis was carried out in three stages:

- Preliminary investigations were carried out by identifying, collecting and analysing water samples on the spot from 37 different locations in Leh town. This yielded results for 16 essential water quality parameters using Tamil Nadu Supply and Drainage Board (TWAD) Water Testing Kits.
- Based on the above test results, few samples were short-listed for further testing in an NABL-accredited laboratory. Water samples from eight major service reservoirs in the town and one sample from T-Trench were sent to New Delhi.
- To validate the laboratory test results, a second batch of samples from the same service reservoirs and T-Trench were sent to a laboratory in New Delhi a second time.

The TWAD-based Water Quality Analysis Field Testing Kit

As part of its effort to institutionalise community contribution and participation in water quality monitoring and observation of all drinking water sources, Government of India has launched NRDWQM & SP for which the TWAD Board developed a simple user-friendly Field water testing kit. TWAD Board has been fabricating simple user-friendly Field water testing kits since February 2006 for water quality monitoring and surveillance at the community-level.

The reason for choosing TWAD Board Field Water Testing Kit is:

- The kit has been evaluated by IIT, Chennai as Grade 'A', approved by NEERI and recommended by WHO and UNICEF for on-site water testing for essential parameters in a simple manner, which provides basic minimum reliable and indicative test results for all 16 essential water quality parameters.
- It is very light to carry (1.5kg) and simple to use.
- Reagents of the kit can be replenished easily through the TWAD Board State laboratories if required.
- It is most efficient if used within a year of production and guarantees a minimum of 100 water quality tests.

Preliminary studies for the determination of most 'in-situ' 16 essential physio-chemical parameters of water were carried out using TWAD field testing kit. The kit also provides a user manual with simple step-by-step instructions on how to conduct the water quality tests.

The essential parameters are :

1. Physio-chemical parameters: **turbidity, odor, pH, alkalinity, hardness, chloride, TDS, Chloride, Fluoride, Iron, ammonia, nitrite, nitrate, phosphate, and residual chlorine**
2. Microbial analysis via **H₂S vile test**

H₂S vile test

The hydrogen sulphide (H₂S) presence/absence test is an inexpensive, easy-to-use, and portable alternative field-based water quality test, which has been used globally for more than two decades and gained popularity as a low-cost method to assess faecal contamination. This is a simple bacteriological testing kit that could be used to indicate the presence of pathogens. The H₂S test does not attempt to identify the pathogens and merely indicates whether there is a risk without specifying the degree of risk. It does not specifically test for standard indicator bacteria such as E. coli or thermo tolerant coliforms. Some microorganisms have the ability to reduce sulfur containing compounds to hydrogen sulfide through their metabolism and this kit detects these changes. Several methods are used to detect H₂S production by micro-organisms that vary with the source of sulphur and the metal salts used to indicate H₂S formation. An iron and a sulphur compound are included in the test medium to test for the production of hydrogen sulphide gas. Hydrogen sulphide is produced when the sulphur compound is reduced by bacterial strain. This test determines if the microbe reduces sulphur-containing compounds to sulphides during the process of metabolism. H₂S is produced by certain bacteria through reduction of sulphur-containing amino acids like cystine, methionine or through the reduction of inorganic sulphur compounds such as thiosulphates, sulphates or sulphites during protein degradation or when anaerobic respiration shuttles the electrons to sulphur instead of oxygen. In either case H₂S is produced (hydrogen sulphide gas), which reacts with the iron compound to form the black precipitate of ferric sulphide. The black colour acts as an indicator for the presence of hydrogen sulphide. The detection of hydrogen sulphide (H₂S) gas produced by an organism is used mainly to assist in the identification of that particular organism. This test can be performed with the use of several media including Triple Sugar Iron (TSI), Kligler's Iron Agar (KIA), SIM medium and Lead Acetate Paper.

Composition:

Beef extract 3.0 g Peptone 30.0 g Ferrous ammonium sulphate 0.2 g Sodium thiosulphate 0.025 g Agar 3.0g Final pH (at 25°C) 7.3±0.2 Distilled water 1000ml.

Drinking Water Quality Sampling Locations Identification

A total of 37 groundwater samples were collected from all 12 zones at various elevation levels. The samples collected were representative drinking water samples from bore wells, springs, taps, tankers, hand pumps, public taps, government offices, hospitals, and tourist destinations. The samples were collected in the period between July and September, 2020 in four phases, so as to evaluate its fitness for drinking purposes and other domestic uses.



Map of water testing sampling locations: Red circles represent the first phase of 37 locations (analysis by kit); blue circles are the nine locations of service reservoirs+ T-Trench (laboratory testing)

Analysis by TWAD Testing kit

A total of 37 water samples were collected in two phases in four batches with none to 10 samples in each batch. This was collected for analysis with TWAD water testing kits

In the first phase (Sl. no. 1 to 22) samples were collected from various sources such as PSP, FHTC, hand pumps, tube wells etc. In the second phase (S No 23- 37) important/VIP locations such as Raj Niwas, SNM Hospital, etc. were selected keeping in mind their usage frequency.

Samples were collected in fresh clean and sterilised PET bottles of 500ml capacity. Prior to sample collection, all the bottles were thoroughly washed and dried. Before sample collection, the bottles were rinsed twice with water sample being collected. Parameters like turbidity and odour were analysed "in-situ", using the water testing kit. The remaining parameters were analysed at IISD Leh office within 10 hours of sample collection.

**see Annexure for complete table on samples.*

Interpretation of Test Kit results

The colour and odour of all samples were agreeable and in keeping with standard norms.

The pH of water is very important indicator of its quality as it depends on the presence of phosphates, silicates, borates, fluorides and other salts in dissociated form. pH represents the effective concentration (activity) of hydrogen ions (H⁺) in water. In general, water with pH values between 6.5 and 8.5 are categorised as suitable for drinking, whereas water with pH value between 7.0 to 8.0 are suitable for all purposes.

The pH value of the water samples of the study area varied from 6.3 to 8.5, which indicated that water is slightly alkaline in nature but suitable for domestic purposes (Herojeet et al, 2013).

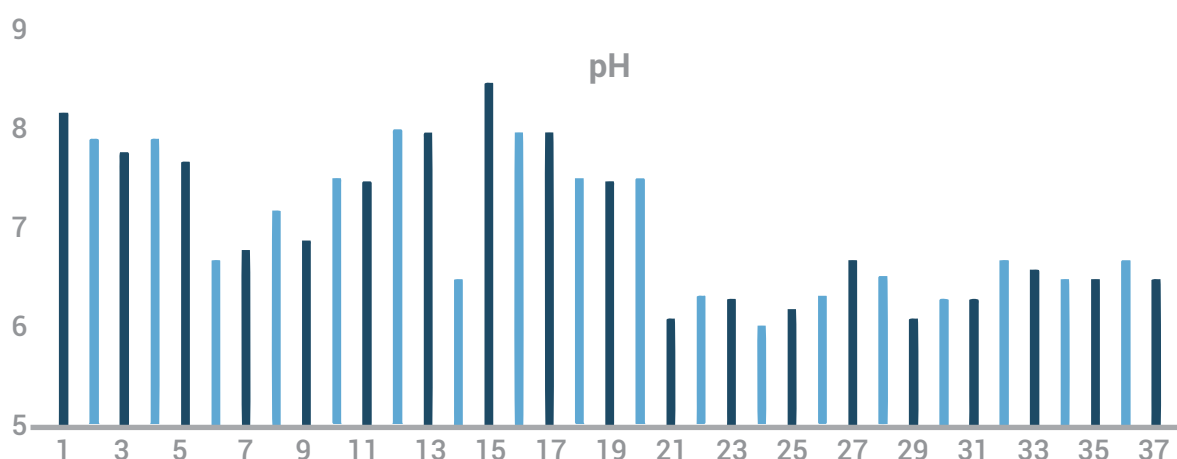


Fig : pH variations in the water samples analyzed by kit

Turbidity is a measure of the amount of suspended particles in water. Algae, suspended sediment, and organic matter particles can cloud the water and make it more turbid. Suspended particles diffuse sunlight and absorb heat. This can increase temperature and reduce light available for algal photosynthesis. If the turbidity is caused by suspended sediment, it can be an indicator of erosion, either naturally or human-induced. The sediment can also carry pathogens, pollutants and nutrients. **All locations were found to be free of turbidity.**

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralise acids. Measuring alkalinity is important in determining a stream's ability to neutralise acidic pollution from rainfall or wastewater. The presence of buffering material helps neutralise acids as they are added to the water. These buffering materials are primarily the bases bicarbonate (HCO₃⁻), and carbonate (CO₃²⁻), and occasionally hydroxide (OH⁻), borates, silicates, phosphates, ammonium, sulphides, and organic ligands. Alkalinity not only helps regulate the pH of a water body, but also the metal content. Bicarbonate and carbonate ions in water can remove toxic metals (such as lead, arsenic, and cadmium) by precipitating the metals out of the solution.

Alkalinity of the study samples were found to be in the range of 60 to 340 mg/l.

Total dissolved salt (TDS) concentrations is the primary indicator of the total mineral content in water and are related to problems such as excessive hardness resulting from the presence of divalent metallic cations of which calcium and magnesium are the most abundant. Water with higher TDS is considered by some health advocates to have a poorer cleansing effect in the body than water with a low level of TDS. This is because water with low dissolved solids has greater capacity for absorption than water with higher solids. Since TDS is not associated with negative health effects, no health-based guideline value for TDS has been proposed so far (WHO, 2011). The U.S. Environmental Protection Agency (2009) recommends a TDS limit of 500 mg/l.

Samples 21, 25, 27, 28 and Mini secretariat SR were slightly above the desirable limit. All other samples were within the desirable limits.

Hardness is measure of polyvalent cations (ions with a charge greater than +1) in water. Total hardness is caused by the presence of the divalent cations of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Water with a total hardness in excess of approximately 200 mg/l; may cause scale deposition in the treatment works, distribution system and pipe-work and tanks. **The concentration of total hardness in the water of the study area varied from 100 to 470 mg/l with 210 mg/l being the average value, which is well within the permissible limits.**

High alkalinity and hardness of water may be corrected by boiling followed by filtration. However, gravity or reverse osmosis (RO)-based multi-staged filters might be useful to remove excess inorganic salts and minerals. Since, the high altitude region has limited electricity coverage, RO filters may not be feasible and gravity-based filter have limited capacity to remove soluble metal salt contaminants (Bharti et al, 2017)

Fluoride (F) is essential in trace amounts for all human beings and is one of the normal constituents of all diets. Fluoride concentrations in all the water samples were found to be in the range of 0 to 3 mg/l. The permissible limit for fluoride in drinking water is 1.5 mg/l but an amount of 3.0 mg/l was found in samples taken from PSP near Degree College and 2.0 mg/l was found in samples collected from FHTC in Ibex Colony and Lion's Club.

Iron: The acceptable limit of iron in drinking water is 1.0 mg/l but concentration of iron in drinking water is normally less than 0.3 mg/l. it might be higher in areas where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanised iron pipes are used for water distribution. Iron was found to be absent in all study samples.

Phosphate is a common constituent of agricultural fertilisers, manure, and organic wastes in sewage and industrial effluent. It is an essential element for plant life, but excess amounts in water can speed up eutrophication. Phosphate was found to be absent in all study areas.

Chlorine: The presence of free chlorine in drinking water indicates that a sufficient amount of chlorine was added initially to the water to render inactive bacteria and some viruses that cause diarrhoea and the water is protected from recontamination during storage. The presence of free chlorine in drinking water is correlated with the absence of most disease-causing organisms, and thus is a measure of the potability of water. Chlorine in drinking water is not generally harmful to human beings unless it is highly concentrated. As there is no known health risks associated with chlorine, no health-based guideline value is proposed for chlorine in drinking water (WHO, 2011). The chloride ion in the surface water of the study area was (20-110 mg/l) much within the acceptable limits. The median chloride concentration values in water were in the range of 20 to 70.

Nitrogen compounds are present in human and animal waste and are released particularly as ammonia and urea to the environment (e.g. via on-site sanitation). Nitrate is formed by sequential, microbiologically-catalysed oxidation of ammonia to nitrite and then to nitrate. In contrast to nitrite, the nitrate ion is the stable form of combined nitrogen in aerobic, oxidising systems and thus is one of the major anions in natural water. Agricultural fields form the main diffuse sources of NO_3^- , which is leached to groundwater. However, NO_3^- is also released from exercise yards and manure storage facilities, which represent important potential point sources of contamination. The problem of groundwater contamination by nitrates appears to be worsening the world over by the end of the 20th Century. Elevated concentrations of nitrate (greater than 2 mg/l) in drinking water are associated with adverse health effects.

Ammonia nitrogen (N) is present in variable concentrations in many surface and groundwater sources. A product of microbiological activity, natural presence of ammonia in water is regarded as indicative of sanitary pollution. It is a biologically-active compound found in water as a normal biological degradation product of nitrogenous organic matter (protein). It also may find its way to ground and surface waters through discharge of industrial process waste containing ammonia and fertilisers. ***Ammonia was absent in all study samples.***

Nitrate: Levels can be greatly elevated due to agricultural activities as well as sanitation practices. The toxicity of nitrate to humans, especially to infants, is mainly attributed to its reduction to nitrite in the digestive system. Excess of nitrates consumed by humans, particularly infants, is likely to cause health hazards and may lead to Methaemoglobinemia (blue baby) disease caused by impaired ability of blood to carry sufficient oxygen to individual body cells causing the veins and skin to appear blue. ***In preliminary investigations, all 37 samples showed slightly high levels of nitrate, but they were within permissible limits.***

Standard Laboratory Analysis

Since the field-testing kit method is only indicative in nature, they do not give a true representation of actual concentrations. It was thus necessary to further validate the results in an accredited laboratory. Advanced laboratory testing was carried out twice for selected samples in Standard Analytical Laboratory (ND) Pvt. Ltd, Delhi.

A total of nine locations were identified for analysis, Water samples from the following SRs were taken:

- i) Khagshal
- ii) Lamdon
- iii) Gompa Nezer
- iv) Changspa
- v) Jumabagh
- vi) BadamiBagh
- vii) Skampari
- viii) Mini. Secretariat and
- ix) T-Trench (open reservoir/spring)

The samples for these were taken twice. The first one was collected late in the evening on 12th September, 2020 and the second was collected late in the evening of 28th September, 2020. They were both sent to Standard Analytical Laboratory (ND) Pvt. Ltd, New Delhi. The laboratory is ISO 9001-2015 certified and recognised by NABL, Bureau of Indian Standards (BIS) and Ministry of Environment, Forest and Climate Change, under the Environmental (Protection) Act. 1986.

Two rounds of sample collection and analysis was done to ascertain the test results of the first batch in accordance with the standard methodology given by APHA (2005).

Both batches of samples were collected in 1000ml sterilised glass PET bottles. The glass bottles were first sterilised in an autoclave, and vacuum-sealed in sterile plastic bags. Sterilisation of the bottles was done at a certified medical facility.

The laboratory submitted the final test results on 5th October 2020, which was the same as the first test results. However since E Coli and total coliform were found in some of these samples; the laboratory was asked to repeat the bacteriological counts for all the samples again to ascertain the second test result.

**see Annexure for certified laboratory results*



sterilization of sample containers in an autoclave

Lab Results:

- Colour and odour of all eight SR + T-Trench water samples were agreeable as per the standard norms and the pH was found to be well within the range of 7.5 to 8.1.
- Most of the physio-chemical parameters were within the desirable limit and were not a cause of concern. Four samples showed hardness above the desirable limit but not significant enough to cause worry.
- However, the presence of nitrite and nitrate levels were found to be on a little higher side at T Trench, Lamdon and Mini Secretariat.

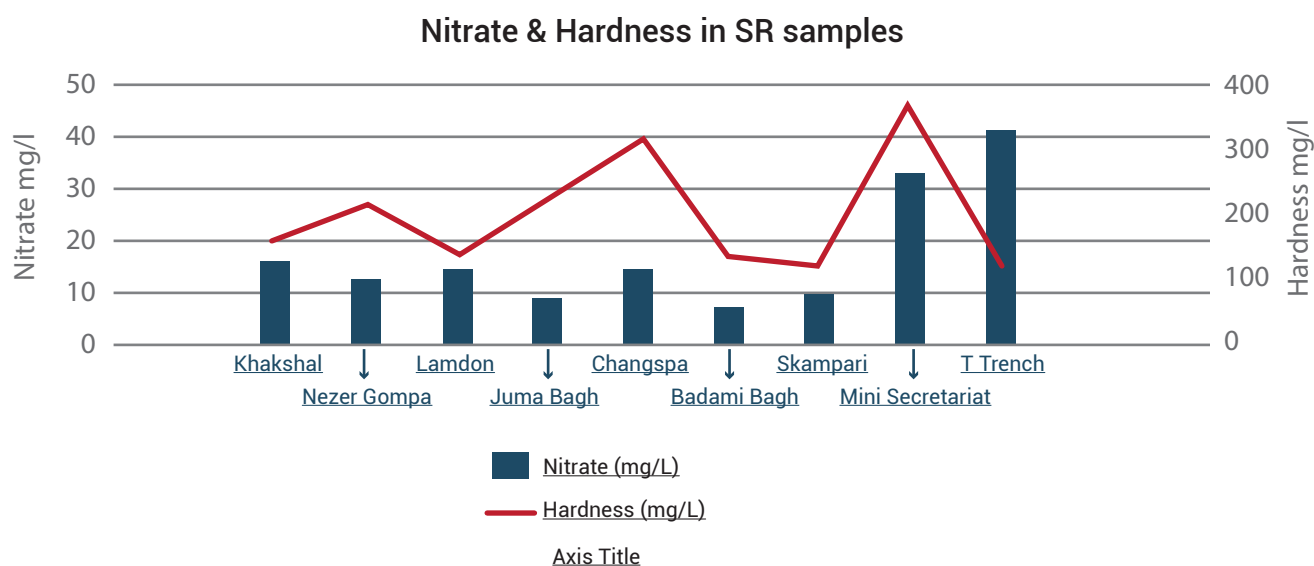
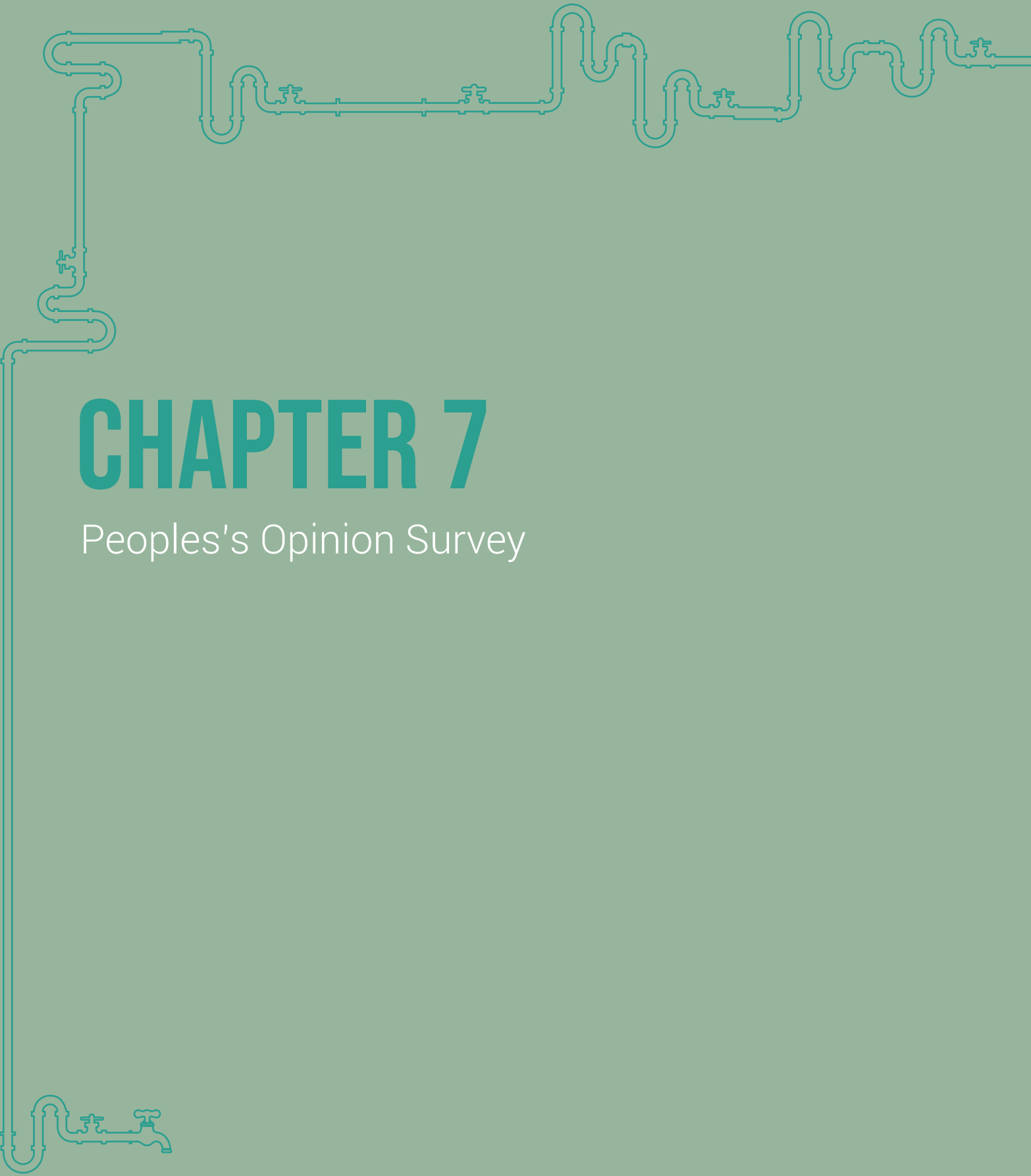


Fig : Nitrate and hardness variations in the SR samples tested in the laboratory

- The complete Bacteriological lab test result has been submitted to the PHE department for their reference and further action.



CHAPTER 7

Peoples's Opinion Survey

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PEOPLE'S OPINION SURVEY

The need to represent the voice and concerns of the local people with respect to water issues was felt. This chapter summarises some of the key findings from the opinion survey* of Leh Town's residents with special focus on its largest water zone (10)

**(The complete survey analysis, questionnaire, methodology etc. is not included in this version due to page constraints but can be produced if requested)*

Distribution based on socio-economic Indicators

The respondents were divided into four categories based on their monthly average incomes: a) HIG: above INR 25,000 b) HMIG: INR 10,000-25,000 c) LMIG: INR 10,000 - 5,000 and d) LIG: below INR 5,000. Based on the survey results, it was observed that with the influx of tourism, average household incomes had gone up, and a majority of the people reported an income in excess of INR 25,000 per month.

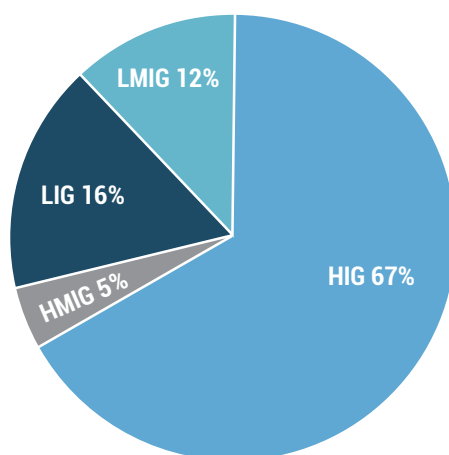


Fig – Respondent distribution based on socio-economic status

Distribution based on the nature of water supply source

As already discussed, the survey has a special focus on Zone 10, which uses the new distribution system and faces a lot of problems. In keeping with our expectations, a majority of the respondents are using FHTC as their source of water, which is prevalent in zone 10.

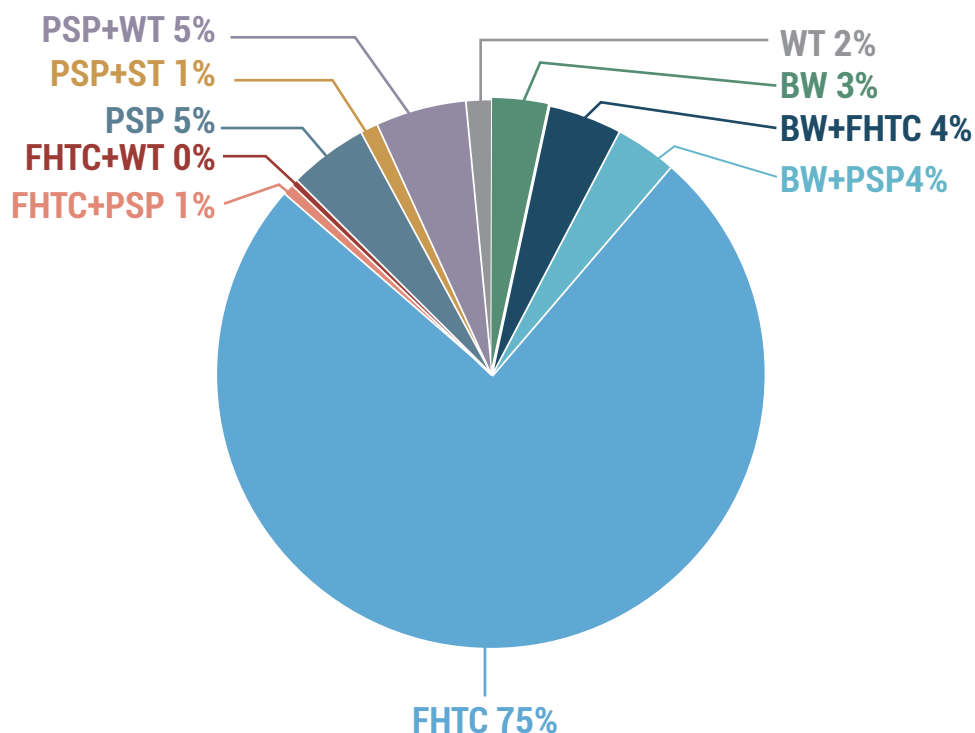


Fig – Respondent distribution based on the type of water supply sources available

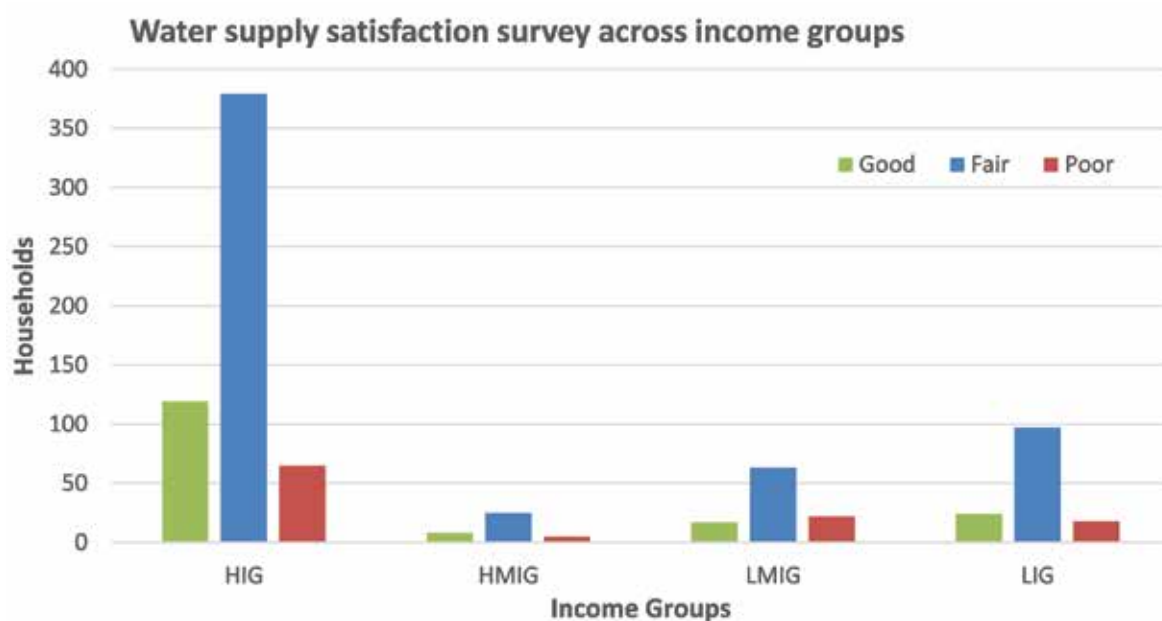
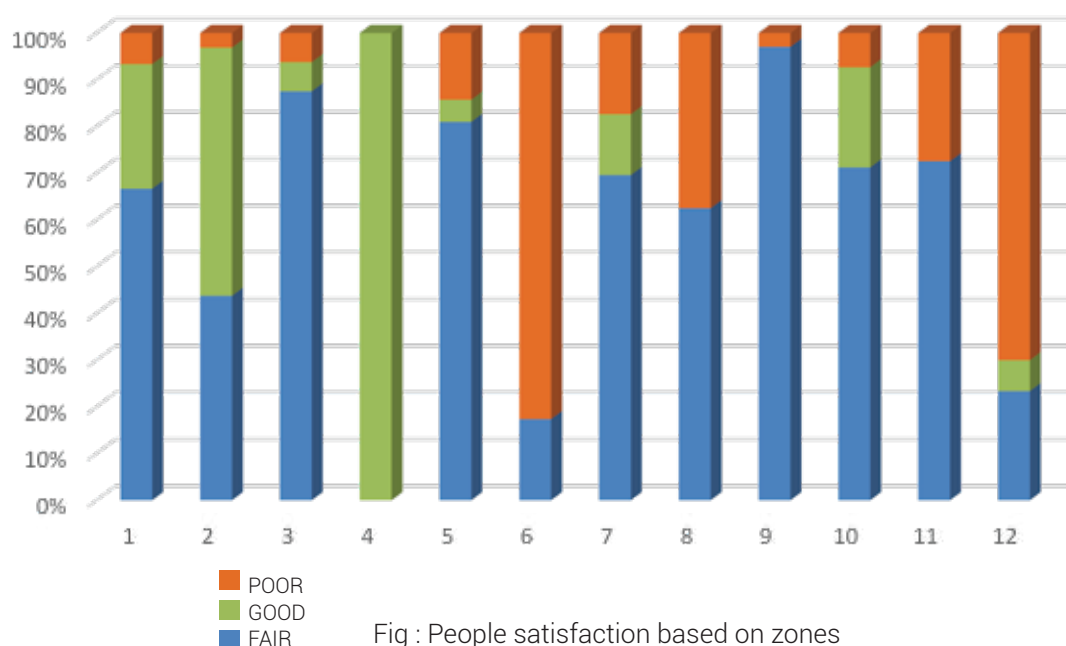


Fig : People satisfaction based on income groups

Clearly, access to water resources in Leh does not vary according to the socio-economic structure and the location of residential areas. A majority of the households rated the water supply as 'neutral' at best considering the geographical and climatic constraints, which leave a significant scope for improvement.



It is evident from the above analysis that respondents from Zone 2 and Zone 4 are satisfied with the present water supply system whereas respondents from Zone 6, Zone 8 and Zone 12 are facing comparatively more supply-related issues.

Revenue vs non-revenue water

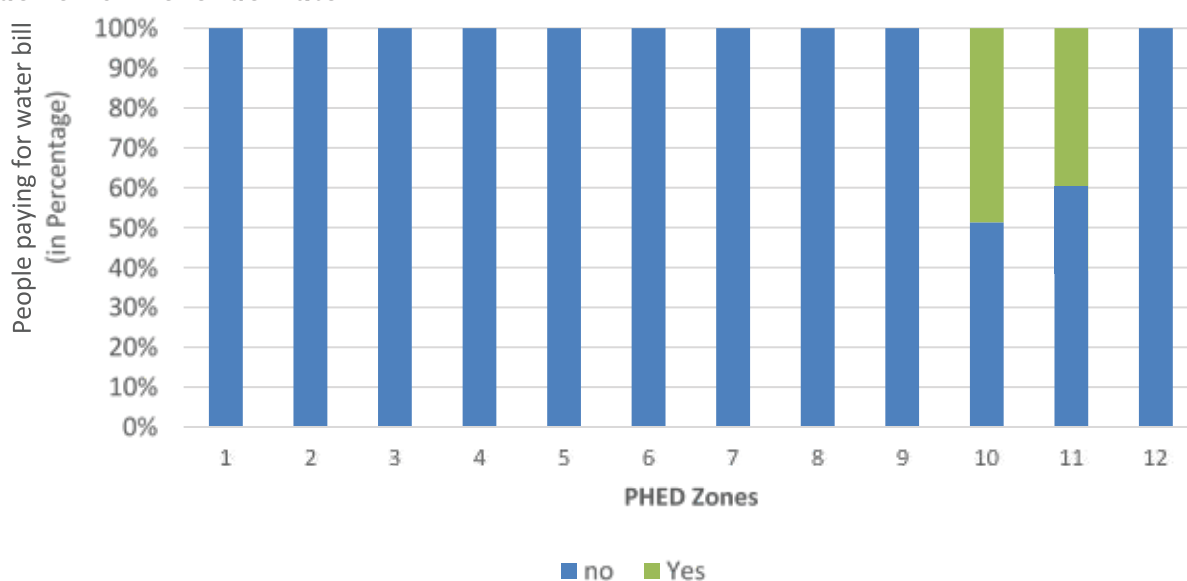


Figure : Zone wise distribution of people paying for water

Currently, PHED follows a system of charging a flat rate of INR 2,415 per annum for water. Only about 50% of the respondents from Zone 10 and 40% respondents from Zone 11 are paying their water bills since many people have received the connections but services have not started or water pressure is low affecting the quantity of water received.

A total revenue of INR 585,053 was generated in the financial year 2019-2020 for the PHE department. When asked about their 'willing to pay' for water all the respondents said they are willing to pay for water. However, considering the current erratic water supply and marked water fluctuation during the day, respondents said they were willing to pay for the water services if a metre system is installed. Also, There is also a claim that charging for water through a metre will reduce the misuse of water. In some zones misuse of water was a big problem for the PHED, which they have been attempting to control along with the Municipal Committee, Leh by carrying out timely inspections and penalising defaulters.

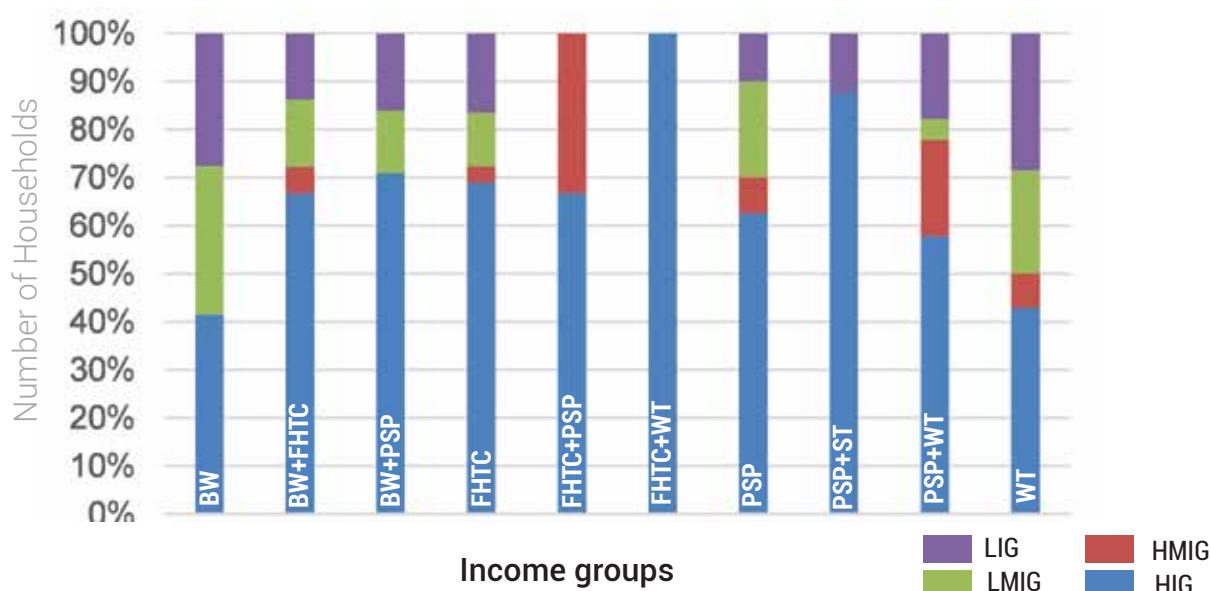


Fig : Sources of water used by different income groups

PSP- Public Stand Post; ST- Stream; WT- Water Tanker; FHTC- Functional household connection; BW- bore-well

The economic state of the households has a positive co-relation with the nature of water supply sources available to them. LIG and LMIG groups are primarily using community-based bore wells (BW) and water tankers (WT) individually or in combination with other sources. About 60% of the respondents using BW and WT sources belonged to LIG and LMIG categories. Sometimes more than 10 families pool their resources together to drill bore wells, which in Leh costs around INR 10,000 per feet and drinking water being available at a average depth of 120 feet below ground.

Many of the houses in Zone 1, Zone 4, Zone 8 and Zone 11 are located in the mountains above the supply pipeline. In some areas, the altitude difference could be up to 200 to 250 feet. To compensate for the water availability issues, many families in Leh town have installed bore wells, which could be private or community-owned. Government-issued community bore wells were also found in some areas, where water supply was disrupted by the 2010 flash floods. The source of water for each zone varied immensely depending on the position of the service provided in the area.

Though the sources of water varied from Public Stand Post (PSP) to functional household connections (FHTC) to bore wells (BW), people in some zones were still dependent on stream water (ST); especially the three upper wards and some have to depend on water tankers (WT). The residents of Leh can no longer rely on stream water or just one water source. Most respondents relied on multiple sources of water supply due to limitations of each source based on supply regularity and season. Zone 10 and Zone 11 were primarily dependent on FHTC as the new water distribution system is functional in these areas. Around 25% of Zone 11 residents also depend on PSPs and these are primarily residents of government quarters in the area.

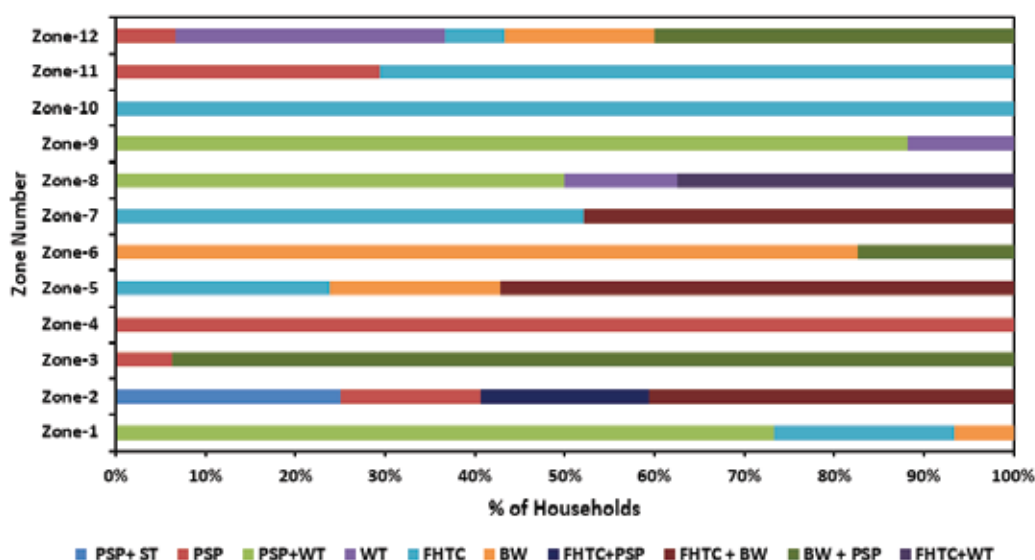


Fig : Zone wise Distribution of Type of water supply

The residents either fetch water from far-off taps or rely on tankers to supply water to meet their daily needs. Depending on their location, this may require them to travel long distances on foot or by vehicle. The tanker service is also rather infrequent, erratic and unreliable, and people have to store large amounts of water in their houses as an emergency measure. A staff member of PHED explained, "The tankers that the department owns are overworked as they cater to both the government and the public. There have been instances when people in power make excessive demands for water brought in by the tankers at the cost of unmet demands for water by the general public." During winters, it is also difficult for water tankers to function smoothly as the roads in some places are 45 degrees steep and become slippery due to snowfall thus making it difficult for movement of heavy vehicles. Residents of Zone 1 were primarily dependent on a combination of PSP+ WT as the old distribution system which was a significant source of potable water in the region was damaged in the 2010 floods. The damaged pipelines have not been repaired yet. Zone 8, which is located above Skampari, was primarily dependent on WT along with a few other sources. The area is located on a mountain slope, it is not possible to have FHTCs in these areas.

People's challenges

In our survey, we inquired about the exact nature of the issues faced by people. The difficulties faced by people can be divided into three parts: Supply, quantity and quality. While 52% of the respondents identify problems related to supply, 42% faced issues related to quality, 5% had issues with quantity, and 1% of the respondents said they had no complaints.

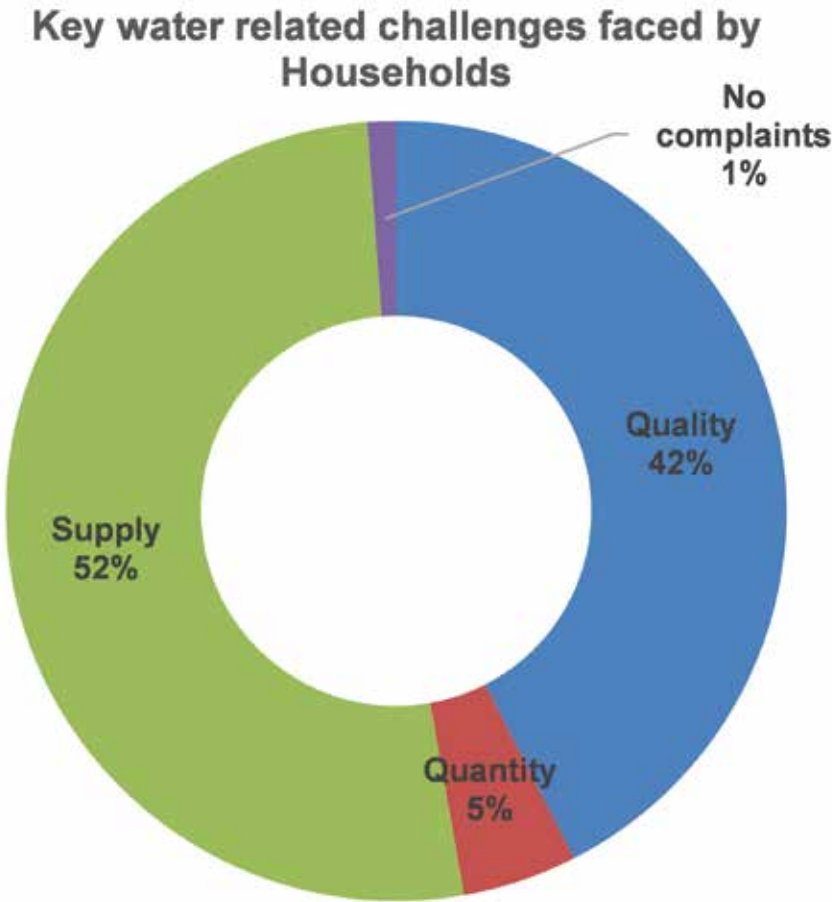


Fig : Nature of challenges faced

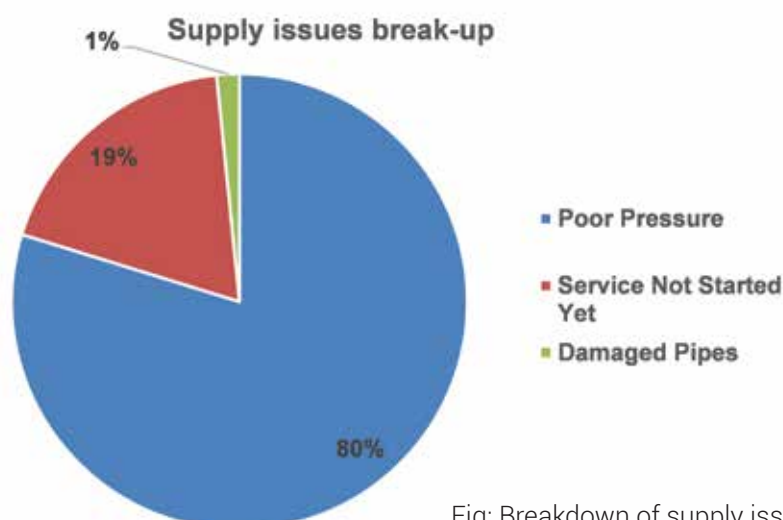


Fig: Breakdown of supply issues

- **Supply**– A total of 52% of the respondents faced issues related to supply. About 80% of them suffered from poor pressure, while 19% said the new water distribution system was not functional yet, and 1% complained about damaged pipelines. A majority of the respondents have FHTC connections and therefore key issues are related to 'poor pressure' and 'service not started'. These issues are primarily related to the new water distribution system. The altitude difference between the SR and households also played a role in reducing the pressure; where households with less difference in altitude from SR experienced poor pressure due to downward gravitational movement. By the time water reaches these households, the water level in the SR is relatively low and is not able to maintain pressure. Damaged pipelines were the result of lack of repair and maintenance, natural disasters like the flash floods of 2010 and collateral damage caused by laying of pipes for the new distribution system.

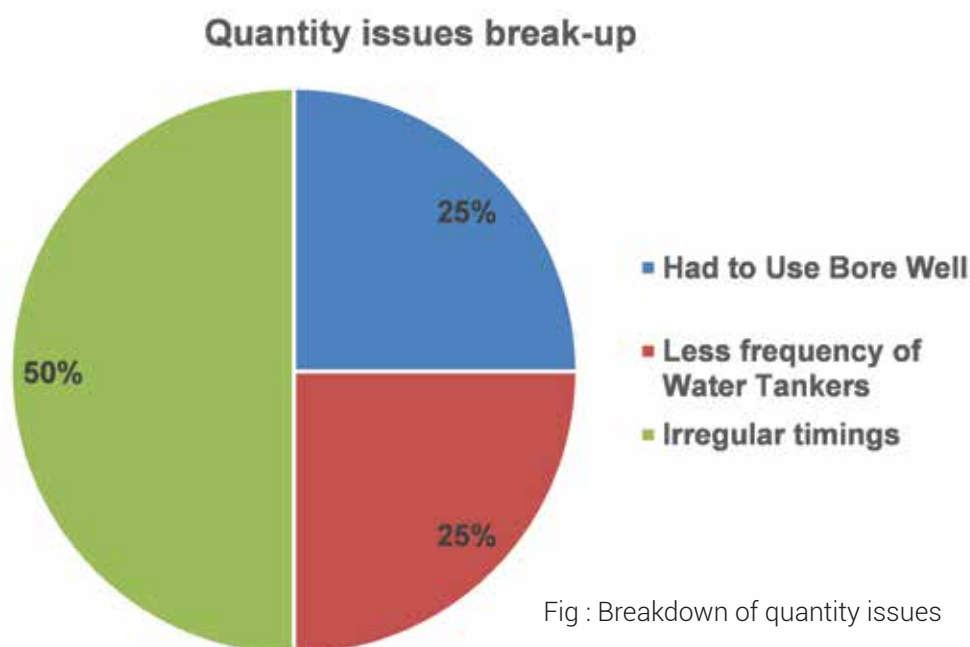


Fig : Breakdown of quantity issues

- **Quantity** - Around 50% of the respondents had issues with irregular water supply timings, 25% had issues with limited frequency of water tankers, and 25% had to use bore wells to meet their needs. In most of the areas, the frequency of WT is barely two to three times a week. People have resorted to using 500 litre water storage tankers to collect water from WT, which is not sufficient to meet their daily needs. In winters, water stored in these tanks freeze due to improper insulation and extreme cold. In many cases, Many people reported that they use their private cars to fetch water in 20-litre cans to satisfy their need for water.

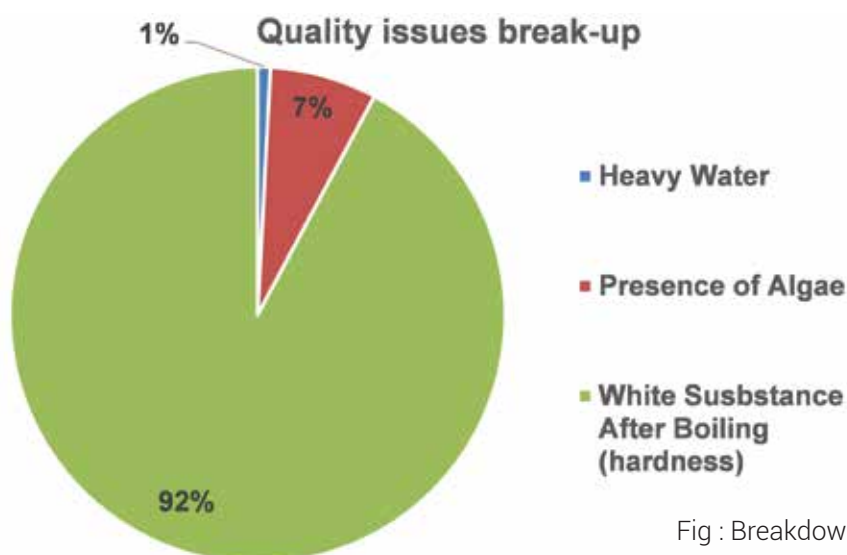


Fig : Breakdown of quality issues

➤ **Quality** of water was another issue identifying during this survey. Around 92% of the people reported the presence of whitish substance when they boil water, 7% reported algal presence and 1% reported heavy water. When asked about water quality, the overall response was positive, and surprisingly, there were no reservations about the quality of water among locals. The hardness due to groundwater salts is manifested as a white substance residue when the water is boiled. In areas where water was supplied through T Trench, which is an open reservoir, people faced the problem of algae since T Trench was infested with algae and has aquatic life-forms. No household reported any health issues due to water quality though they did complain about the changing taste of water. This is contrary to our water quality laboratory analysis and findings as well as the number of diarrhoea cases reported by the medical department. Clearly, most people are not able to correlate their stomach-related ailments with water quality or find it too insignificant to report.

Further patterns emerged when the data was analysed at the zonal level. Zone 3, Zone 4, Zone 6, Zone 7, Zone 9 and Zone 12 had supply-related issues. Zone 6, Zone 8 and Zone 12 primarily faced quantity-related issues. Zone 1, Zone 2, Zone 10 and Zone 11 had quality-related issues. This could help in designing a zone-wise strategy for issue resolution.

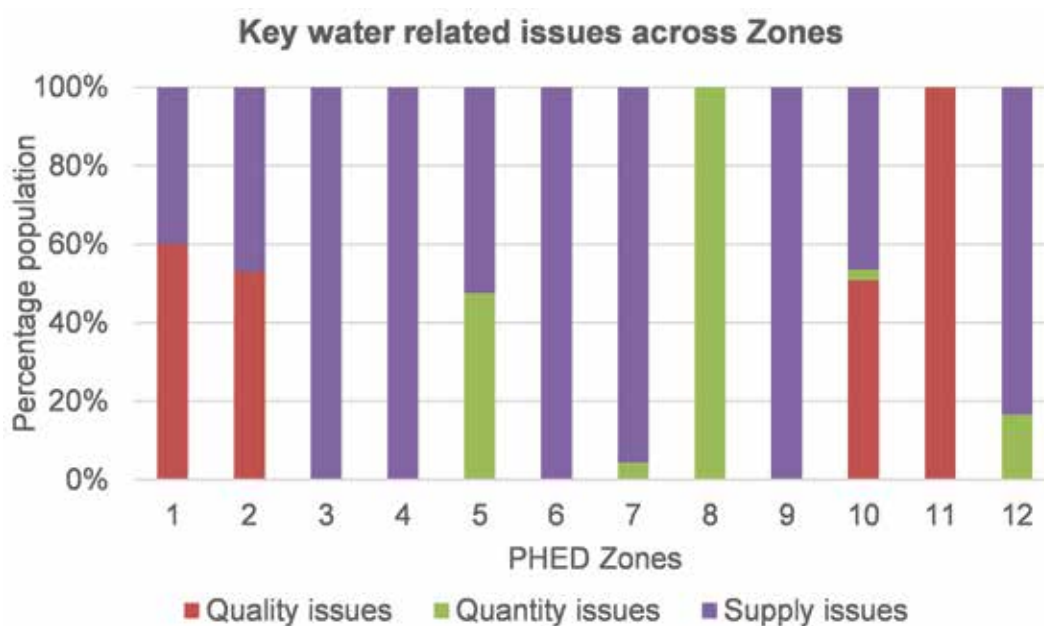


Fig : Water quality, quantity and supply constraints across PHED zones

The presence of the whitish substance after boiling was reported primarily from Zone 9 and Zone 10 where the water source is either functional household tap connection or both FHTC and PSP. Bacterial contamination of one of the main spring sources for drinking water, frequently used by commercial water carriers who deliver water to restaurants, shops, or offices with carts has also been reported (Muller et al 2020). This source was officially shut down in the summer of 2017 due to contamination. The presence of algae was reported from households where the water was supplied from T-Trench service reservoir in Khakshal. Although T-Trench is cleaned on a regular basis (as claimed by PHED), visual inspection of the open reservoir suggests otherwise.

Analysis of actual duration of supply across zones and type of water supply :

To further understand the supply issue, we enquired about the duration of water supply and categorized the same based on the number of hours. Detailed analysis is presented below.

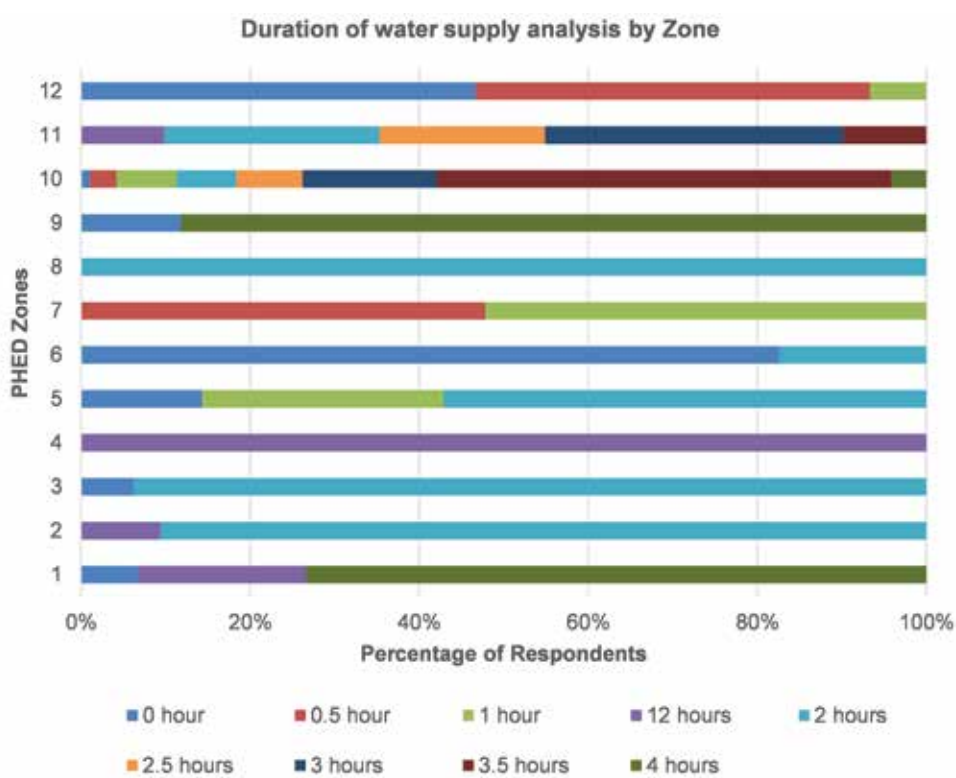


Fig : Water timings according to the zone derived from the household survey

The water distribution service timings were dependent on the size of the service reservoirs and the population of areas covered, which affected the operational timing. Though the service hours in each zone varied, water was mostly supplied in the morning between 6 to 11 am (summer timing) which amounted to three to four hours of water supply on an average. Many respondents in Zone 7 and Zone 12 have reported water supply for one hour only. Zero operation timing in the graph above indicates the areas where the new water distribution system has not started yet. The diverse timing range in Zone 7, Zone 10 and Zone 11 was due to low pressure problem, which hindered supply timings.

Zone wise analysis of Per Capita consumption:

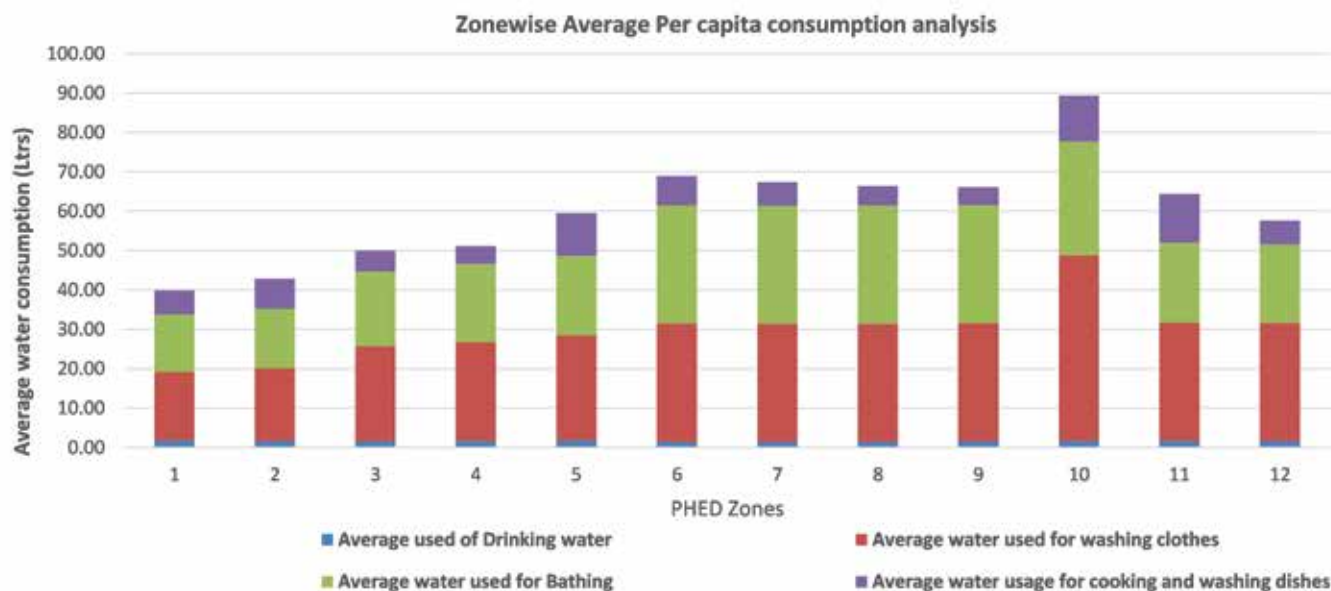


Fig : Average water consumption distributed by zones and type of consumption

Average water consumption per capita varies across zones and also co-relates with the nature of supply.

- Zone 10 receives piped water at the household level and has higher consumption.
- Zone 1 to Zone 4, which have less FHTC have lower consumption.
- Maximum water supplied was used for washing clothes and bathroom purposes, while a part of it was used for washing dishes and cooking.

Analysing zone-wise water consumption, revealed:

- Average LPCD used across all zones ranged between 41 to 80 litres.
- In Zone 10, water usage for more than 55% of the respondents ranged between 81 to 120 LPCD. Whereas for around 8% of the respondents in Zone 10, water use was calculated at more than 120 LPCD. This suggests that households with FHTC in Zone 10 are receiving surplus water.
- Zone 1 and Zone 2 had the lowest LPCD consumption as they are totally dependent on water tankers and PSPs. Residents in some parts of Zone 2 also use stream water.

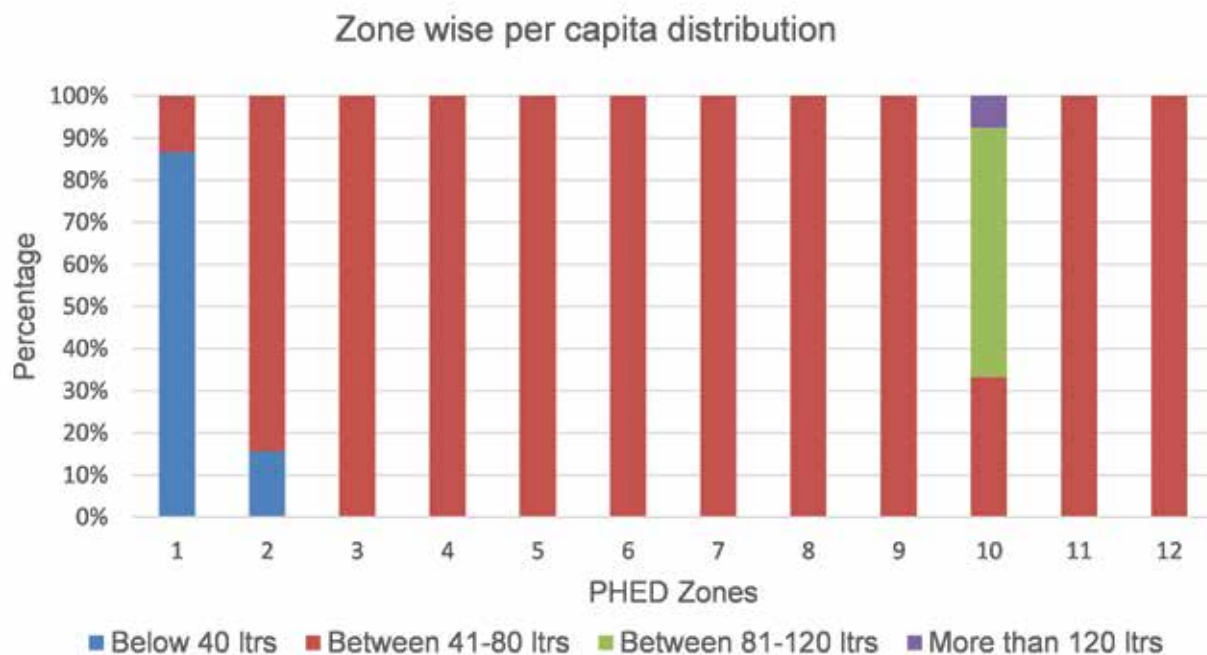


Fig : Zone-wise per capita water consumption categorisation

Note that the survey was done in the summer months. In winters, water consumption levels decrease significantly due to the cold and non-functioning of the supply network as pipes freeze over.

It was evident that with changing urban lifestyles and diminishing traditional habits, water consumption in the town is growing. Around 40% of the respondents admitted that they now use more water due to improved sense of personal hygiene, use of flush toilet systems, water for kitchen gardens, cars etc.

Another interesting fact is that most people were able to relate to the difference in water supply in the old and new water distribution system (OWDS and NWDS). Most households felt that water supply in the OWDS was better (timing and quantity) and that they regretted agreeing to the NWDS as now water was available for less time. This is contrary to the very objective of the New Water Distribution System, which was to connect 100% of households with FHTC and supply water of adequate quantity and acceptable quality.

Water shortages – reasons and distribution

Water shortages mapped with seasonality - people's feedback

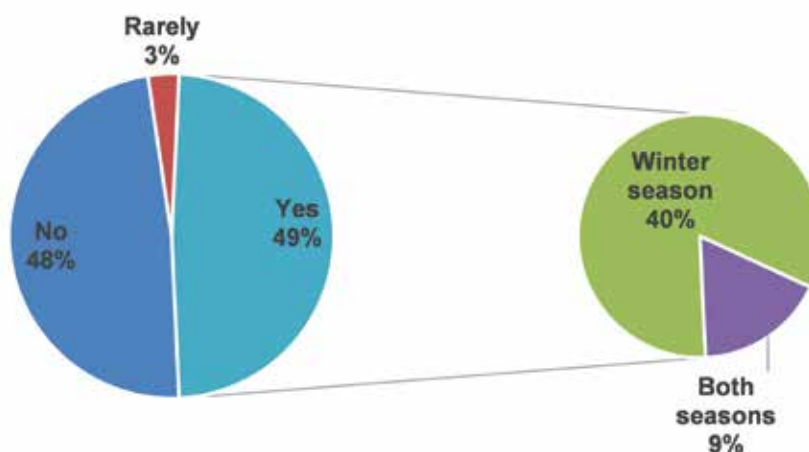


Fig : Water shortages reported along with seasonal distribution

A total of 49% of respondents have reported shortage of water as a major issue. Of this more than 80% reported that they are facing acute shortage of water in the winters. Analysis of the people facing shortages across the source of water gave expected results. People dependent on FHTC and water tankers are more severely impacted by water shortages or supply issues in winters as compared to private Bore well owners or households with functional PSPs nearby.

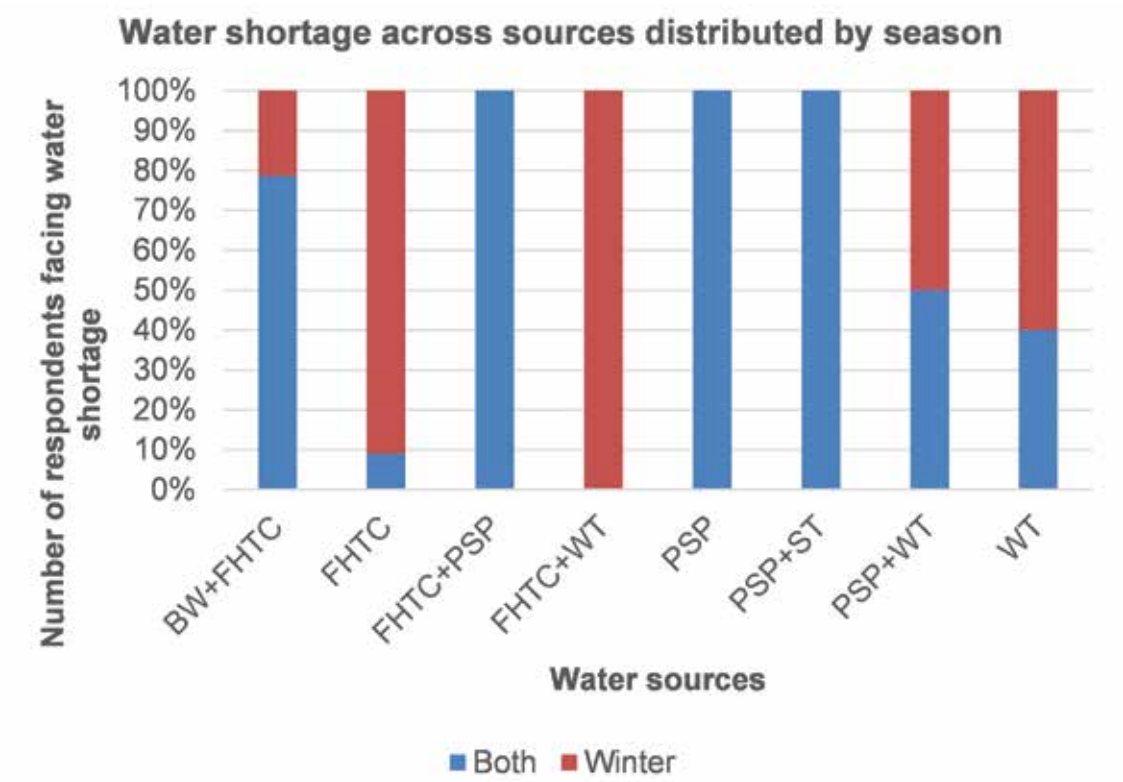


Fig : Seasonal water shortages distribution across water supply sources

Freezing of the pipe network in winters is a major issue. The department is hoping that the introduction of Ductile Iron (DI) pipes in the New Supply Distribution System will show some positive results compared to the old network's Galvanized Iron (GI) pipes. However without proper insulation of the entire network, it seems unlikely that the pipes will not freeze.

Human effort to access water

The distance covered and time taken to fetch water was analysed in areas where people were dependent on PSPs, PSPs + WT and PSP +ST.

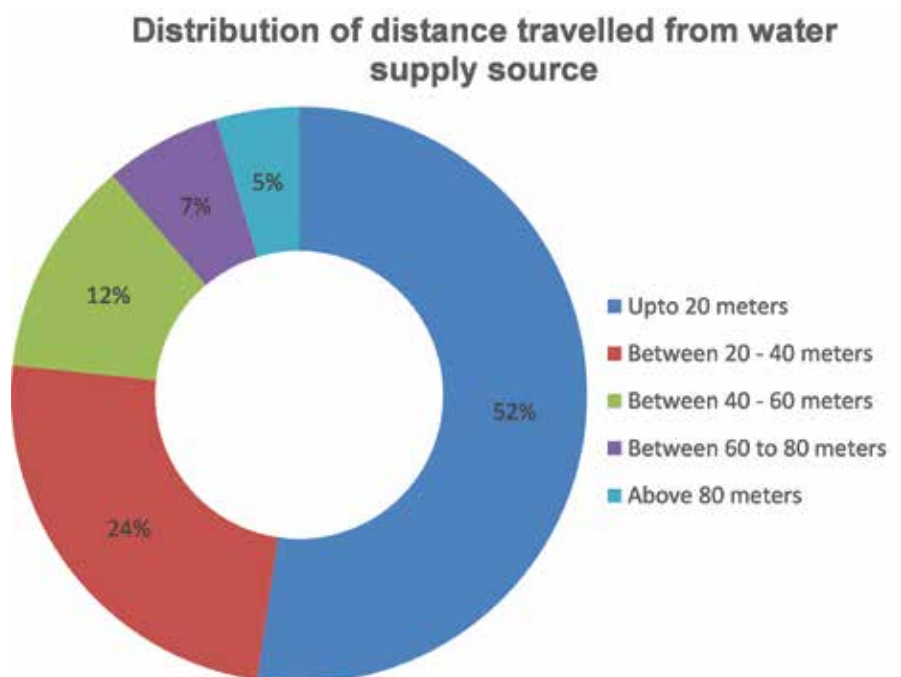


Fig : Analysis of distance travelled for water access

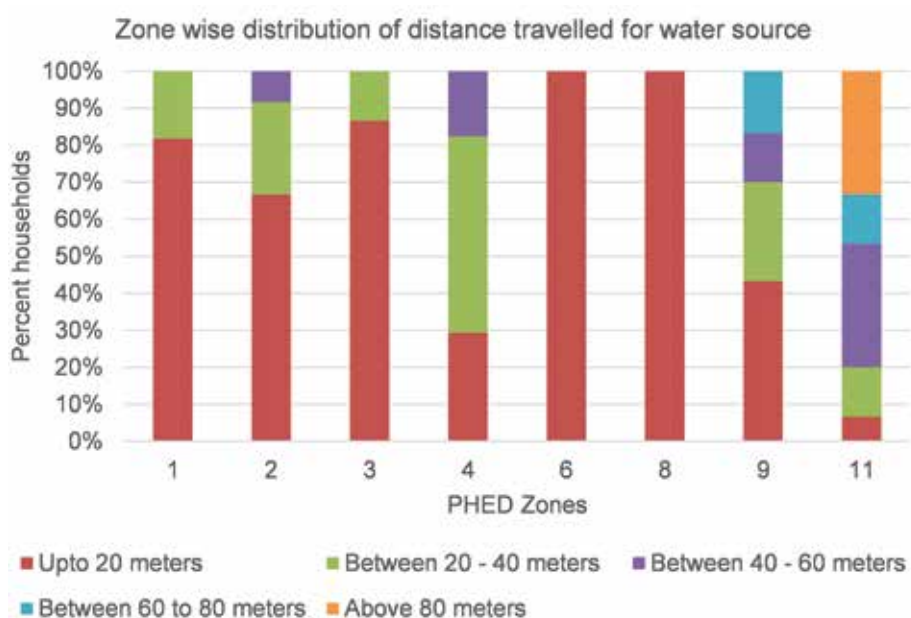


Fig : Distribution of distance travelled across PHED zones to access water

Socio-economic status of the people had a significant impact on the distance travelled to fetch water. LIG and LMIG groups had to walk the longest distances compared to other categories. This could also be a function of their physical location or zone.

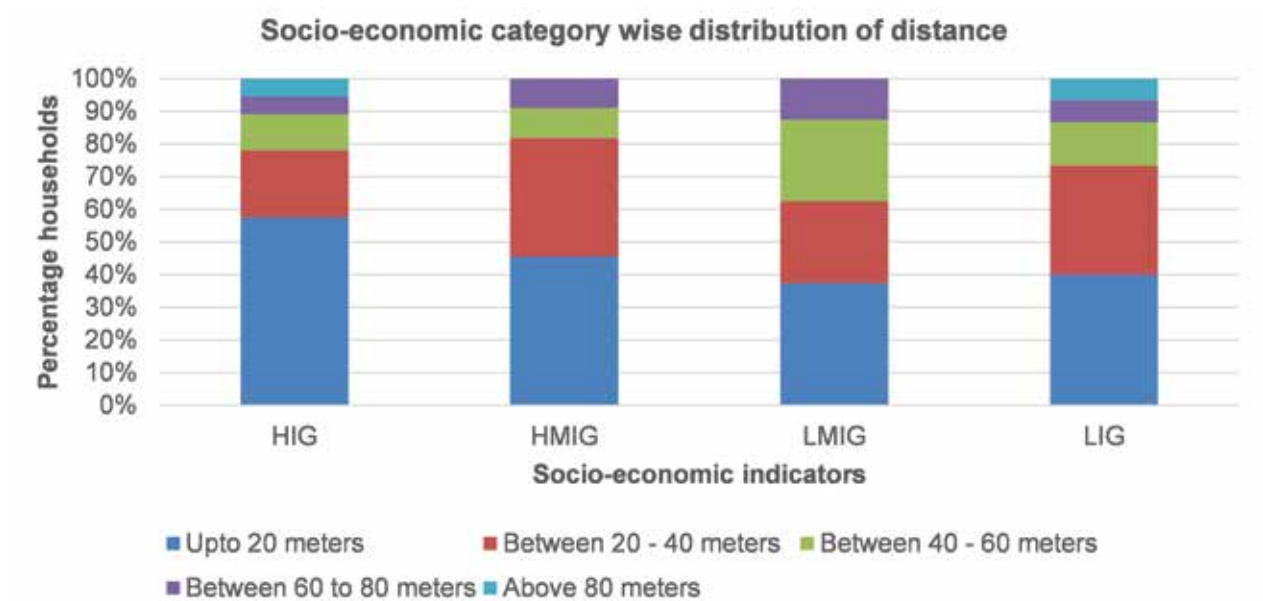


Fig : Distribution of distance travelled across income groups to access Water

From people's opinion surveys, it is evident that people are facing many water-related challenges including lack of connections, non-operating connections, poor or no pressure, irregular supply timings, difficulties of accessing water at higher elevations, inconsistent timing and low frequency of water tankers etc. PHED is aware of many of these challenges. People are dependent on PHED to solve water issues and are willing to pay based on their actual consumption. People are also expecting PHED to solve their acute water supply shortage issues and huge difficulties to access water, especially during winter months.

ANNEXURES

Table : Sample location details of 37 samples analysed by testing kit

S.No.	Sample location	GPS	Sample source	Source	Location zone	Altitude (M)
1	Choglamsar ⁷	N 34° 06.405 E077° 35.129	Tube Well	Choglamsar TW	Just outside Leh	3,229
2	Horzey	N 34° 12.115 E077° 36.209	PSP	Gyalung Spring	1	3,840
3	PHE BW ³	N 34° 12.228 E077° 36.517	Bore well	Ground Water	1	3,883
4	Gangles TW	N34°12.148 E077°36.619	Bore well	Bore Well	1	3,906
5	Sankar ⁶	N 34° 10.458 E077° 35.255	Tube Well	Sankar TW	2	3,613
6	Sangto	N 34° 09.790 E077° 34.389	Hoppipolar Restaurant	Tukcha TW	2	3,481
7	Chhutey Rantak	N 34° 09.955 E077° 35.109	PSP	JumaBagh TW	3	3,585
8	LEDeG office	N34°10.079 E077°35.050	Hand pump	Hand pump	3	3,535
9	LG Residence	N34°10.071 E077°34.986	Bore well	Bore Well	3	3,535
10	Shanti Stupa		Water Tanker	Water Tanker	3	
11	Moravian Mission School	N 34° 10.013 E 077° 34.819	Bore well	Bore Well	3	3,538
12	T Trench	N 34° 11.417 E077° 35.627	Reservoir (6 feet from bank)	T Trench SR ⁴	4	3,717
13	Gompa IHC ⁵	N 34° 11.350 E077° 35.370	IN House water Connection	NezerGompa TW	4	3,748
14	Lamdon School	N 34° 10.452 E077° 35.432	PSP	Lamdon TW	5	3,721
15	Chubi Village	N 34° 10.420 E077° 35.452	PSP	Lamdon TW	5	3,261
16	CMO Office	N34°10.022 E077°35.075	PSP	Lamdon TW	5	3,531
17	PSP near Coffee Culture	N34°09.906 E077°35.061	PSP	JumaBagh TW	5+6	3,516
18	Skara CH ¹	N 34° 09.320 E077° 34.312	PSP	Skara TW	6	3,430
19	Old Town	N 34° 09.886 E077° 35.123	Brazil Café, (Popular cafeteria)	Gyalung Spring	6	3,518
20	Moravian Church Leh	N34°09.962 E077°35.043	IHCO	JumaBagh TW	6	3,531
21	Leh Mosque	N34°09.982 E077°35.140	Tap	Bore Well	6	3,522
22	Tourism office	N34° 09.036 E 077°34.511	Bore well	Bore Well	6	3,415

23	Gompa Soma	N 34°09.858 E077°35.102	PSP	Skampari	6	3,713
24	Tukcha	N 34° 10.233 E077° 34.408	IN House water Connection	Tukcha TW	7	3,520
25	Ibex Colony	N 34° 08.379 E077° 34.078	IN House water Connection	Indus Lift	10	3,331
26	Near Degree College	N 34° 08.836 E077° 34.750	PSP	Murtsey TW	10	3,401
27	Ibex Hand Pump	N34° 08.128 E077°34.151	Hand pump	Hand Pump	10	3,318
28	EJM Degree College	N 34° 08.787 E 077° 34.819	PSP	Mini Sectrate SR Indus Lift	10	3,400
29	Housing Colony ²	N 34° 08.886 E077° 34.900	PSP	Indus Lift	11	3,407
30	Maney Tselding	N 34° 09.374 E077° 35.057	PSP	Indus Lift	11	3,480
31	Com/Sec Residence	N34°08.859 E077°34.827	Water Tanker	Water Tanker	11	3,407
32	Grand Dragon	N34°09.427 E077°34.799	Bore well	Bore Well	11	3,471
33	Lion's Club	N 34° 09.067 E 077 ° 34.895	PSP	Balashram SR, Indus Lift	11	3,434
34	SNM Hospital	N34° 09.271 E 077°34.859	Bore well	Bore Well	11	3,451
35	Industrial Area	N 34° 08.914 E077° 33.338	PSP	Tukcha TW	12	3,351
36	Skara Yogma	N 34° 08.809 E077° 33.533	PSP	BadamiBagh	12	3,355
37	Skalzangling	N 34° 08.820 E077° 34.194	PSP	Skalzalang ling TW	12	3,391

1- Community Hall; 2- Govt Staff Quarters; 3- Boring Well; 4- Service Reservoir; 5- In House Connection; 6- Only used for Water Tankers; 7- Only Used for Water Tankers

Name of location	Type	Temperature (Degree Celsius)*	Zone	Elevation
T Trench	Open Reservoir	18.2	2	3,763 mts
Khakshal	Service Reservoir	12	3	3,661 mts
Nezer Gompa	Service Reservoir	12.8	4	3,760 mts
Lamdon	Service Reservoir	14.5	5	3,425 mts.
Juma Bagh	Service Reservoir	12.1	6(1)	3,542 mts
Changspa	Service Reservoir	13.1	7	3,541 mts
Skampari	Service Reservoir	17.2	9	3,560 mts
Mini Secretariat	Service Reservoir	14.6	10	3,425 mts
Badami Bagh	Service Reservoir	14	12	3,397 mts.

Table : Location details of water samples from nine service reservoirs

Table : Water testing analysis results by field water testing kit

	Location	Appearance	Odor	Turbidity	pH	Alkalinity (mg/L)	Hardness (mg/L)	Chloride (mg/L)	TDS (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Ammonia (mg/L)	Nitrite* (mg/L)	Nitrate (mg/L)	Phosphate** (mg/L)	Chlorine (mg/L)	H ₂ S
S . N o	Standard BIS IS 10500	Colorless	No ne	No Turbidity	6.5	600 mg/L	600 mg/L	1000 mg/L	2000 mg/L	1.5 mg/L	1.0 mg/L	0.5 mg/L	-	40 mg/L	-	0.2 mg/L	F D
1	Horzey	Colorless	No ne	No Turbidity	6.7	70	100	40	338	0.1	0	0	0.0	0.0	0	0	F D
2	PHE BW ³	Colorless	No ne	No Turbidity	6.8	80	110	40	218	0.1	0	0	0.0	15	0	0	F D
3	Gangles TW	Muddy	Soil Smell	Modestly Turbidity	6.7	60	140	40	204	0.5	0	0	0.0	14	0	0	F D
4	Sankar ⁶	Colorless	No ne	No Turbidity	7.5	70	120	50	256	0.1	0	0	0.0	17	0	0	F D
5	Sangto	Colorless	No ne	No Turbidity	8	340	320	70	396	0.2	0	0	0.1	12	0	0	N F D
6	Chutey Rantak	Colorless	No ne	No Turbidity	7.5	150	120	20	250	0.1	0	0	0.1	12	0	0	N F D
7	T-Trench	Slightly Greenish	Algal Smell	Slightly Turbidity	7.2	190	130	30	238	0.2	0	0	0.1	45	0	0	N F D
8	Gompa IHC ⁵	Colorless	No ne	No Turbidity	7.8	200	210	40	356	0.1	0	0	0.0	15	0	0	F D
9	Lamdon School	Colorless	No ne	No Turbidity	7.5	150	140	30	248	0.1	0	0	0.2	15	0	0	N F D
10	Chubi Village	Colorless	No ne	No Turbidity	7.5	160	120	30	256	0.1	0	0	0.1	12			N F D
11	Skara CH ¹	Colorless	No ne	No Turbidity	7.9	100	160	30	416	0.1	0	0	0.0	10	0	0	F D
12	Old Town	Colorless	No ne	No Turbidity	8.5	110	110	40	296	0.3	0	0	0.2	10	0	0	F D

13	Housing Colony ²	Colorless	None	No Turbidity	7.7	220	310	40	496	2.0	0	0	0.1	30	0	0	NFD
14	Tukcha	Colorless	None	No Turbidity	8	320	310	60	452	0.5	0	0	0.1	15	0	0	NFD
15	Ibex Hand Pump	Colorless	None	No Turbidity	6.3	220	370	50	625	0.5	0	0	0.0	25	0	0	FD
16	Industrial Area	Colorless	None	No Turbidity	7.9	110	310	70	462	0.3	0	0	0.2	12	0	0	NFD
17	Skara Yogma	Colorless	None	No Turbidity	7.8	150	230	30	396	0.2	0	0	0.0	20	0	0	FD
18	Near Degree College	Colorless	None	No Turbidity	7.5	260	320	50	440	3.0	0	0	0.1	12	0	0	NFD
19	Skalzung Ling	Colorless	None	No Turbidity	7.0	160	230	50	450	0.2	0	0	0.0	10	0	0	FD
20	Choglamsar ⁷	Colorless	None	No Turbidity	8.5	110	180	60	266	0.1	0	0	0.2	10	0	0	FD
21	Ibex Colony	Colorless	None	No Turbidity	8.2	300	350	60	550	2.0	0	0	0.1	10	0	0	NFD
22	Maney Tseding PSP	Colorless	None	No Turbidity	8.5	120	120	60	248	0.1	0	0	0.2	10	0	0	FD
23	Gompa Soma	Colorless	None	No Turbidity	7.6	160	120	30	217	0.1	0	0	0.1	13	0	0	NFD
24	EJ Memorial College	Colorless	None	No Turbidity	8.5	270	320	60	490	0.1	0	0	0.1	10	0	0	NFD
25	Com/Sec Residence	Colorless	None	No Turbidity	8.1	230	300	50	562	3.0	0	0	0.1	10	0	0	NFD
26	Grand Dragon	Colorless	None	No Turbidity	6.7	200	250	40	486	0.0	0	0	0.0	10	0	0	FD
27	Lions Club				8.5	230	380	60	541	2.0	0	0	0.1	10	0	0	NFD
28	SNM Hospital	Colorless	None	No Turbidity	7.5	240	350	30	670	0.5	0	0	0.0	14	0	0	FD
29	PSP near Coffee Culture	Colorless	None	No Turbidity	7.2	230	210	50	405	0.5	0	0	0.2	8.0	0	0	FD
30	LEDeG office	Colorless	None	No Turbidity	6.1	90	160	20	252	0.5	0	0	0.1	40	0	0	NFD
31	LG Residence	Colorless	None	Slightly Turbid	7.3	80	140	30	223	0	0	0	0.0	20	0	0	FD
32	Shanti Stupa	Colorless	None	No Turbidity	6.7	70	120	40	226	0	0	0	0.0	20	0	0	FD
33	Moravian Mission School	Colorless	None	No Turbidity	6.7	150	210	40	400	0.5	0	0	0.0	20	0	0	FD
34	CMO Office	Colorless	None	No Turbidity	7.3	210	210	40	364	0.1	0	0	0.0	10	0	0	FD

35	Moravian Church Leh	Colorless	None	No Turbidity	7.6	220	250	50	375	0.2	0	0	0.0	15	0	0	FD
36	Leh Mosque	Colorless	None	No Turbidity	7.3	220	470	60	701	0.1	0	0	0.0	20	0	0	FD
37	Tourism office	Colorless	None	No Turbidity	7.5	130	190	20	358	0.5	0	0.0	0.0	20	0	0	FD

1-Community Hall; 2- Govt Staff Quarters; 3- Boring Well; 4- Service Reservoir; 5- Functional Household Tap Connection; 6- Only used for Water Tankers; 7- Only Used for Water Tankers

*FD- Fit For Drinking, NFD- Not Fit For Drinking. * No Guideline value prescribed, however if Nitrite and Phosphate (any or More) are present at more than 1.0mg/L, it indicates pollution (mainly due to domestic liquid wastes and leachates from solid wastes).** To ensure effective disinfection, minimum residual chlorine of 0.2 mg/L should be present.*

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