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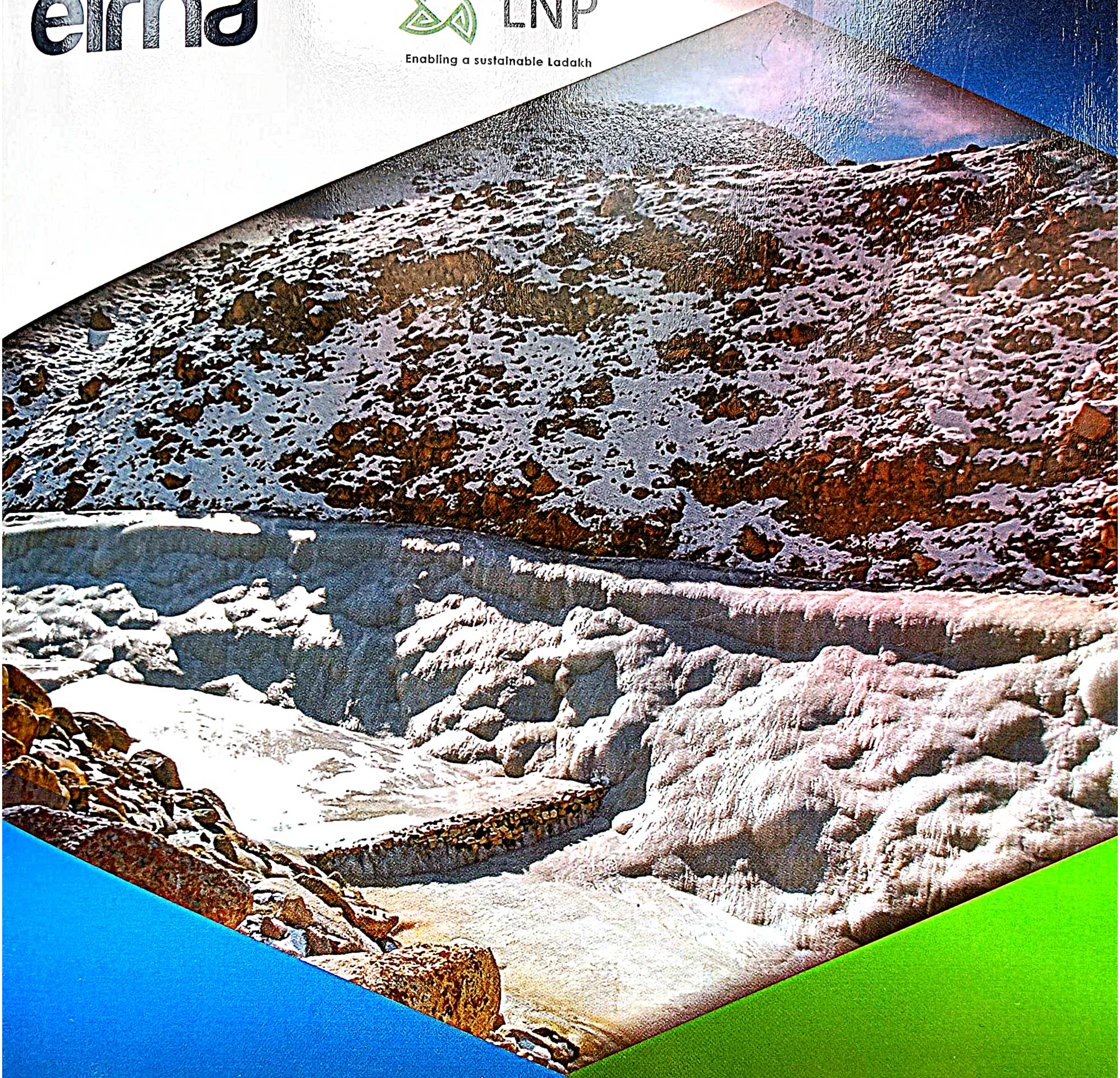

Artificial Glaciers

Past, Present and Future: a Report (December, 2022)

Leh Nutrition Project (LNP), Leh

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Executive Summary

Research findings reveal that the high mountains of Asia (Hindukush Himalayan ranges) are the worst hit by global warming. One manifestation of the climate change impact on regions like Ladakh is a gradual receding of its natural glaciers in past few decades, leading to excess flow of water during summer and its scarcity during the sowing season (April/May). This problem is more apparent in villages facing south (in the Indus belt, in particular) and those without proper glaciers, i.e., depending on springs and snow packs only. This trend has been threatening livelihoods and even inducing outmigration in some villages.

Traditionally, villages in Ladakh consider water sources as sacred and, therefore, keep them free from pollution and desecration, as far as possible. There are intricate systems of water reservoirs and irrigation channels along with effective systems of water management and distribution in every village/ hamlet. There are instances of 'Ice reservoirs' having been built in some villages during earlier times. However, the decline in water availability during April and May has been posing challenges to timely sowing of crops in increasing number of villages.

In late 1980s, Mr. Chhewang Norphel (Engineer) and his team at Rural Development Department (RDD) came up with the idea of 'Artificial Glaciers' (AGs) whereby cascade type walls were built at the higher reaches in Nang and Shara. These walls slowed down and checked water flow on the perineal streams in order to allow ice formation during winter (November/December) which melted in the spring season, thus enabling availability of additional water for irrigation at the sowing time. From 1990s, this concept was taken forward by several NGOs in more villages facing water scarcity. Currently, LNP, LEHO, LEDeG, HIAL and Himothan are active in the field. Apart from WDP of GOI, various agencies including Tata Trusts, DST, NABARD, Operation Sadbhavna, Minsitry of Tribal, RBS, HDFC, ICICI Foundation, GB Pant Institute and Elrha supported the concept, while some innovations were also made.

Currently, there exist five types of AGs – basin type, cascade type, diversion type, 'Ice Stupa' and 'Ice Mountains' or 'Ice Fall'. While there is a lack of systematic and scientific data collection and analysis on the effectiveness of AGs, there are enough anecdotal evidences and some data on ice accumulation on AGs leading to timely availability of water for critical first watering of fields. HIAL, LEHO and LEDeG have been gathering data on volume of ice formed on their AGs. LNP, in its current work at Mudh and Tsaga, is collecting information on water flow as well as ice accumulation of ice at its AGs.

Unfortunately, this low tech engineering solution and climate adaptation strategy is yet to catch the attention in the mainstream development discourse of the region.

In this context, five recommendations are made:
a) A policy framework is put in place with appropriate institutional arrangements, a realistic road map, and adequate resources allocation,

b) each village is given space for having its own combination of responses to the issue,

c) the central role of village community in planning and implementation is recognized,

d) scientific data collection, analysis and sharing is not lost sight of, and

e) due consideration is given to local sensitivities in planning and implementation of AGs.

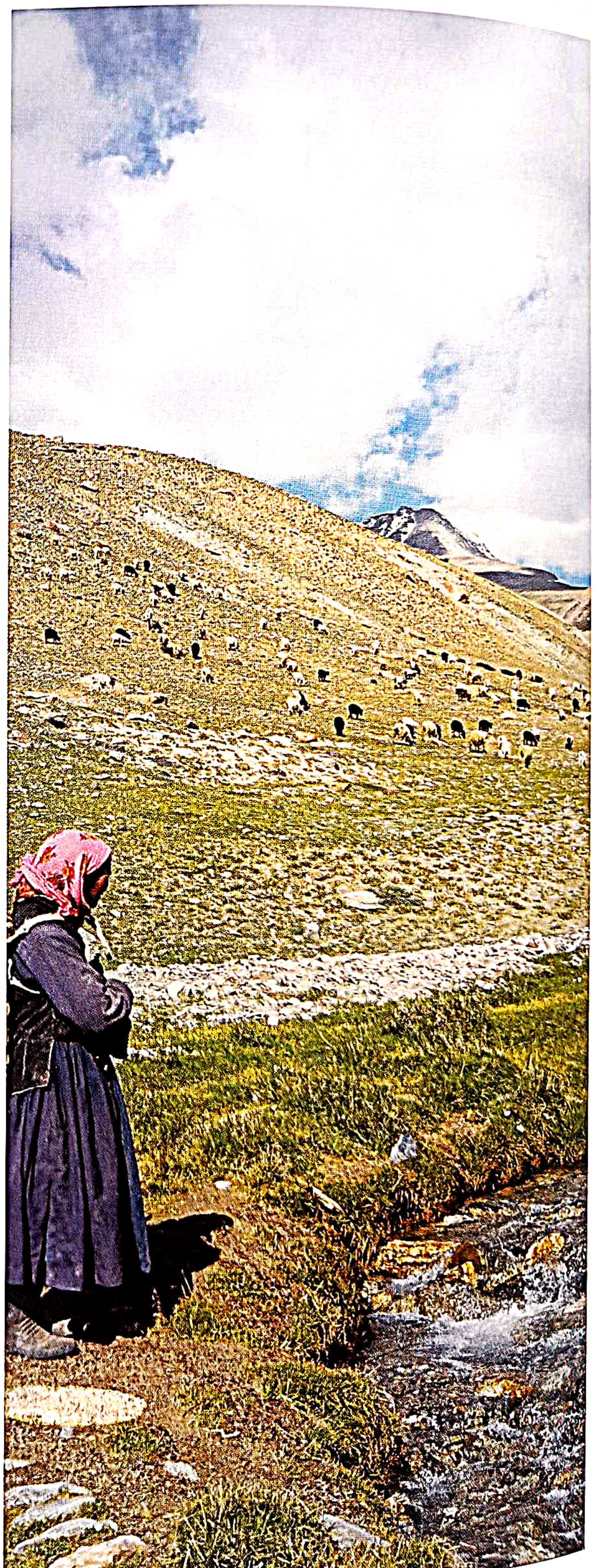
1 Introduction

This paper summarises a detailed report prepared by LNP on its ongoing project entitled 'Conservation of water in Ladakh through artificial glaciers' (COWLAG), with funding from Elrha (UK), which aims at documenting the existing knowledge and experiences from the field (i.e., Leh District) and helping in replication, adaptation and up-scaling of the concept including policy formulation on future role of ice formation through AGs as a water conservation strategy in the region. It includes some additional information generated from discussions within the team during a review of the detailed report. The project includes construction of AGs of appropriate types in Tsaga and Mudh villages of Changthang as a collaborative effort between LNP and village communities concerned while pursuing the best practices and know-how available on the subject. This one-year project was funded by ELRHA (UK) and undertaken at LNP by a team consisting of Tsering Tundup (project coordinator) and Padma Rigzin (researcher) under the supervision of Chhotak Gyatso (executive director). Mr. Chhewang Norphel provided overall guidance to the project. The project covered the period between April and November 2022, with provision for a follow-up in April/May 2023 (when a final draft of this report including a brief on the immediate impact of work done at Tsaga and Mudh is expected). As such this report may be considered as a live document in which outcomes of follow-up on sharing with stakeholders will be included.

2 Water situation in Ladakh

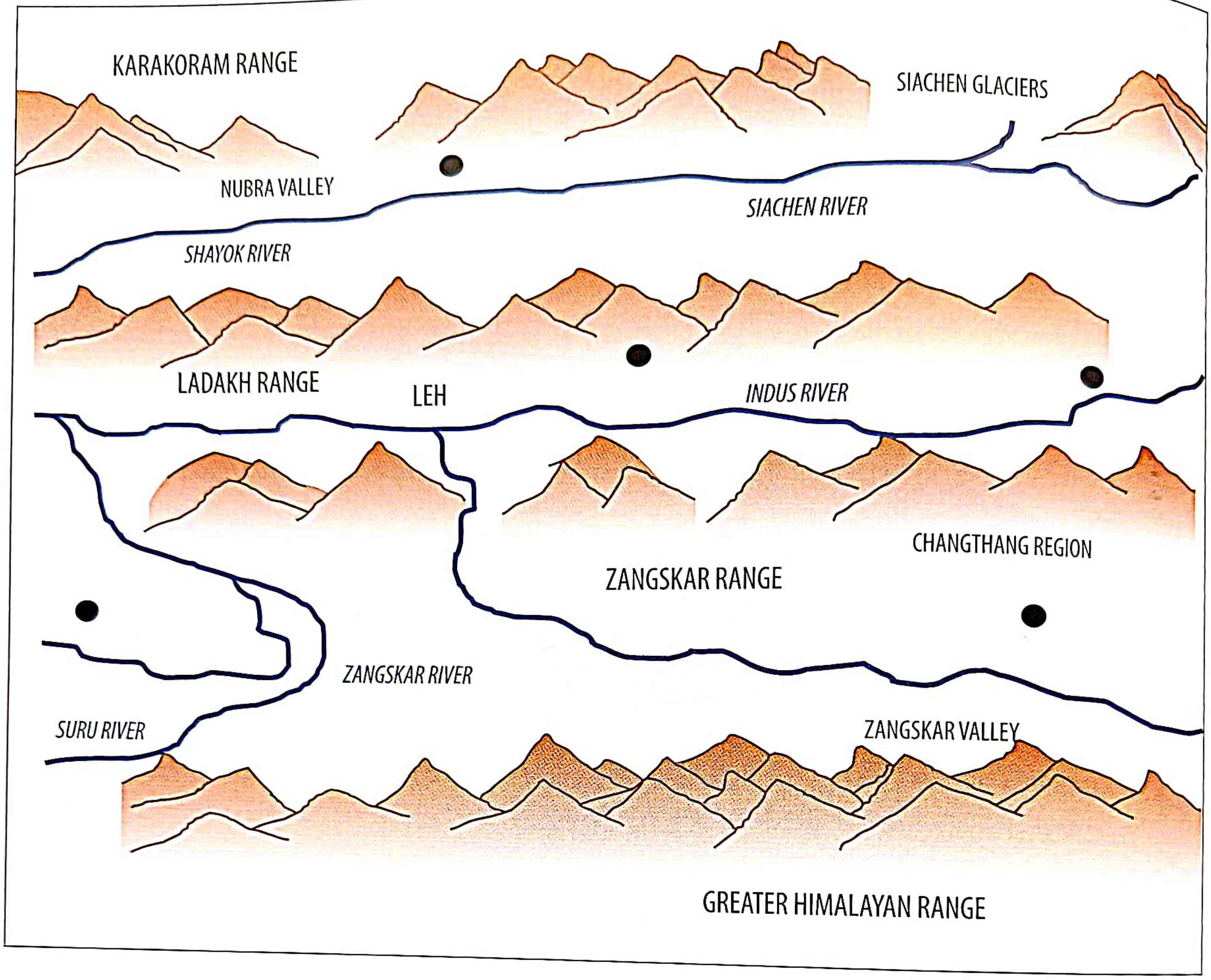
Situated at the extreme southern end of the Tibetan plateau, Ladakh is a cold, arid and water stressed region of the Indian Trans-Himalayas. The annual precipitation is below 100 mm, 70% of which occurs in the form of snowfall between November and March. In Leh district, around 6 % of a total of around 215 villages/hamlets use river water (Indus, Shayok and Siachan) whereas the remaining 94% depends on own glaciers (and/or snow packs/springs) for drinking and irrigation purposes. A similar situation exists in Kargil District as well. Whereas villages along rivers have canals (Mayur) stretching into the land as far as gravity permits (with some examples of water lifting through use of technology). Villages at higher reaches have an intricate system of irrigation channels fed through water reservoirs, with traditional practice of water distribution (called 'chhurpon'/'Chhures') and watering cycles in place, with range of criteria depending upon local conditions (though in cases like Leh town the system is disappearing with increased dependence on piped and ground water).

Ladakhis believe that water sources are abodes of spirits (Lha and Lhu) and their desecration brings bad luck. Rituals like 'Jive Sangchot' and 'Pungpa Chukches' involving puja and cleaning are regularly performed. As a part of this belief, human activities (e.g., road construction, tourism, etc.) in and around water sources are avoided, as far as possible, and this aspect needs to be considered while planning water conservation measures. Villages/ hamlets in Ladakh have been experiencing, on the one hand, acceleration in quantum of water flow during summer months (July to September) and, on the other hand, less and less of it available during the sowing season (April/May). In view of the short agricultural season, this increasing delay of melt water in reaching the fields during spring time is attributable largely to the fact that glaciers are melting faster during summer, thus shrinking towards higher reaches and unable to melt during spring.



3 The larger picture - Climate change and its impact

In climate sciences, there is an 'increasing focus on high mountains of Asia due to their fragility as well as significance. This includes the Tibetan plateau and the Hindukush Himalayan mountains popularly known as the 'third pole'. This is because its ice cover carries the biggest fresh water stock beyond the two polar regions. The ten major river systems including Yangtse, Indus and Ganges originate here, providing power, drinking and irrigation water to close to 2 billion people – over 24% of the world population'. According to ICIMOD, Hindukush Himalaya Assessment (2019), the 'Third Pole' will have a higher rate of increase in temperature'. 'If the global average temperature increases by 1.5 degree C, the 'Third Pole' will experience a rise of 2 degrees C' (Wester et al, 2019). Harvey (2022) observes that 'the phenomenon of climate change, with its rising temperature, is fastening the melting of glaciers'. There is an acknowledgement that the earth is becoming increasingly inhabitable for humans. Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (AR6) states that 'human activities are solely responsible for inducing global warming and the world will observe a shortage of food and water'. 'Satellite and in-situ observations of changes in glacier areas, length and mass show a globally largely coherent picture of mountain glacier recession in last decades, although annual variability and regional differences are large' (IPCC Special Report on Ocean and Crysophere in a changing climate, 2019). The report predicts that 2/3rd of the region's glaciers will disappear by 2100' (Hock et al 2019). 'Rapid changes in mountain glaciers have multiple impacts on socio-ecological systems, affecting not only bio-physical properties such as run off volume and sediment fluxes in glacial fed rivers, glacier related hazards and global sea level but also eco-systems of human livelihoods, socio-economic activities and sectors like agriculture and tourism as well as other intrinsic assets such as cultural values' (Hock et al, 2019). Vince (2019) notes that many scientific studies assert that the 'Third Pole' will be the first to witness outmigration due to water scarcity and water related issues (Dollfur, 2013).



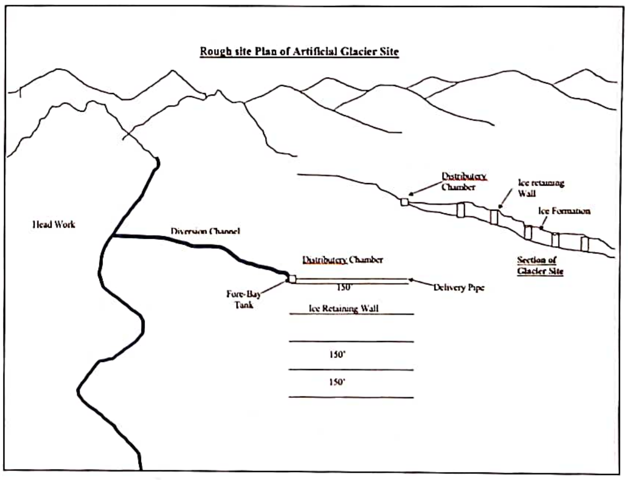
The local experience shows that phenomena like reduced and erratic snowfall and retreating glaciers, have been increasing the vulnerability of more and more villages in terms of availability of water during crucial sowing season. In past few decades, this issue has become more critical for villages (and their glaciers) facing south, particularly in the Indus belt, as they have been experiencing a faster rate of increase in distances between the land and the water source. Evidence seems to suggest that this trend will continue and intensify in times to come, threatening livelihoods and triggering out-migration (already happening in villages with springs as their only source). Also, villages using river water have to keep shifting headwork of their canals in upstream direction to ensure adequacy of water available during spring time while having to deal with damages to the same headworks during summer due to rising water levels. The climate change pattern is negatively impacting highland pastures as well. 'Drying up of traditional routes of livestock rearing leads to dents in economic security. Many people have migrated to urban centres where they work as unskilled labour or any low.

4 Artificial Glaciers (AGs) – the concept

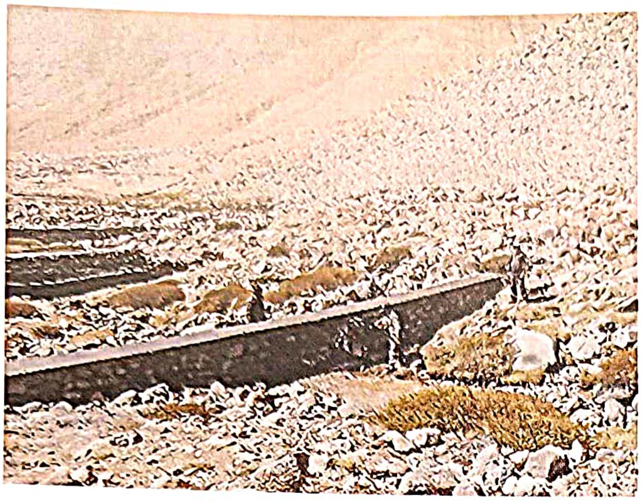
In 1987, a team (led by engineer Chhewang Norphel) of RDD (Rural Development Department Leh) developed and experimented (at Shara and Mudh villages) the idea of building AGs as a means to enhance the process of ice formation at higher reaches (below the natural glaciers). Mr. Norphel took forward the idea in 1990s (when he joined LNP) and used the experience in building AGs in some more villages under Watershed Development Programme (WDP) of GOI. By early 2000, the concept got attention of more villages and PIAs of WDP and, as a result, AGs were tried out in more villages. Mr. Norphel came to be known as 'the ice man of India' and won several awards for his contributions. Unfortunately, many of the structures built in 1980s and 1990s were washed away in 2010 and subsequent flash floods. In government programs, AGs do not feature as an important part of the strategy towards water conservation. However, in past decades, local NGOs and external agencies have promoted and even innovated on the concept in several villages (chapter 5 & 6, annexure 1).

Artificial glaciers are simple water harvesting techniques aimed at enhancing the process of ice formation at higher reaches below existing natural glaciers and snow packs. 'AGs are locale specific water conservation techniques' (Hock et al, 2019). 'AG involves use of simple building technology, local materials, tools and labour, thus making it maintainable by local population' (Hock et al, 2019). Ladakh has a short agricultural season, and it is crucial to get water for sowing so as to allow crops to mature on time. 'Harvesting water through freezing it at lower elevations during winter means availability of water during April/May, as this ice melts earlier than the natural glacier or snow packs' (Norphel). The technique involves 'regulating melt water of one season to make it available for consumption and irrigation in the next season' (Nusser et al, 2019). With the onset of winter, the water from glaciers drains into streams without much use. AGs arrest the glacial water melt from November onwards, containing it through erection of cascade type walls (of dry stone masonry) and/or guiding it to selected (preferably shady) locations through diversions (channels or pipes), thus allowing it to freeze. The stockpile of ice thus formed melts earlier (due to their lower altitude than natural glaciers), i.e., April/May. These structures also help better percolation of water into the soil, enhancing recharging of ground water and springs. 'The efficacy of AGs depends on whether ice is there or not between November and May. In November, ice begins to fill and in April it melts, thus solving the problem of water scarcity' (Nusser et al, 2019).

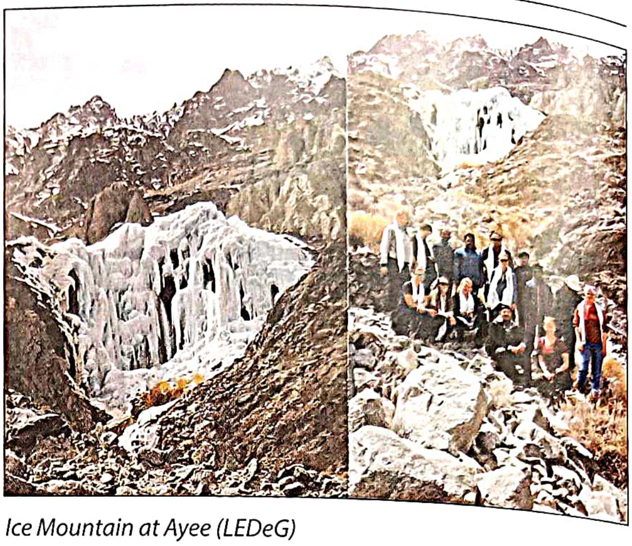
A basin structure (LNP)



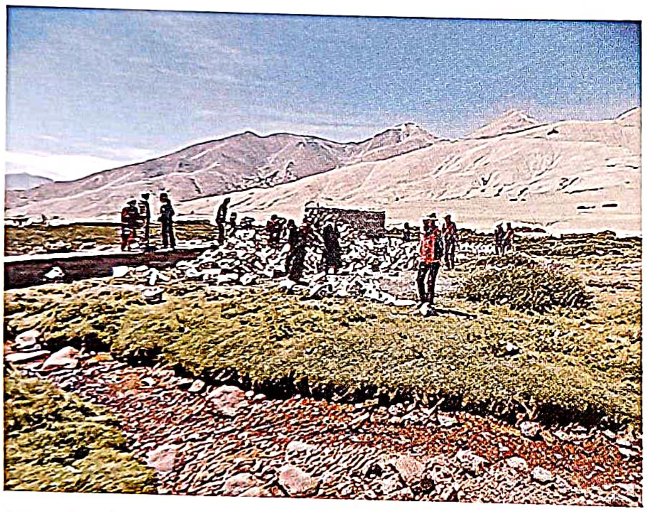
A sketch map of cascade with diversion (LNP)



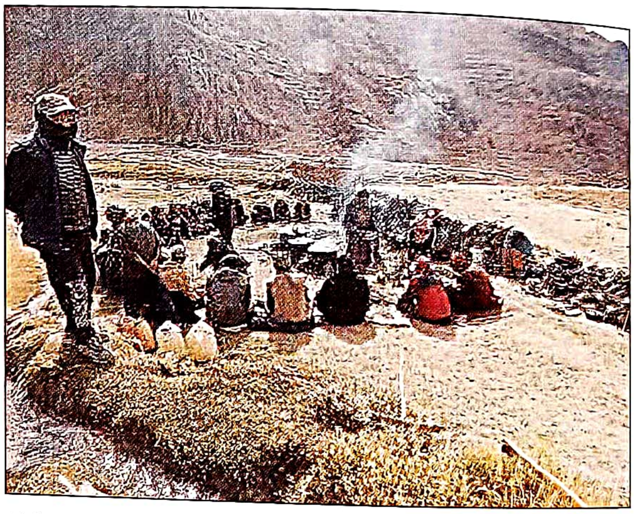
A set of cascades (LNP)



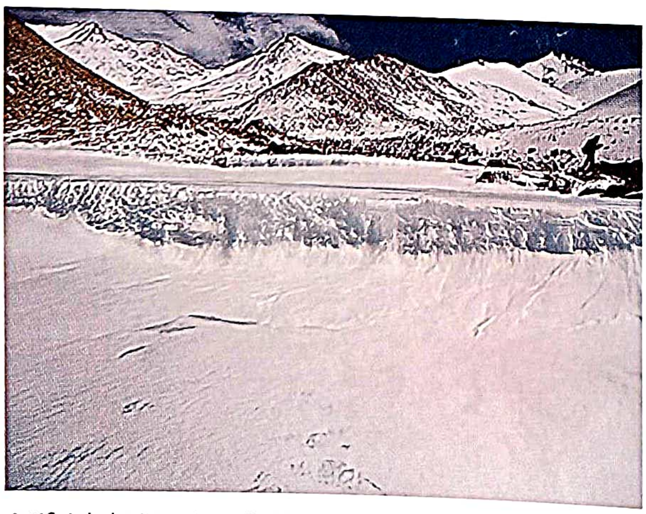
Ice Mountain at Ayee (LEDeG)



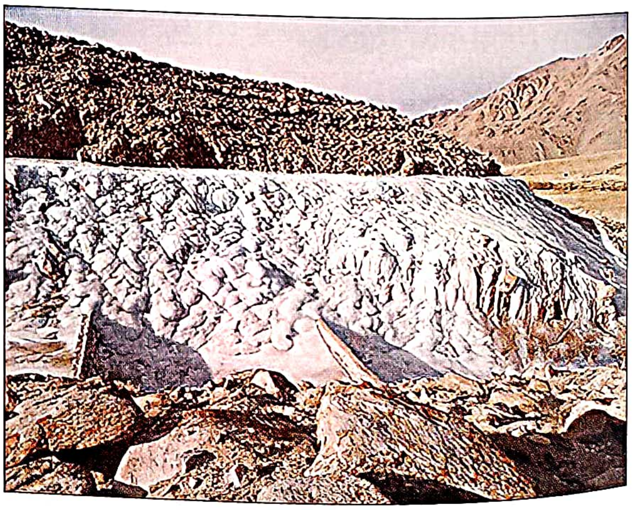
An artifical glacier in progress (LNP)



Village meetings in progress (LNP)



Artificial glacier at Igoo (LNP)



Diversion type (LNP)

Ice stupa at Phyang (HIAL)

As we observe, five types of AGs are in practice today:

a) The first type is the basin type structure including the traditional 'ice reservoirs' dug out on or near the perennial stream at a convenient location (with natural depression) between the natural glacier and the village (such structures can be seen at Igoo, sakti and Shara) and the more recent type involving construction of walls on all sides, holding a large amount of water for freezing (as the one built at Gangles in Leh). Digging of a large number of small percolation tanks over the landscape between the natural glacier and the village may be considered a third variation of the basin type. Such structures, primarily aimed at better recharging of ground water, also helps with the process of ice formation during winter.

b) The second type of AGs involves construction of a series of cascade type ice retaining walls of dry stone masonry over the stream or at nearby locations fed through diversion channels.

c) The third is the diversion type in which stream water is led to nearby slopes (and shady areas) through digging of series of diversion channels and allowed to freeze. Often, a combination of the second and third types is seen in most places.

d) The fourth and fifth types are more recent innovations. Named as 'ice mountain' or 'ice fall', the fourth type involves diverting stream/spring water through ordinary rubber pipes to shady areas and spraying the water over a cliff (using the force of gravity) to form ice. This has been tried out at Takmachik (by LEHO) and Yulkham and Ayee (by LEDeG), with encouraging results.

e) The fifth type is known as 'ice stupa', experimented by HIAL at Phyang and promoted in several villages. The design involves fabrication of a conical structure (of locally available materials) at a suitable location on which water taken from the stream/spring is led through pipes and showered either from below (fountain type) or from above the structure (sprinkler type), thus allowing a stupa-like structure of ice to be formed, which melts during the spring time. HIAL has developed a manual and is providing technical support to village communities interested.

5 AGs – experience so far

Although the concept of AGs was developed at Rural Development Department (RDD) Leh, it was promoted, by and large, by local NGOs. During late 90s and early 2000, resources under WDP of DRDA (GOI) were extensively used by its various project implementation agencies (PIAs) for construction of AGs. Most AG structures built were cascade types (though many of them got severely damaged during the 2010 and subsequent flash floods). During these 3 decades, some innovations have also been witnessed, with promises of further improvement in the technology in future. Currently, NGOs active in the field include Leh Nutrtion Project (LNP), Ladakh Environment and Health Organisation (LEHO), Ladakh Ecological Development Group (LEDeG), Himalayan Institute of Alternatives (HIAL) and Himothan (Tata Trusts). A variety of agencies and institutions have come forward in providing financial and technical support for promoting AGs These include Tata Trusts, NABARD, Operation Sadbhavana (Indian Army's goodwill program), NIHE (GB Pant Institute), Department of Science and Technology (GOI), Ministry of tribal Affairs (GOI), Royal Bank of Scotland (UK), HDFC Bank and ELRHA (UK). However, the concept is yet to find its place in the agenda of mainstream development plans and programs on water conservation and livelihoods improvement.

Table 1: List of villages in Leh District with AGs

S.No	Village/Hamlets	Agency	Years	Type of AG	Supporting agency
1	Takmachik	LEHO, HIAL	2010, 2015, 2018-22	Cascades, 'Ice mountain & Stupa'	WDP, Tata trusts
2	Umla	LEHO, HIAL, RDY	2010s, 2013, 2019	Cascades, 'Ice stupa	WDP, Tata Trust, RDY
3	Likir	LEHO	2010s, 2016	Cascades	WDP, Tata Trust
4	Saboo	LNP	2004, 2011, 2016	Cascades	WDP, RBS, Sadbhavna, DST
5	Stakmo	LNP	2006, 2009,	Cascades	WDP
6	Nang	LNP, HIAL	2006, 2011, 2016, 2019	Cascades, 'ice stupa'	WDP, DST, Tata Trusts
7	Sakti	LNP, Himothan, HIAL	1998, 2006, 2009, 2018	Cascades, 'Ice stupa'	WDP, Tata trust, NABARD
8	Shara	RDD, LNP	1987, 2007, 2013, 2018	Ice reservoir, Cascades, 'Ice stupa'	RDD, WDP, Tata trust, Sadbhavna
9	Igoo	LNP, HIAL	2005, 2009, 2014, 2019	Ice reservoir, cascades, 'Ice stupa'	WDP, Sadbhavna
10	Leh	RDY/Irrigation?	2012,	Basin	WDP
11	Hundri	Himothan	2021	Cascades	HDFC, NABARD
12	Murgi	Himothan	2021	Cascades	HDFC, NABARD
13	Yulkham	LEDeG	2021	Ice mountain	NIHE (GB-Pant)
14	Alchi	LEDeG, HIAL	2000s, 2016, 2018	Cascades, 'Ice stupa'	WDP, Tata/NABARD
15	Kulum	LNP, HIAL	2000s, 2019-21	Cascades, 'Ice Stupa'	WDP, Min. of Tribal
16	Tuna	Himothan	2018	cascades	Tata Trust
17	Phyang	RDY, HIAL	2000s, 2019	Cascades, 'Ice stupa'	WDP, HIAL
18	Matho	ICICI foundation	2022	Cascade	ICICI foundation
19	Ayee	LEDeG	2021	Ice Mountain	Tata trust
20	Gya/Rumtsey	HIAL	2017	'Ice stupa'	HIAL
21	Satsedho/Washudho	HIAL	2018	'Ice Stupa'	HIAL
22	Skyurbuchan	HIAL	2019	'Ice stupa'	HIAL
23	Tarchit	HIAL	2019	Ice Stupa	HIAL
24	Gangles	RDY, LNP, HIAL	2010, 2018, 2020	Basin, 'Ice stupa'	WDP, RBS, HIAL
25	Puga	HIAL	2020	'ICE stupa'	HIAL
26	Tsaga	Hemothan, LNP	2021, 2022	Cascades	Tata, Elrha
27	Mudh	LNP	2022	Cascades	Elrha

As clear from above, cascade type of AGs have been built in 17 villages, 'Ice mountains' tried out in 3 villages and 'Ice stupa' experimented in 16 villages in the Leh district (and 8 villages in Kargil). 25 more 'ice stupas' have been built in 2021-22. For a brief profile of prominent villages, with AGs constructed, kindly refer to annexure 1.

Some key learnings from the work of NGOs in AGs so far are as follows: 1) Villages/hamlets with no natural glaciers are the most vulnerable, 2) Villages/hamlets facing south (Indus belt in particular) are more vulnerable, 3)Villages other than those in the Indus valley also deserve attention, 4) Smaller the village, easier/greater the participation of village community, 5) Shorter the distance between the AG and the village, greater the scope for regular maintenance of the structure, 6) Introduction of new technologies/ideas is increasing choices of options suitable to local conditions, 7) Lack of documentation and scientific data is an impediment to effective planning and impact assessment.

6 AGs and their impact

The concept of 'Ice Reservoir' is an old one, and some village communities (e.g., Igoo, Sakti and Shara) have successfully used it during earlier times. However, such structures are dependent on availability of suitable locations. Basin type structures hold a large volume of water but are expensive and run the risk of posing threats to the population during floods. Percolation tanks are possible almost everywhere, though tried out at a few locations only. Together, these three variations have the potential for holding significant amount of water and helping with recharging of groundwater and springs downstream. Cascades, with or without diversion channels, are more expensive but these structures last many years and require minimum maintenance if looked after properly. On the hind side, basins, diversion channels and cascades are prone to damages due to erosions, sedimentation, landslides or flash-floods. There is a lack of data on ice formation and changes in volume of water. However, anecdotal evidence exists (e.g., Nang, Yangthang, Igoo, Shara, etc.) on increases in volume of water, availability of water in spring by 10 to 20 days earlier, significant decline in the practices of leaving the land fallow, and increased instances of tree plantation on additional land.

'Ice stupas', with availability of technical guidance from HIAL, has been tried out in around 24 villages (including 8 villages in Kargil) with positive outcomes. A disadvantage is that, this technology involves a lot of human effort due to the need to repeat the whole exercise every year, with some villages considering it too cumbersome. However, there is a scope for reducing labour input if the structures are made permanent, with use of high density pipes and durable materials. Following initial experiment at Phyang, HIAL instituted a system of technology transfer through a competition among villages on creation of 'ice stupas' with provision of technical support and prize money. Between 2018 and 2021, 24 villages have taken part in the exercise, with two villages (Tagmachik and Lamtso) having participated every year and one village (Phyang) twice. In terms of impact, HIAL reports show that the average height of these structures ranged between 45 and 108ft in height and 155 and 450ft in circumference. Total volume of ice formation in these villages is estimated at 156 million litres (32 million litres in 2018, 58 million in 2019 and 67 million in 2020)

Regarding 'Ice mountains', there are reports of positive outcomes in terms of the quantum of ice formation. For example, in Takmachik where this exercise was undertaken in 2018 and repeated in 2019, significant quantity of ice is reported to have been formed (40x45x2 m at Chumikchan and 35x20x2 m at Hemidok). At Youlkham (Nubra), the ice formed at the location measured 27m in height. It is reported that the structure helped in availability of water for irrigation 17 days earlier than normal while allowing tree plantation on 2 hectares of additional land, not possible earlier. At Ayee, a similar result has been achieved. Such structures are relatively cheaper, though their success depends on availability of suitable locations (shady areas). The need for repeating the exercise every year exist here as well. One possibility that seems to emerge is to use the technology by deploying motor pumps (using electricity) to allow ice formation at suitable locations even within villages.

In terms of cost, exact figures are not available. However, as per our estimates at Tsaga and Mudh, cascades cost around Rs; 200 per cft. (including cost of crate wire and cementing. 'Ice mountain' and 'Ice stupas' can be built within a range of Rs; 20,000 and Rs; 50,000 - Rs: 1 lakh respectively.

Table 2: Strengths and weaknesses of different types of AGs (team's perception)

AG type	Cost involved (high = 1, low =3)	Technology (complex=1, simple=3)	Need for maintenance (low=3, high=1)	Longevity (long=3, short=1)	Labour Input (low=3, high=1)	Need for outside material (low=3, high=1)	Need for external help (low=3, high=1)	Need for suitability of site (low=3, high=1)	Score
Ice reservoir	Low (3)	Simple (3)	Low (3)	Long (3)	Low (3)	Low (3)	Low (3)	Medium (1)	22
Basin structures	High (1)	Complex (1)	High (1)	Long (3)	High (1)	Medium (2)	High (1)	High (1)	11
Percolation tanks	Low (3)	Simple (3)	Medium (2)	Medium (2)	Medium (2)	Low (3)	Low (3)	Low (3)	21
Cascades	Medium (2)	Simple (3)	Medium (2)	Long (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	18
Cascades with diversion channels	High (1)	Simple (3)	High (1)	Long (3)	High (1)	Medium (2)	Medium (2)	High (1)	14
'Ice stupa'	Medium (2)	Medium (2)	Medium (2)	Short (1)	High (1)	Medium (2)	Medium (2)	Low (3)	15
'Ice Mountain'	Low (3)	Simple (3)	High (1)	Short (1)	High (1)	Low (3)	Medium (2)	High (1)	15

Ranking: 1. Ice reservoir, 2. Percolation tank, 3. Cascades, 4. Ice stupa and Ice mountain, 5 Cascade with diversion channels, 6. Basin structure.

Note: As pointed out by HIAL team during sharing sessions, the Ice Stupa has the potential to significantly alter the status on parameters like complex (to simple) technology, higher (to lower) cost, low (to high) on longevity and higher (to lower) reliance on external help. As per the HIAL team, this is already happening in their ongoing projects. As such, Ice stupa may rank 4 with a score of 15 points.

Table 3 a: Volume of ice formed at 'Ice Stupas' in different villages (source: HIAL)

Year	No. of participating villages	Volume/million ltr.	Villagers trained	Ice stupas made
2018-19	10	31.83	250	16
2019-20	13	57.6	370	21
2020-21	13	67.0	225	21
	36	156.43	845	58

Note: Calculations on the volume of ice formation was done through measuring height and circumference.

Table 3 b: Volume of ice formed at 'Ice mountains'(source: LEHO, LEDeG)

Village	Year	No. of AGs	Volume of ice formed
Tagmachik	2018	2	5900 cft.= 1.5 ML
Ayee	2021	1	?
Youlkham	2020	1	Height= 27 mtrs.

Table 3 c: Measurement of water flow taken at Tsaga and Mudh villages (2022)

Village	Date	Width (ft.) avg.	Depth (ft.) avg.	Length (ft.) avg.	Time (seconds) Avg.	Velocity (ft/sec.)	Discharge (cubic ft. per second)
Tsaga	23/05/2022	4	1	10	65	0.12	0.48
	20/06/2022	4	1	12	62	0.16	0.64
	15/07/2022	7	0.9	15	56	0.22	1.38
	21/09/2022	6	2	10	50	0.17	2.04
	17/10/2022	6	1	10.	10	0.85	5.1
Mudh	24/05/2022	7	3	10	50	0.17	3.57
	20/06/2022	8	3	10	65	0.12	2.88
	15/07/2022	9	2	10	60	0.13	2.34
	22/09/2022	6	2.5	10	45	0.18	2.7
	23/10/2022	6	2	10	20	0.42	5.04

Note: 1) At Mudh, an unusual spell of snowfall was experienced for 3 days in the month of May 2022. 2) At Mudh again, a sudden decline in water level was observed in November due to freezing.

Table 3.d: Volume of ice formed at Cascades built at Nang and Shara villages (recorded in February 2022)

i) Shara

Cascade	1	2	3	4	5	6	7	8	9	10	Total
Avg. length (ft)	100	250	100	110	150	400	100	400	1100	700	3410
Avg. width (ft)	200	250	250	200	30	50	100	70	80	50	1280
Avg. height (ft)	4	3	7	8	7	4	5	5	5	4	52
Ice volume (cft.)	80,000	187,500	175,000	176,000	31,500	80,000	50,000	140,000	440,000	140,000	1.5 million
Water volume (cft.)**	73,600	172,500	161,000	161,920	28,980	73,600	46,000	128,800	404,800	128,800	2.7 million
Water volume (ML.)**	2.08	4.88	4.55	4.58	0.82	2.08	1.30	3.64	11.45	3.54	39.06

ii) Nang

Cascade	1	2	3	4	5	6	7	Diversion*	Total
Avg. length (ft)	150	74	118	64	100	60	0	600	1166
Avg. width (ft)	30	20	30	30	10	10	0	70	200
Avg. height (ft)	5	5	7	7	5	5	0	4	38
Ice volume (cft)	22,500	7,400	24,780	13,440	5,000	3,000	0	168,000	244,120
Water volume (cft.)**	20,700	6,808	22,798	12,365	4,600	2,760	0	154,56 0	224,590
Water volume (ML)**	0.58	1.92	0.64	0.35	0.13	0.08	0	4.37	6.35

*Ice formed at diversion channel built above cascades

**Volume of ice multiplied by 0.92 = volume of water, volume of water in cubic feet multiplied by 28.31 = volume of water in ltr.

An important issue facing the impact of AGs in water conservation efforts is the lack of scientific data and an absence of systematic data collection in the project planning and implementation processes. Some efforts have been made to measure the volume of ice formed and to collect anecdotal evidence and observations made in the volume of water available during spring time. HIAL is reported to be gathering data on various aspects of ice formation at 'ice stupas' and their impact on village communities concerned. There is a need for developing a framework for information gathering on water situation (both positive and negative aspects) in each village, particularly those facing or highly vulnerable to water scarcity. This can be done at different levels. At level 1, changes in precipitation and the status of water sources, i.e., glaciers, ice packs and springs can be observed and recorded. At level 2, regular measurement and recording can be done on water flow in streams and volume of ice formation at AGs constructed. At level 3, factors like the status of springs (quantum of water, drying out of existing one or emergence of new ones), pastures as well as time taken in filling of water reservoirs during spring, etc. can be assessed. At level 4, status of water management systems of villages concerned (reservoirs, distribution channels, Chhurpon system, watering patterns, etc.) can be assessed. At level 5, aspects like land use, cropping pattern, etc. can be determined. Such information, if collected accurately and regularly, could be of immense help in developing holistic plans for dealing with water related issues. Moreover, capacity building of village communities in collection and analysis of such information could go a long way in evolving a sustainable process for ensuring water conservation and mitigating the climate change impact.

Table 4: A simple method of measuring water flow in a stream using a plastic bottle (half filled with water) or a piece of wood

Steps:

1. You need to have 2 persons, a plastic bottle, a timer and a calculator (mobile phone).
2. Choose a portion of the stream, uniform enough for taking measurements.
3. Mark point A & B 10 ft apart.
4. Half fill the bottle with water and let 1 person toss it at point A (upstream)
5. Let the other person note time taken by the bottle to reach point B, repeat the exercise 3 times and get the average.
6. Measure the width and depth of water at 3 points at cross section and get the average each.

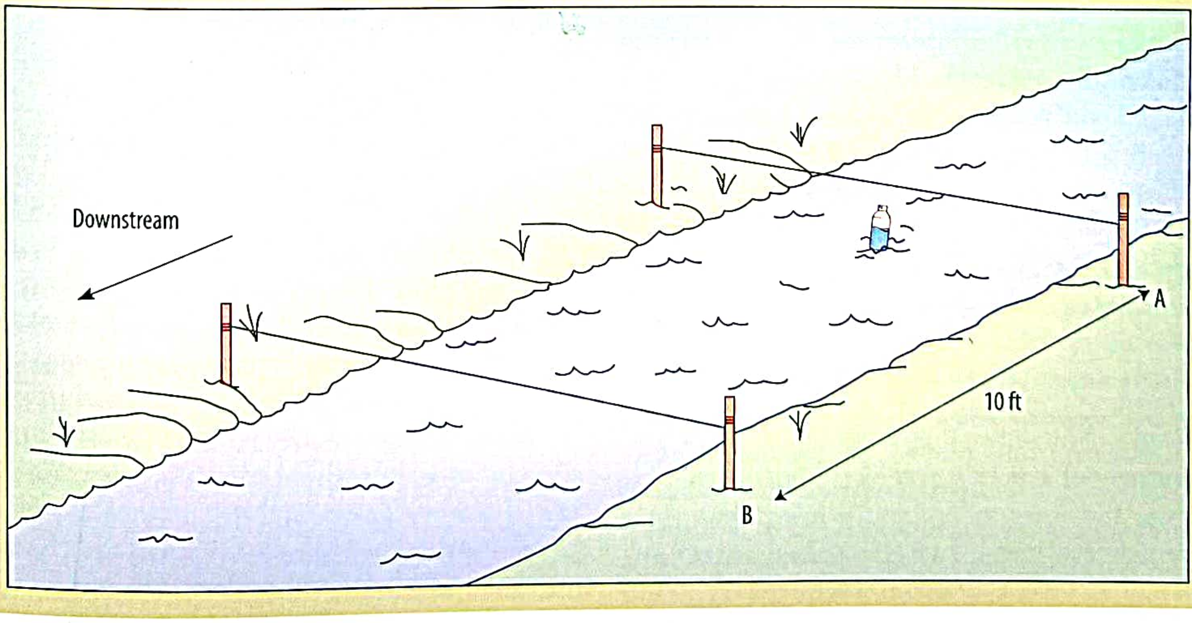
Surface velocity= length/ time (avg.)= 10ft/8 sec. = 1.25ft/second.

Mean velocity= surface velocity x 0.85 = 1.25 x 0.85 =1.06 ft/second.

Area (cross-section) = depth (avg.) x width (avg.) = 2ft x 5 ft = 10 sq. ft.

Discharge= area x velocity = 10 ft x 1.06 =10.6 cubic feet per second.

Note: 0.85 is the correction factor to offset surface flow which is faster than below.



7 Project implementation at Tsaga and Mudh villages – an account

As a part of 'COWLAG' project, LNP constructed two cascade-type AGs at Tsaga and Mudh villages of changthang region, making the best use of available know how on the subject. The following are some highlights of the work done.

- Between April and July, LNP team made several visits to the two villages involving meetings with community members, FGDs with village leaderships and site visits.

-Following the emergence of a broad consensus on water situation, types of AGs suited, selection of convenient locations, discussion on management aspects as well as budgetary implications (including project contribution towards a corpus) and identification of support needs, a meeting in May 2022 focused on arriving at decision points and developing detailed work plans. This led to adoption of resolutions, formation of WMCs and appointment of animators.

-Tsaga has a small glacier with glacial lake (known as Shaki Tso), the water from which reaches the village in mid-June while the barley crop requires its first round of watering in early May (farmers in Tasaga grow three types of crops, i.e. barley, peas and yukpo) during their short single crop season. As such, this watering is done with whatever is available in the two springs above the village, which is not enough. For instance, three household (Sonam Chodon, Tashi Namgial and Meme Sonam) were unable to get their first watering for their fields. The village has two water reservoirs and both were empty in May 2022. In 2021, Hemothan built two cascade-type AGs measuring roughly 30m x 1.5m x 3m each, part of which got destroyed later due to lack of maintenance.

-On formation of WMC at Tsaga, village elders suggested one member each from the 4 wards and appointment of Tsetan Angchok (retired teacher) as animator. However, village youth insisted on their involvement and hence 4 youth representatives (Angdu Thinles, Jigmat Stanzin, Tsering Targes and Sonam Tashi) got elected as WMC members. The sarpanch (Skarma Dorjay) recorded the proceeding and signed the resolution on behalf of the village community. It was decided that, over the stream, a cascade type AG measuring 120 ft x 3 ft x 4 ft foundation of dry stone masonry, with cement topping, built by excavating a trench beneath the frost line with an upper structure of 120 ft x 5 ft x 3 ft with crate wire bunding will be appropriate.

-At Tsaga, the animator undertook to monitor water flow in the stream at periodic intervals while the WMC worked out a detailed plan for community mobilisation. By beginning of November 2022, the structure was completed. During team visits then, it was suggested that the sides of the wall should be flanked by wings (with dry stone masonry bound by crate wire) to allow maximum retention of water. By end November 2022, with the beginning of ice formation, the villagers started closing the opening in the middle with loose rocks. In his December 2022 visit, Tundup observed that the ice had reached above the foundation wall. On this occasion, he also held a detailed round of meeting with WMC on issues related to maintenance of the structure. This included ensuring continuous monitoring of ice formation and water flow by the animator, allocation of tasks of maintenance to four groups of 20 families each on a weekly basis for ensuring maximum ice formation, appropriate use of project contribution towards a corpus as seed money for mobilising community contribution for maintenance work, and developing linkages with NREGA in maintenance of AGs.

-Mudh is more pastoralist in its economy and depends heavily on its flocks of goats, yaks and sheep. Agriculture is, however, crucial for the village to be able to feed humans as well as animals. Barley, peas (including a hybrid variety introduced by SKUAST) and potatoes are the main crops grown. The village has no natural glacier and depends solely on snowfall and springs, with water collected in three water reservoirs within the villages. The village has system

of groups of 7 families each taking turns in irrigating their fields. The situation of water scarcity is so dire that the phenomenon of crop loss is common (with instance of complete crop loss in 2004 and 2018).

-Mudh was one of the villages (along with Shara) where cascade-type AGs were built in late 1980s. For the current project, LNP team made several visits to the village involving FGDs, meetings and site visits. In late May, details on the project implementation were finalized, timelines were drawn, WMC was formed, animator was appointed and decisions were recorded in a resolution signed by Goba (Tsering Choldan) on behalf of the village community. While Nawang Gyaltsen was appointed as animator, four members (one male, i.e. Thinles Tamchos and three females, i.e. Dorjay Youdon, Stanzin Dolma and Stanzin Angmo) were elected as WMC members.

-In Mudh, AG structures built earlier do not exist anymore due to flash floods of 2010. In 2021, Himothan built a cascade type AG which is reported to have given encouraging results. Therefore, villagers were upbeat about prospects of proposed cascade under this project. By August 2022, the foundation measuring 120 ft x 3ft x 4ft with cement coping on top was ready, and by September 2022, the structure on top measuring 120 ft x 5ft x 3ft with crate wire bunding was complete. By late November 2022, the villagers had started closing of central opening as the ice started forming. During his December visit, Tundup observed ice formation up to 2 ft, which is satisfactory if situation of water scarcity in Mudh is considered. It is expected that, by February the level of ice formed on the cascade will reach up to 6 ft. The flanking of the wall (which came as a suggestion during earlier meetings) on both sides of the structure with wings of dry stone masonry had been completed by this time. On this occasion, the team had a detailed discussion with the WMC on follow up plans as discussed at Tsaga.

8 Overall Analysis and the Way Forward

a) Analysis:

1. Experiences from the field suggest that a gradual shrinking of glaciers coupled with the phenomenon of erratic and declining snowfall in past few decades has increased the number of villages facing scarcity of water during sowing season. Research findings indicate that this phenomenon is attributable primarily to climate change and its impact, though local interventions are partly responsible. This brings us to the realisation that the problem facing Ladakhi villages will grow bigger in times to come, unless water conservation efforts are intensified. This highlights the importance of adopting a holistic approach to water conservation efforts.

2. The traditional ways of conserving water have revolved around belief systems that water sources are the abodes of spirits (Lha and Lhu) and hence sacred places to be protected from desecration and pollution as far as possible. Rituals like 'Jiway Sangchod' and 'pungpa Chugches' are some examples. There exists a long tradition of local communities preserving as well as harvesting water for drinking and irrigation. At some locations, we find remnants of 'ice reservoirs' built by village communities to hold water for allowing percolation and recharging of springs. Ancient practices also included use of charcoal and bushes and 'ice marriage' (bringing ice from another location). In addition, the traditional way of construction and maintenance of water reservoir and irrigation channels along with 'Churpon' system of water management (with local specific mechanisms for distribution) continue to be in practice in most villages. These aspects need to be kept into consideration while developing water conservation strategies.

3. The concept of Artificial Glaciers (AGs) evolved in late 1980s when a team of Rural Development Department (RDD) Leh led by Mr. Chhewang Norphel (engineer) experimented with regulating the excess water of one season to make it available for the next season. This was done by building stone wall barricades or cascades thus reducing the follow of water and allowing it to freeze during November-December. This concept was taken forward by Mr. Norphel and various NGOs in villages facing water scarcity during spring time. In past three decades, it has expanded to more villages while some innovations have also being made. Currently, there exist five types of AGs, i.e. basin type, diversion type, cascade type, 'ice stupa' and 'ice mountain'. Agencies and village communities have used these types in various combinations, and the concept has established itself as a low cost technology and an example of climate adaptive response mechanism, and such efforts need to be intensified in times to come.

4. At present, five NGOs are proactive in the implementation of AG in Ladakh. These are Leh Nutrition Project (LNP), Ladakh Environment and Health Organization (LEHO), Ladakh Ecological Development Group (LEDeG), Himothan (of Tata Trust) and Himalayan Institute of Alternatives Ladakh (HIAL). Among these, LNP has been the longest in the field. More than 50 AGS have been built in around 25 villages/hamlets so far. In addition, 'Ice mountains' have been experimented in 3 villages and 'Ice Stupas' have been tried out in around 25 villages (16 in Leh and 8 in Kargil). Agencies having supported the work on AGs include Watershed Development Programme (WDP), Operation Sadhbhavna, Tata Trusts, NABARD, GB Pant Institute, Ministries of Science and Technology and Tribal Affairs (GOI), HDFC Bank, Royal Bank of Scotland (RBS) and Elrha.

5. Among various types, the cascade type are being considered to be the most successful so far. These structures are one of the easiest to construct as these are made of dry stone masonry which is based on traditional ecological knowledge and generally known to Ladakhi villages. These structures cost around Rs: 200 per cubic feet. Cascades have a longer life, requiring less maintenance. Diversion types are the least successful due to the need for regular maintenance of channels which get frequently covered due to erosion and flooding during summer. 'Ice mountains' and 'Ice stupas' are relatively newer

concepts being experimented by more and more villages. These structures are less expensive but require the exercise to be repeated every year. There is a need to take forward a comparative analysis of various types while encouraging further innovations.

6. One of the weaknesses in AGs has been a lack of focus on data collection and analysis on overall water situation of villages in general and assessing the impact of projects undertaken in particular. Although, there are feedbacks from various communities on the availability and increase in quantum of water during spring, a systematic gathering of information is missing. HIAL and LEHO have generated data on volume of water stored in 'ice stupas' and 'Ice Mountains'. LNP, in its current projects, has made some efforts on developing a system of measuring water flow in the stream over time as well as the quantum of ice formation on cascades built in Tsaga and Mudh this year. Capacity building (along with provision of basic instruments) can play an important role in basic data gathering at community level. There is a need to strengthen and streamline the process of data collection in order to have better assessment of water situation in Ladakhi villages and for ensuring appropriateness of responses towards water conservation in future. There has been some research works done in past few years, e.g. by Nueser at al (2019), Clouse et al (2014), Dallfus et al (2013), Westen et al (2019), etc. which provide valuable insights into the subject.

7. An issue deserving adequate attention relates to the role of village communities concerned in planning and implementation of AGs (and data collection in particular). So far, the work on construction of AGs has been undertaken by agencies in a 'partnership mode', with village representatives expected to look after all post-project interventions on maintenance and upkeep of infrastructures built during project implementation phase. Efforts made so far on increasing community ownership of 'projects' include detailed discussions/negotiations with village communities before and during project period, formation of water management committees, appointment of animators, creation of a corpus for post project maintenance (with provision for contribution from the agencies as well as community members), etc. Such efforts need to be steamelined further through measures like increased focus on post-project plans/exit strategies, provisions for building local capacities, establishing effective linkages with Government schemes (e.g. NREGA), etc. HIAL has adopted a unique approach in promoting 'Ice Stupas' by which villages compete for a prize, and the impact of such exercises need to be assessed as well.

8. Lastly, despite three decades of local experience in construction of AGs in Ladakh, the technology does not seem to figure in the existing water conservation strategies of the region. It is perhaps an opportune time to stress upon UT administration of Ladakh and LAHDCs to bring AGs into their agenda.

b) Recommendations:

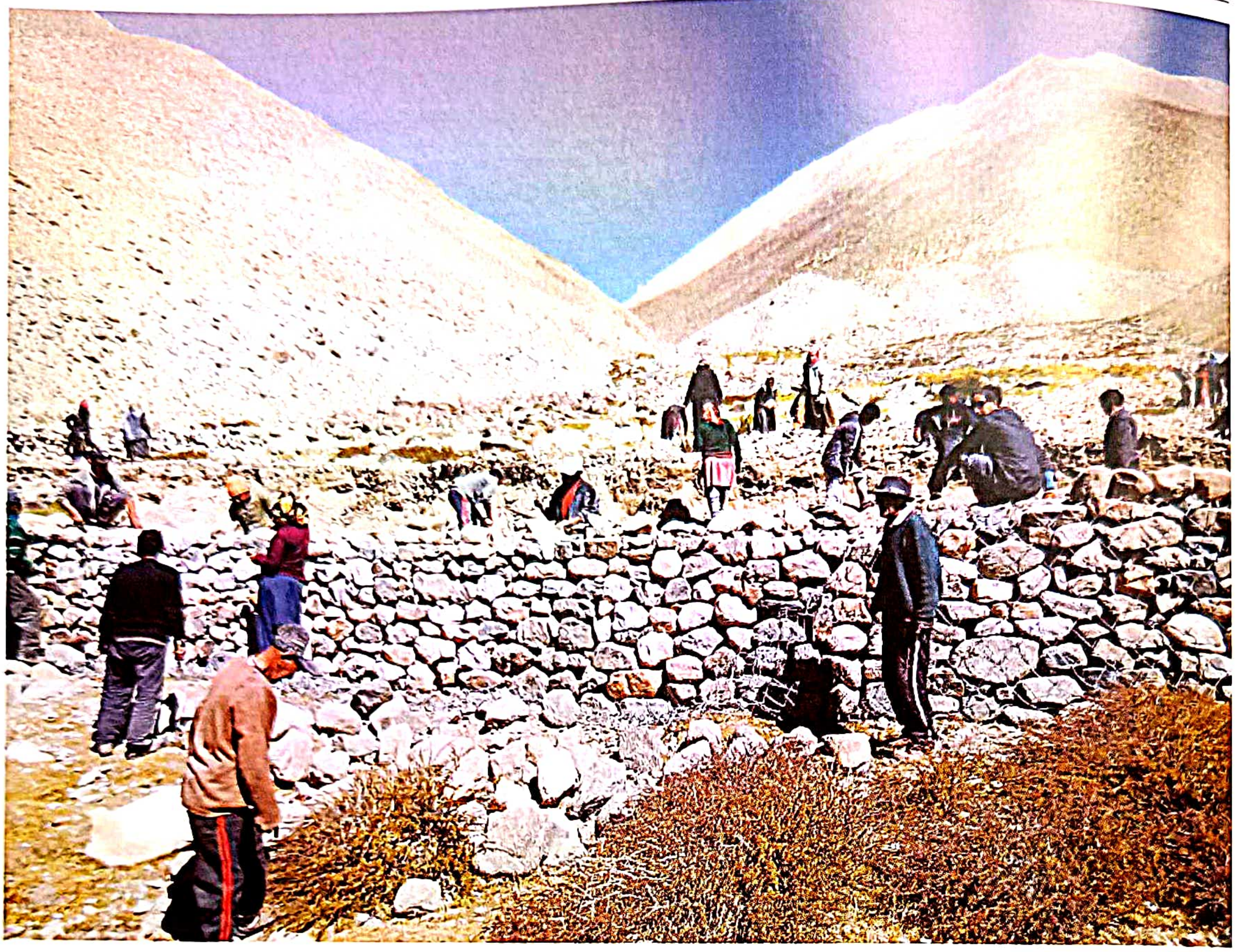
1) Recognising Artificial Glaciers as an effective strategy for water conservation:

AG offers a low-tech engineering approach to address the problem of water scarcity through regulating the flow of water and retaining it as far as possible in the form of ice so as to allow it to absorb into the landscape or to make it available for irrigation in early spring. Either way, it serves as an effective water conservation strategy. It may be emphasized that the issue of water scarcity is likely to remain and get exacerbated in times to come.

It is perhaps an opportune time to stress upon UT administration of Ladakh and LAHDCs to bring AGs into their agenda through appropriate institutional arrangements and resource allocation. Moreover, to be effective, the strategy on water conservation needs to adopt a holistic approach involving a better understanding of water situation in each village including water management system, agricultural practices and community organisation.

2) Recognising that situations vary from village to village:

The situation of water and water resources differ from village to village. It is clear enough that some villages/hamlets, e.g., those with glaciers facing south or those without natural glaciers are more vulnerable to the threat of increased water scarcity and, therefore, need to be prioritised in the future



strategies on water conservation. It may also be noted that effectiveness of AGs is highly dependent on availability of suitable site/location as well.

3) Recognising the critical role of village community:

Promoting greater ownership of village communities and their institutions/leadership in planning, implementation and follow-up of AGs will be crucial. Some measures have been taken by implementing agencies in ensuring sustainability of various processes introduced. This needs to be strengthened further and as such, building of local capacities becomes crucial for future interventions on water conservation in general and building of AGs in particular.

4) Recognising the importance of data collection /analysis:

The work of AGs so far has not paid much attention to collection, analysis and use of scientific data on the status of water and water resources in different villages as well as the impact of AG structures built. Some methods on measuring water flow and ice formation have been adopted by implementing agencies. However, use of scientific methods, ongoing analysis of data, periodic sharing and learning on information thus generated would be extremely valuable for effective planning for future.

5) Recognising local sensitivities:

As mentioned earlier, Ladakhi society considers water and sources of water as sacred, and avoids human activities causing pollution at such locations, as far as possible. This requires to be kept into consideration while developing plans and implementing projects aimed at water conservation including creation of AGs.

Annexure 1:
Brief profile of villages with significant work on AGs, and their experience so far

1. TAKMACHIK (LEHO): Situated at 120 kms south of Leh , Takmachik consists of 67 households. Located above the bank of Indus, this village is famous for its apricot production and organic farming. Though facing the north, it has no permanent glacier and depends solely on springs located at Chhumikchan and Himidok (at 1½ and 3½ hour walk above respectively). There are 3 cascade type walls (of dry stone masonry measuring 30 to 75 ft x 4 x4 ft.) as well as a few smaller ones, built in 2015 and 2018. In November 2018, LEHO team (led by Tashi Thokmet) took up the task of trying out a new idea for ice formation, i.e., guiding spring/stream water through ordinary rubber pipes to a shady area and showering water, using the force of gravity, over a cliff to allow ice formation. The concept was discussed with the village community and the work was undertaken at two locations, one at Chhumikchan and another at Himidok. The exercise involving community members was undertaken for several days. The team reports that ice formation was around 50 x45 x 2 meters at Chhumikchan and 35 x 20 x 2 meters at Himidok. This exercise was repeated every year, with some further experimentation through change of sites. The cost of material and labour was borne by the agency, with some budgetary provision made as project contribution for meeting post-project expenses. Although, data on its impact on availability of water during spring do not exist, the village community is optimistic about its usefulness. However, prospects for sustenance of this yearly exercise (in November) in future is yet to be seen. Takmachik also participated in HIAL's competition on building 'ice stupas' on 3 occasions (2018 to 2020), and feed back on their impact need to be obtained.

2. UMLA (LEHO): Umla is a small village of 23 households facing South and located at 30 kms west of Leh. It has no permanent glaciers, and depends on snow packs and springs. Water from the stream is collected in 2 reservoirs (one on top and another in the middle of the village). Umla has always faced scarcity of water during its sowing time. Therefore, in spring time, it follows a system of allotting its water reservoirs to two families in a day, and this way each family gets its turn after 12 days. The village has instances of outmigration by some families, and faces shortage of human resources as well. At about 2 hours walk above the road-head, 2 cascade type walls (of sizes 10 x 8 x 5 ft) bound by crate wire were built in 2013, and both are functional at this point. As a result, as per community feedback, reservoirs are filled earlier (by 7 days) than before. In 2019, the village community experimented with building an 'ice stupa' which did not succeed.

3. LIKIR (LEHO): With around 300 households, Likir is a fairly large village located at 60 kms west of Leh, with agriculture as its main source of livelihood and tourism as a secondary source. It has a natural glacier as well as a few springs but faces problems with availability of water during sowing season. In 2016, a cascade type AG with a holding wall (20 m long) was built on the stream at Phu, about 2 hrs walk above the village. Since the location of the AG is not shady, ice accumulation is low. Moreover, the project has not been maintained by the village community since its construction despite the fact that a post-project maintenance grant was made available by LEHO. The AG is functional, with potential for better performance if looked after properly.

4. SABU (LNP): Sabu is a fairly large village of around 280 households, facing south and stretching over 10 kms from north to south in the east of Leh at a distance of 5 kms. It has a natural glacier at Digarla and another at Sabula. Despite this, with agriculture as its mainstay (with specialisation in vegetable saplings and potato seeds), Sabu faces water scarcity during its sowing season in early May, crucial for maintaining its two-crops pattern. Therefore, it has a longer history of AGs as well. In 2004, 7 cascade type structures were built at Koyok under WDP. In 2011, 2 cascades with a 900 ft long diversion channel were constructed with support from the Department of Science and Technology (GOI) and, in 2016, some cascades were built with funding from RBS (UK). These structures are at around 6, 5 and 4 kms respectively above the village road head.

While there are no data available on the impact of these structures, community feedback is positive about speeding up of water availability in April/May. The village has a series of reservoirs for storage of water and a traditional system of its distribution. The lower part of Sabu, known as Ayu, is fed by springs. Of late, part of Sabu has been diversifying its economy with tourism (through construction of resorts/hotels).

5. STAKMO (LNP): Stakmo, a small village of 40 household, situated at 30 kms from Leh above Thiksay, has a small glacier of its own and a few springs as its water source. It had 2 cascades with diversion channels, one built at Chhumik Tangpo in 2006 (about an hour above the village) under WDP, and another at Phu (about 30 minutes) in 2009 under Operation Sadhbhavana. Sizes range between 20 x3 x3 ft. and 30 x 4 x 4 ft. These structures were destroyed in 2010 flash flood, and since then the village is without any AGs.

6. NANG (LNP): Situated at 25 kms east of Leh, above Ranbirpur, Nang (with 72 households) is another south-facing village in the Indus belt with a small glacier and a few springs as its water source. While relying entirely on agriculture for its sustenance, Nang faces acute shortage of water during spring time. As early as in 1999, 6 cascades were built over the stream (7 x 1 x 3 m) with a km long diversion channel leading to an ice reservoir. In 2006, another set of cascades with diversions were built under WDP, and another set in 2011 with financing from the Department of Science and Technology, and yet another in 2016. In total, there are 43 structures of dry stone masonry (averaging 30 to 100 ft in length and 4 to 8 ft in height) with crate wire binding. Although, there was no provision of funding for maintenance work, the village has a system of community contribution (Rs. 200 per household) on an annual basis which is used in supporting a person designated for looking after the structures and for organising community labour as and when needed. The AGs are functional and, with annual up-keeping, diversion channels are also functioning efficiently. Although there is no data on changes in the water situation, as per the village community, AGs have led to significant improvements in availability of water during sowing time (20 days earlier than before, according to Tsering Angdu, Ex Sarpanch). The village also took part in 'Ice stupa' competition in 2019. Nang, therefore, stands out as an example of severity of the problem of water scarcity, reliance on land based economy and, commensurate with this, community ownership of the reponse in addressing the issue.

7. SAKTI (LNP/ Himothan): Situated at 55 kms east of Leh, Sakti is a large sized village (around 360 households) located above Chemre and Kharu (all connected) sharing the same water sources, i.e., 2 glaciers (one at Warila, feeding its western part – Taknak and another at Changla, feeding the eastern part - Takkar). It is a south facing village with acute shortage of water throughout the season. As a result, these three villages have a large network of water reservoirs and irrigation channels along with a stringent and efficient system of water distribution system (Chhurpon/ Chhures). The first set of AGs was built in 1990s under WDP at Zingrul (a small lake below Changla) and consisted of 11 cascades. In 2006 (again under WDP), 6 more walls with diversions were built, with some bound by crate wire. More recently, in 2021, a new AG has been built (by Hemothan under Tata Trust). In 2018, Alchi took part in 'Ice stupa' competition as well.

8. SHARA (RDD/LNP): comprising 180 households and consisting of two parts, i.e., Shara and Sharnos/Phuktse, each being fed by own glaciers, this south facing village of the Indus belt, situated at 70 kms east of Leh, has been suffering from water shortage during spring for a long time. Shara was, therefore, chosen in 1987 for RDD experiment with the concept of AG. This was followed in 2007 with construction of 17 cascades with and without diversions under WDP, in 2013 with 6 cascades under RBS (UK), in 2014 with 9 cascades under Tata Trusts. These walls, 32 in total, some with crate wire binding, were in the range of 50 to 150 ft in length, 5 ft in height and 3 to 44 ft in width. Locations include Shara Phu as well as upper reaches of Sharnos and Phuktse. All these structures are functional, with regular maintenance done by the village community. In 2018, Shara participated in HIAL's competition program in building an 'ice stupa', The experiment was highly successful, and the village won the first prize. However, the exercise was not repeated again. The reason given was that the 'ice stupa' attracted a large number of visitors causing pollution at higher altitudes (considered sacred) and seen as a bad omen with potential for causing anger to spirits (Lha/ Lhu).In 2017, when LNP built some more cascades (measuring 10 ft in height each) under Tata Trust. On this occasion, a WMC (Water management committee) comprising 2 members from each ward was constituted, which monitors and mobilises the community on maintenance work.

9. IGOO (LNP): Igoo, with around 260 households, is another south facing village in the Indus belt located in a 10 km long narrow valley, situated at 50kms east of Leh. The village has a natural glacier at about 2 Kms from the road head. It has a long history of water scarcity during sowing time. In 2009, 2 sets of AGs were built at Phu (about one hour above the village) under WDP and Sadbhavana, with 9 and 4 cascades respectively. These are dry stone structures without crate wire binding. Some of these had underground pits with pipes fitted for allowing discharge and diversion channels using cement. The diversion channel did not function properly due to silting. Therefore a de-silting plant consisting of gate, culvert, chamber and pipes was installed. In 2014, under RBS (UK), another set of 26 structures was built, with walls ranging in size between 20 and 100 ft in length, 4 ft in width and 3 to 5 ft in height. In 2021, an 'ice stupa' was built in a narrow valley when Igoo took part in HIAL's competition. The project won first prize and the ice structure is reported to have survived till August that year. However, the community is unsure about building it again. The village has a WMC (water management committee) which maintains these structures, though there is no provision for creation of a corpus.

10. HUNDRI (Himothan): Hundri is a small village of 50 households located at around 150 ms from Leh on the northern bank of Shayok river in Nubra valley and accessed through Udmaru. It has a small glacier of its own, not adequate for irrigation needs during spring time. In 2021, Himothan (with HDFC funding) built an AG over the sole stream a set of cascades made of dry stone masonry.

11. MURGI (Himothan): Murgi is a small village consisting of 20 households situated in the Panamic belt of Nubra valley on the western bank of Siachan river. It has a small glacier unable to provide enough water during the sowing season. In 2021, Himothan (with HDFC funding) built a set of cascades made of dry stone masonry. Thorns and shrubs have been used for increasing water retention on the walls.

12. YULKHAM (LEDeG): Situated at around 160 kms north of Leh, Yulkham is one of the cluster of villages (sandwiched between Pinchimik and Tirisha) on the eastern bank of Siachan river in Panamic belt of Nubra valley. It is a small village of 22 households with no independent source of water except a spring, thus depending on irrigation channel of its neighbouring village. As a result, it often faces scarcity of water throughout the agricultural season. In 2020, the local councillor (Rigzin Lhundup) approached GB Pant National Institute of Himalayan Environment (NIHE) which in collaboration with LEDeG funded laying of pipes which was used for diverting the spring water to a shadowy area (a gorge) and sprinkled up from the ground via 3 fountains. NIHE deputed a research scholar (Dr. Subrat Sharma) to monitor the progress. Village community arranged transportation and volunteered labour input. Noticing slow progress of ice formation in 2021, the pipe was further extended to a nearby valley. Ice formation recorded in 2021 was reported to be 27 meters high which resulted in availability of melt water 17 days before than in the past. The village community is reported to have been able to undertake tree plantation on 2 hectares of additional land. It is also expected that the ice formed has opened up the scope for ice skating and climbing to attract tourists!

13. ALCHI (LEDeG): Alchi is a medium sized village (with 110 households) situated at around 70 kms south of Leh in Saspol block of Sham region. It has no glacier of its own, and depends on snow packs and springs for its water requirements. Agriculture is its traditional source of livelihood, with tourism as a secondary source of income (thanks to its famous Nangpar-Nangzad monastery). Scarcity of water has been a perennial problem of Alchi, and so is its history of AGs. Between 2000 and 2010, several cascade type structures were built at its upper reaches under WDP but these were destroyed by flash floods. In 2016, under Tata Trust, five cascades made of uncut stone boulders were constructed (30 to 50 ft sizes) by diverting the stream water to a shadowy area. Village youth group (Drukling

Tsospa) has played an active role in the construction work and it is maintaining these structures through use of a corpus created under the project. Villagers feel that these AGs have helped in enhancing water availability during spring, though there is no data to substantiate it. In 2018, Alchi took part in building an 'Ice Stupa' as well.

14. Kulum (HIAL): Kulum is a hamlet (of 12 households) divided into an upper and a lower part, depending solely on springs. It is situated around 50 kms east of Leh and close to Igoo above the northern bank of Indus river. In 2010, flash flood destroyed the springs feeding the upper part and, as a result, all families had to migrate to other villages. Availability of water for the lower part was also affected and, therefore, the hamlet has been suffering from water scarcity throughout the year. In late 1990s and 2000, some cascades were built at the water source under WDP, and some of these are still functional. From 2019 to 2021, HIAL (with support of Ministry of Tribal Affairs, GOI) implemented here an 'ice stupa' project involving construction of 7 dome-like structures (1 in 2019, 3 in 2020 and 3 in 2021) involving laying of HPDE pipes and sprinkling water at shadowy areas. The HIAL team has been visiting the village every year and providing technical support to the village community in maintaining these structures. It is reported that the ice accumulation on these structures was estimated at 0.2 million litres (in 2019), 10 million litres (in 2020) and 12 million litres (in 2021). However, it is not clear if, owing to the small size of the hamlet, Kulum will be able to sustain the process in times to come.

15. AYEE (LEDeG): Consisting of 40 households and situated on the western side of Siachan river in Nubra valley, this small village near Kubet in the Panamic belt (about 200 kms from Leh) has no glacial source of water. It has a spring which does not provide enough water for irrigation in spring time. In 2021, LEDeG implemented a project in which water from the spring was directed through pipes and showered over a cliff into a shady area which led to significant ice formation and increased availability of water during spring.

16. TUNA (Himothan): Tuna is another hamlet (consisting of 7 households) situated at around 70 kms from Leh on the southern side of Indus river close to the tail end of Gya Miru valley. With no glacier of its own, this hamlet depends solely on springs for its water requirements. In 2018, Himothan built a set of 7 cascades below the spring, which resulted in increased availability of water for sowing.

17. Mudh (LNP): Mudh is a village consisting of around 100 households, located at around 200 kms east of Leh and relatively closer to Chinese border. The village economy depends on livestock, agriculture and labour work. It has no glacier of its own, and depends on snowfall, snow-packs and springs, the water from which is collected in reservoirs and distributed through a traditional system whereby groups of 7 households take turns irrigating their fields. This semi nomadic community is famous for its livestock (yaks, sheep and goats) and it grows barley, local pea or potatoes (and a hybrid pea introduced recently by SKUAST). However, water is so scarce that some land has to be left fallow every year. According to the Goba (village head), there were complete crop losses in 200-05 and 2018 due to water shortage. Mudh is one of two villages selected by LNP for construction of AG (with funding from ELRHA) as a part of this project .

18. TSAGA (LNP): Situated at 220 kms from Leh in the eastern end of Changthang near the Chinese border, Tsaga is a medium sized village of around 100 households with a natural glacier of its own. The population is semi-nomadic and depends heavily on livestock (yak in particular), agriculture and labour work for its livelihood. Like Mudh and Chhushul in its neighbourhood, farmers grow barley, local pea and potatoes as its main crops. Tsaga keeps facing scarcity of water during spring time and, as a result, some land has to be left fallow every year. Tsaga is another village chosen by LNP for construction of AG as a part of COWLAG project (under ELRHA)..

In addition to the above five more villages in Leh district, i.e. Leh town (Gangles), Phyang, Gya/Rumtsey, Satshey dho, Washudho, Skyurbuchan, and Tarchit built 'Ice stupas' between 2018 and 2020. In 'Ice stupa' competition, 8 villages from Kargil also took part during this period. These are Lamtso, Karath, Chiktan, Stongsdey, sandho, Mulbek, Sanjak and Apathy.

Annexure 2:
A comparison of villages/hamlets in Leh District in terms of their water situation during sowing season

HH= No. of Households,
WS= Water Source (G= Glacier, R=River, S=Spring),
O= Other (pipe, ground water),
VR= Vulnerability Ranking (HV= Highly Vulnerable, V= Vulnerable, LV= Less vulnerable)

Leh Block				
S. No.	Village/Hamlet	HH	WS	VR
1.	Bazgo	180	G	LV
2.	Choglamsar	170	R	LV
3.	Solar colony	900	O	LV
4.	Likir	170	G	V
5.	Ney	110	G	LV
6.	Nemo	170	G	LV
7.	Phyang	440	G	V
8.	Rumbak / Yurutsey	21	G	HV
9.	Skyu-Kaya	30	G	LV
10.	Jingchen	5	G	LV
11.	Cheling	15	G	LV
12.	Hankar/Doltklung	20	G	V
13.	Rumchung	5	G	LV
14.	Sumdha Chun	10	G	LV
15.	Sumdha Chenmo	10	G	LV
16.	Sumdha Dho	10	G	LV
17.	Tsogsti	5	S	V
18.	Sabu	290	G	HV
19.	Spituk	160	R	LV
20.	Phay	70	S/G	HV
21.	Pharka	25	R	LV
22.	Agling	25	R	LV
23.	Palam	30	R	LV
24.	Taru	110	S	HV
25.	Umla	25	S	HV
26.	Leh town	5000?	G/O	V

Diskit Block Nubra				
S. No.	Village/Hamlet	HH	WS	VR
1.	Bogdang	330	G	LV
2.	Chulunkha	50	G	LV
3.	Diger	65	G	V
4.	Tangyar	45	G	LV
5.	Khema	25	G	LV
6.	Khyungru	20	G	LV
7.	Diskit	340	G	V
8.	Hunder	314	G	V
9.	Khardong	170	S	LV
10.	Pharka	30	G	LV
11.	Rongo	12	G	LV
12.	Rongjuk	13	G	LV
13.	Khalsar	35	S	LV
14.	Lakjung	35	R	LV
15.	Tsati	30	G	LV
16.	Tirith	40	G	LV
17.	Partapur	170	G	LV
18.	Skamphuk	120	S	LV
19.	Hunder Dok	30	G	LV
20.	Tyakshi	250	G	HV
21.	Thang	20	G	LV
22.	Tertsey	60	G	LV
23.	Skuru	50	G	LV
24.	Rakuruk	10	G	LV
25.	Largyap	40	G	LV
26.	Patsathang	60	G	LV
27.	Turtuk	300	G	LV
28.	Utmaru	90	G	V
29.	Hundri	50	G	V
30.	Waris	40	G	LV
31.	Phastan	10	G	LV

Nyoma Block Changthang				
S. No.	Village/Hamlet	HH	WS	VR
1.	Chuma thang	90	G	V
2.	Mahey	30	G	LV
3.	Kairey	13	G	V
4.	Kotsa ??	250	G	LV
5.	Pongok/Kungi	70	G	LV
6.	Buk Shadho	35	G	LV
7.	Naga	15	G	LV
8.	Gonpa	20	G	LV
9.	Khaldo	75	G	LV
10.	Himya	50	G	LV
11.	Tarchit	60	G	LV
12.	Kharnak	35	G	LV
13.	Korzog	125	G	LV
14.	Kuyul	90	G	LV
15.	Demchok	25	G	LV
16.	Kyungyam	50	G	LV
17.	Kumdok	20	G	LV
18.	Tiri	35	G	LV
19.	Liktsey	30	G	LV
20.	Phulak	25	G	LV
21.	Tukla	30	G	LV
22.	Nyoma	100	G	HV
23.	Nyidhar	45	G	V
24.	Mudh	70	G	HV
25.	Samadh	70	S	V
26.	Skitmang	50	G	HV
27.	Kesar	17	R	V
28.	Nee	16	G	HV
29.	Sriyul	10	G	V
30.	Tsaga	40	G	HV
31.	Rongo	60	G	LV
32.	Chumur	60	G	V

Durbuk Block Changthang				
S. No.	Village/Hamlet	HH	WS	VR
1.	Chushul	150	G	V
2.	Durbuk	140	G	LV
3.	Shayok	25	G	V
4.	Maan	25	G	V
5.	Merak	50	G	V
6.	Spangmik	15	G	V
7.	Phobrang	80	G	LV
8.	Lukung	20	G	LV
9.	Yurgo	80	G	V
10.	Sato	40	G	LV
11.	Barma	20	G	LV
12.	Khera pulu	17	G	LV
13.	Pila Salsal	10	G	LV
14.	Chibra	11	G	LV
15.	Erath	30	G	LV
16.	Chilam	14	G	LV
17.	Pholonglay	12	G	LV
18.	Shachukul	120	G	LV
19.	Pharka	20	G	V
20.	Tangtsey	110	G	LV
21.	Tharuk	70	G	LV
22.	Relay Itching	30	G	LV

Kharu Block

S. No.	Village/Hamlet	HH	WS	VR
1.	Kharu	40	S/G	V
2.	Gya	80	G	LV
3.	Sasoma	35	G	LV
4.	Rumtsey	25	G	LV
5.	Miru	35	G	LV
6.	Upshi	20	G	LV
7.	Tuna	7	S/G	HV
8.	Igoo	250	G	HV
9.	Kulum	10	S	HV
10.	Himis	22	G	LV
11.	Shang	64	G	LV
12.	Changa	65	G/R	LV
13.	Martselang	85	G	LV
14.	Sakti Takar	200	G+S	V
15.	Sakti Tagnak	210	G+S	V
16.	Shara	180	G	HV
17.	Chemday	300	G	V

Chushot Block

S. No.	Village/Hamlet	HH	WS	VR
1.	Chushot	1100	R	LV
2.	Matho	456	G	V?
3.	Nang	70	G	HV
4.	Rambirpur	140	R/O	LV
5.	Shey	350	R	LV
6.	Stakna	103	R	LV
7.	Stok	387	G	LV
8.	Thiksay	500	R	LV

Panamik Block (Nubra)

S. No.	Village/Hamlet	HH	WS	VR
1.	Yulkham	21	G	V
2.	Burma	20	R	V
3.	Chamshen	75	G	V
4.	Charasa	84	R	V
5.	Sasoma	6	G	V
6.	Changlung	5	G	V
7.	Henachi	20	G	V
8.	Tongstet	50	G	V
9.	Nyungster	15	G	V
10.	Gonbo	5	G	LV
11.	Kimi	30	G	V
12.	Kubet	30	G	V
13.	Ayee	40	S	HV
14.	Aranu	70	G	V
15.	kyagar	200	G	HV
16.	Panamic Yogma	46	G	V
17.	Panamig Gongpa	32	G	V
18.	Murgi	19	G	V
19.	Kuri	44	G	V
20.	Hargam	12	G	V
21.	Pukpuchey	25	G	V
22.	Tagsha	57	G	V
23.	Tirisha	23	G	V
24.	Sumur	200	G	V

Khalstey Block (Sham)				
S. No.	Village/Hamlet	HH	WS	VR
1.	Achina Thang	50	G	LV
2.	Gongma Thang	20	G	LV
3.	Yogma thang	15	G	LV
4.	Lungba	10	G	LV
5.	Dha	40	G	LV
6.	Bema	20	G	LV
7.	Lasthang	20	G	LV
8.	Sanith	25	G	LV
9.	Baldes	20	G/S	HV
10.	Domkhar Gong.	85	G/0	LV
11.	Domkhar Barma	33	G/0	LV
12.	Domkhar Dho	70	G/0	LV
13.	Ursi	25	S	HV
14.	Phanjila	20	G	LV
15.	Hanufata	20	G	LV
16.	Hinju	30	G	LV
17.	Hinjoo Yangtsey + Solpon dok	14	S	V
18.	Hanu gongma	50	G	LV
19.	Hanu yogma	120	G	LV
20.	Hanu thang	40	G	V
21.	Kanji	50	G	LV
22.	Photolalog	20	G	V
23.	Photogsar	50	G	LV
24.	Skyurbuchan	300	G	LV
25.	Tagmachik	70	S	HV
26.	Lehdho	60	S	HV
27.	Urbis	25	G	V
28.	Timisgam	230	G	LV
29	Nurla	50	G	LV
30.	Tia	215	G	LV
31.	Wanla Maal	72	G	LV
32.	Bukbukza	8	G	LV
33.	Zomal	18	G	V
34.	Sheela	12	G	LV
35.	Lamayuru	150	S	HV
36.	Lingshed	80	G	V
37.	Dipling	15	G	V
38.	Yulchung	20	G	HV
39.	Nyarags	20	G	HV
40.	Gongma Skyumfata	15	G	V

Note: Figures given above are approximate only.

Index: HHs= No. of households, WS= water source (R=river, G= natural glacier, S= spring and snow packs, 0= other), VR= vulnerability ranking (HV= highly vulnerable, V= vulnerable, LV= less vulnerable).

Summary

Total number of villages: 215,

Village size: Large (above 200 HHs): 23 (11%),

Medium (50-200 HHs): 56 (26%),

Small/ hamlets (below 50 HHs): 136 (63 %).

Water source:

Glacier: 183 (85%),

Spring/snow pack:17 (8 %),

O= other: 0 (0%), River:15 (7%),

Vulnerability ranking:

HV:25 (12 %), V: 61 (28%), LV:129 (60%)

As evident, 63% of villages in Leh district are small/ hamlets. In addition, around 93% of villages depend on springs/snow packs or glaciers of their own (7% of whom depend solely on river). Moreover, 41% of Ladakhi villages can be categorised as currently vulnerable to the phenomenon of water scarcity (12% of whom can be termed as highly vulnerable).

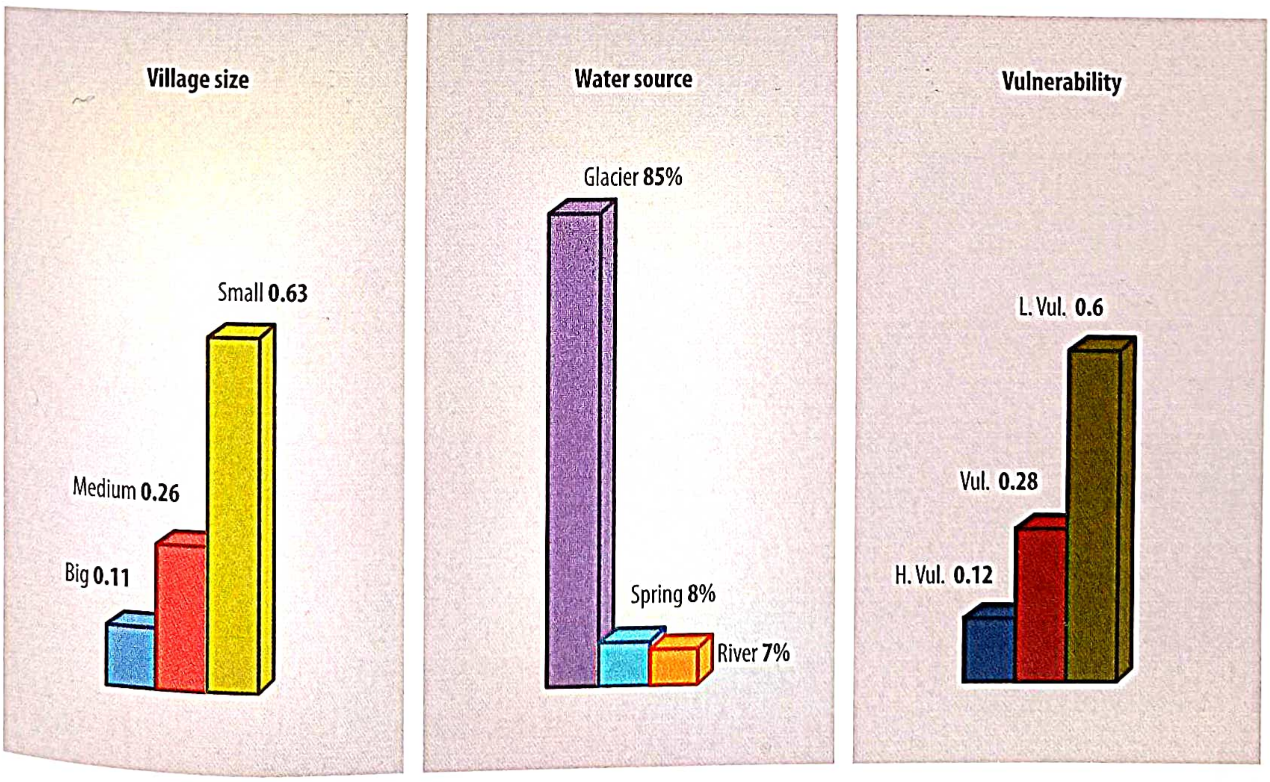
Villages/hamlets categorised as highly vulnerable: 25

Rumbak/yourutsey, Saboo, Phay, Taru, Umla, Tyakshi, Nyoma, Mudh, Tsaga, Sktimang, Tuna, Igoo, kulum, Shara, Ayee, Kyagar, Hipti, Alchi, Baldes, Ursi, Tagmachik, Ledho, Lamayuroo, Youlchung, Nyaragѕ

Villages/hamlets categorised as vulnerable: 61

Likir, Phyang, Rumbak, Hankar/Doltoklung, Tsogsti, Leh, Digger, Diskit, Hunder, Udmaru, Hundari, Chumathang, Kairey, Nyidhar, Samadh, Kesar, Sriyul, Chumur, Chushul, Shayok, Maan, Merak, Spangmik, Yourgo, Pharka, Matho, Kharu, Sakti Takar, Sakti Taknak, Chemday, Youlkham, Burma, Chamshen, Charasa, Sasoma, Changlung, Henachi, Tonsted, Nyungster, Khemi, Kubet, Aranu, Panmik yokma, Panamik Gongma, Murgi, Kuri, Hargam, Phukpuchey, Stagsah, Terisha, Sumoor, Mangyu, Tar, Umlung, Hinjoo Yanggtsey/Solpon dok, Hanuthang, Photolalog, Urbis, Zomal (wanla), Lingshed, Dibling, Gongma-Skyumfata.

Table 5: Status of Ladhaki villages on water scarcity



Annexure 3:
Inputs received on the report during sharing sessions

- Include meteorological data on changes in weather patterns during past few decades, if possible.
- 'Ice Mountains' are also called 'Ice fall'
- Building of basin structures on barren land besides or below the village should be considered wherever possible.
- Status of traditional/indigenous systems, if studied and documented, could be very useful.
- The UT administration has produced a 'water report' which should be read and discussed.
- The practice of watering the fields during winter (khyakchu), thus helping sowing in spring without water, is well established in some villages. This can be promoted in other villages facing water scarcity, if feasible.
- The practice of 'Ice marriage', still followed in Baltistan as a tradition, needs to be studied as well.

Annexure 4:
References

Clouse, Carey 2014, Dollfus, Pascale 2013, (2019, Harvey (2022) ICIMOD (2019), IPCC (2019) LEDeG, HIAL, Hock et al 2019, Nusser et al 2019, LEHO, Vince 2019, Wester et al 2019.

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Enabling a sustainable Ladakh