Disaster Risk Reduction Sector – PDNA

A Case Study of Joshimath Town, Garhwal Himalaya

Training Programme on

Post Disaster Needs Assessment (PDNA): Disaster Recovery Practices

December 28-30, 2023

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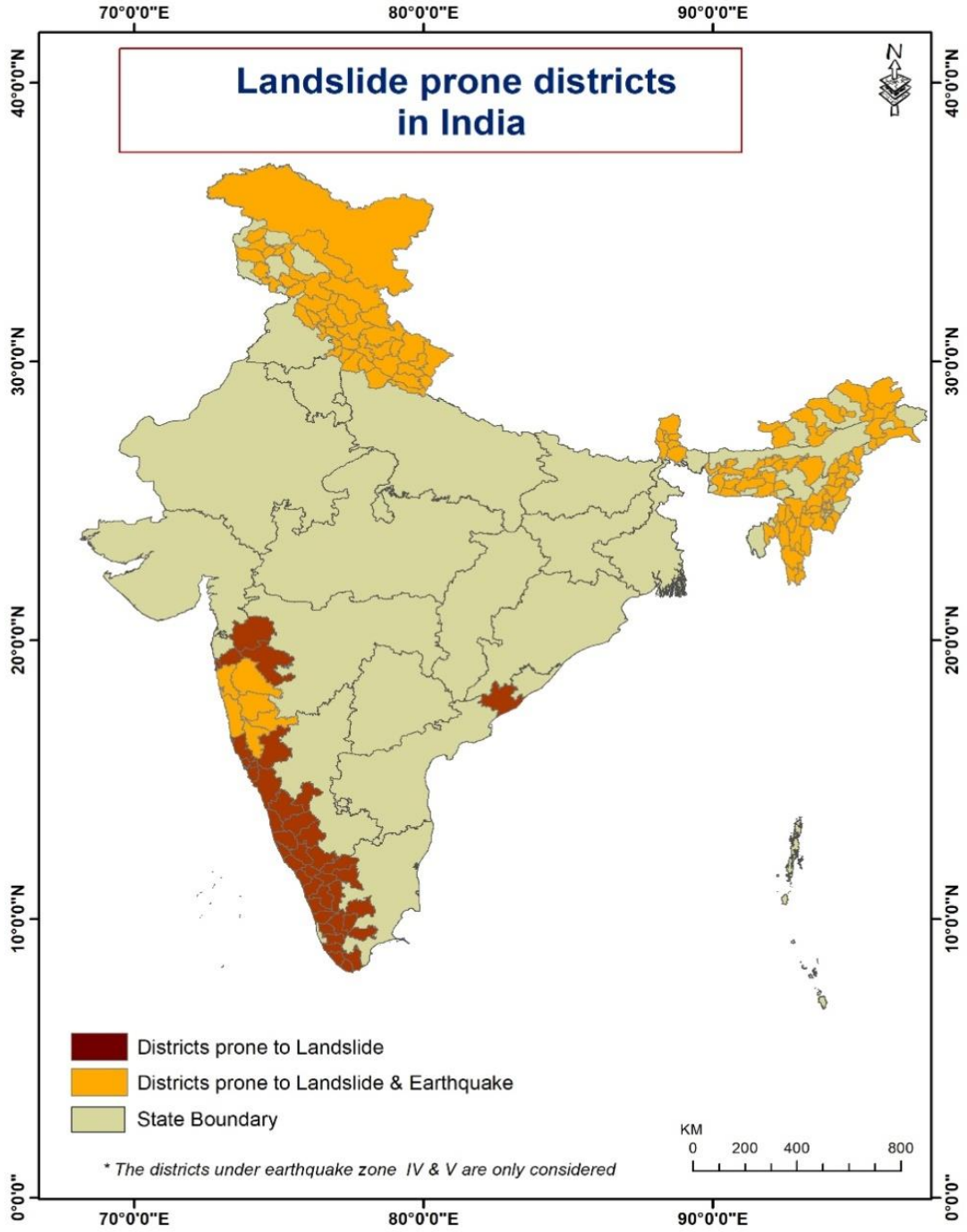
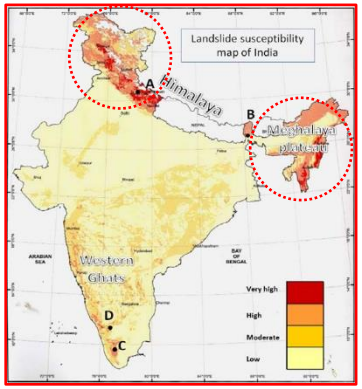
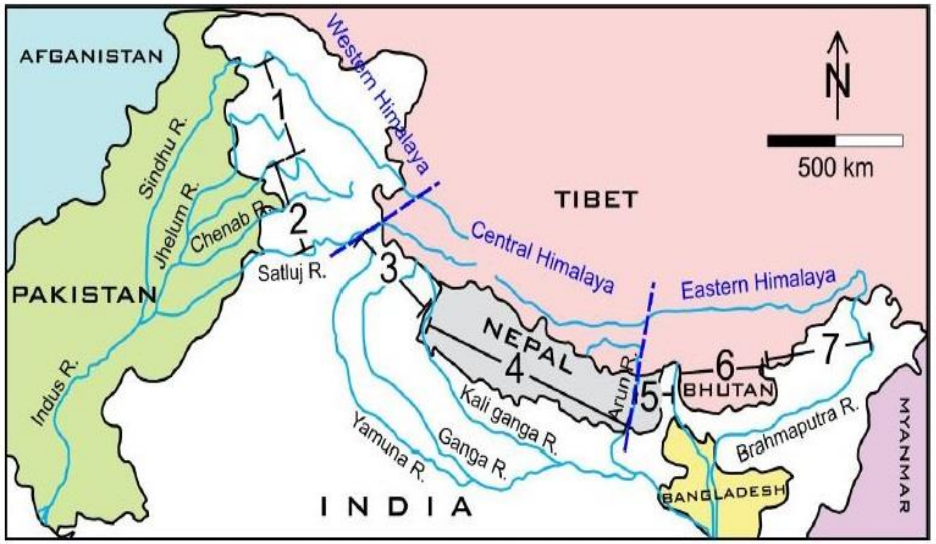
MITIGATION
PREPAREDNESS
CAPACITY BUILDING
PREVENTION
DISASTER MANAGEMENT
ASSESSMENT
RESPONSE
IMMEDIATE RELIEF
RECONSTRUCTION
REHABILITATION


Landslide prone districts in India
70°0'0"E
80°0'0"E
90°0'0"E
40°0'0"N
30°0'0"N
20°0'0"N
10°0'0"N
0°0'0"
N
Districts prone to Landslide
Districts prone to Landslide & Earthquake
State Boundary
* The districts under earthquake zone IV & V are only considered
KM
0 200 400 800

Fragile Himalayas





- immature geology
- unstable geological structures
- rugged topography
- triggering factors like earthquake forces & heavy precipitation

Earthquake
Landslide
Flash Flood, GLOF & LLOF
Drought
Cloud Burst
Snow and Rock-Ice Avalanches

- Very *destructive* and *unpredictable* natural processes in mountain regions worldwide
- Capable of travelling a long distance with a rapid to extremely rapid velocity
- Engulf properties, people, engineering infrastructures etc.

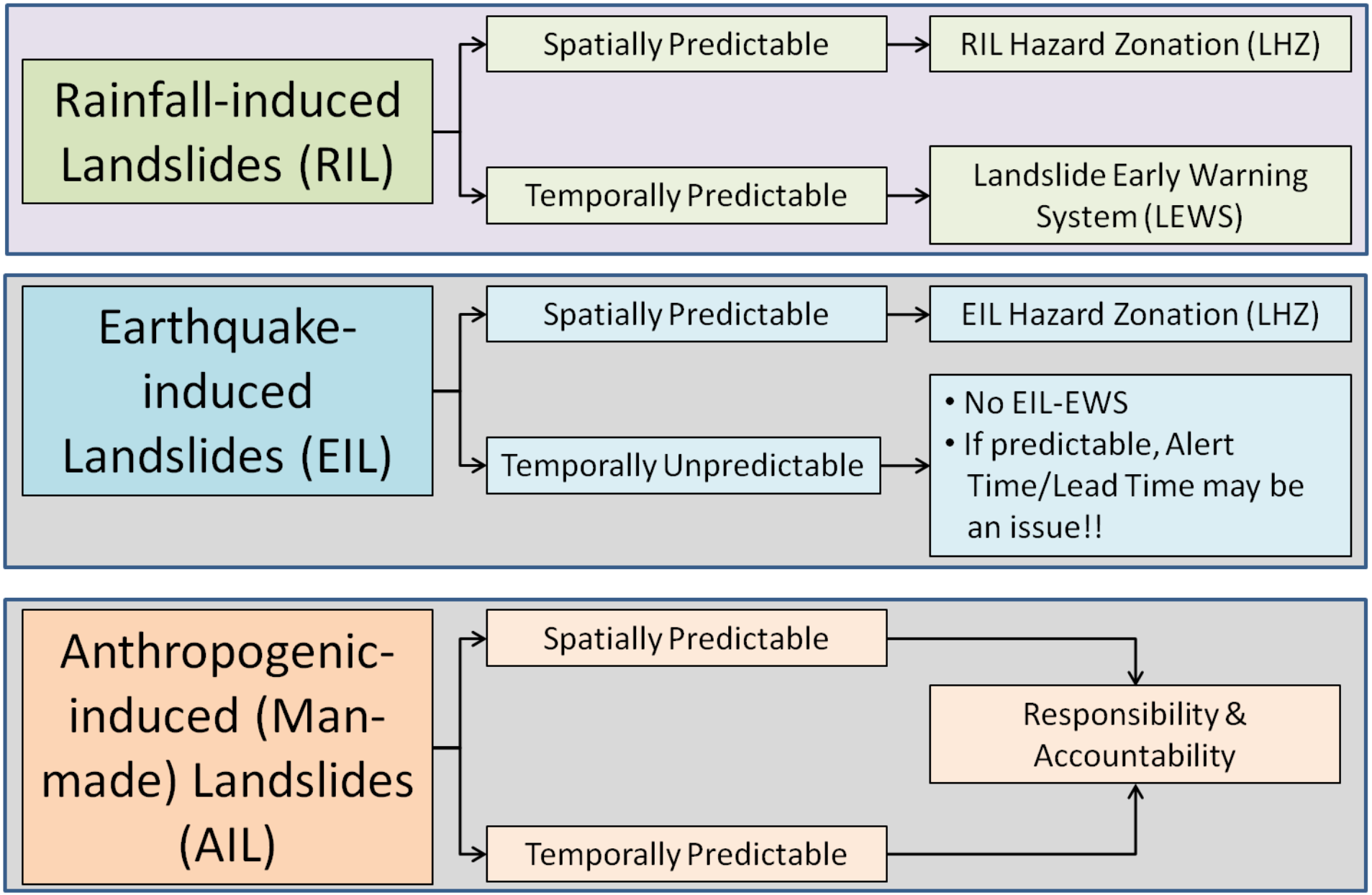
LANDSLIDE DISASTERS

Rainfall-induced Landslides

Earthquake-induced Landslides

Anthropogenic-induced (Man-made) Landslides

LANDSLIDE DISASTERS



Overview of the Major Disasters in Uttarakhand (Last three decades) and its impact on the community

1991 Uttarkashi Earthquake: 6.8 magnitude, 768 lives lost and thousands of homes destroyed

1998 Malpa Landslide: 255 lives lost, including 55 Kailash Mansarovar pilgrims

1999 Chamoli earthquake: 6.6 magnitude, over 100 lives lost and the adjoining Rudraprayag district heavily affected

2013 Uttarakhand Flood: >5,700 lives lost, bridges and roads were destroyed, more than 3 lacs people trapped in valleys leading to Char Dham

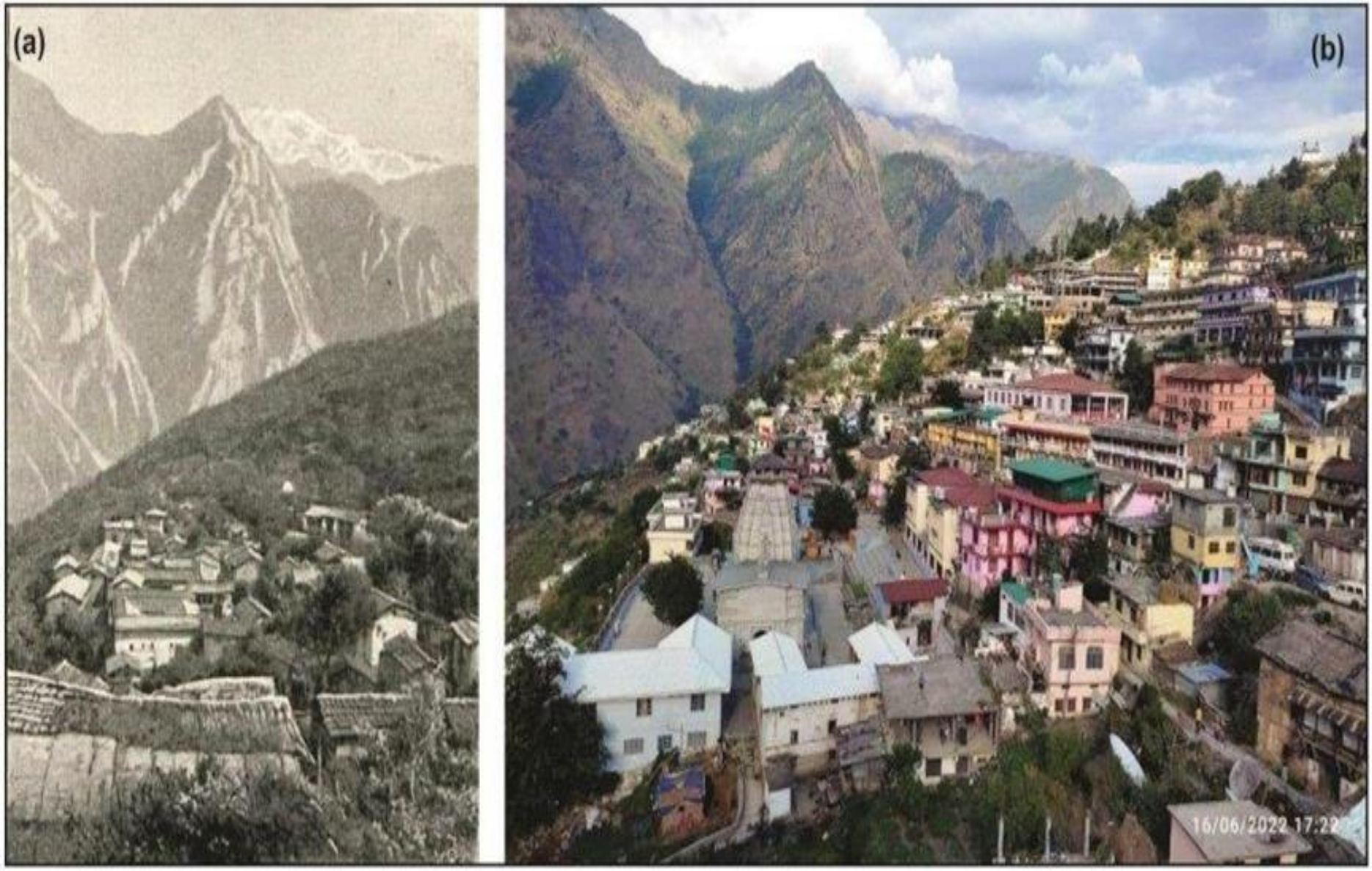
2021 Uttarakhand flood (Chamoli disaster): 200 lives lost, Tapovan-Vishnugarh Hydropower project badly affected

2023 Joshimath Land Subsidence

PDNA Sectors

- Housing and Resettlement
- Public Buildings - Education, Health and Civic Amenities
- Tourism
- Drinking Water and Sanitation
- Local Level Infrastructure (Roads, Bridges, Power etc.)
- Disaster Risk Reduction & Environment

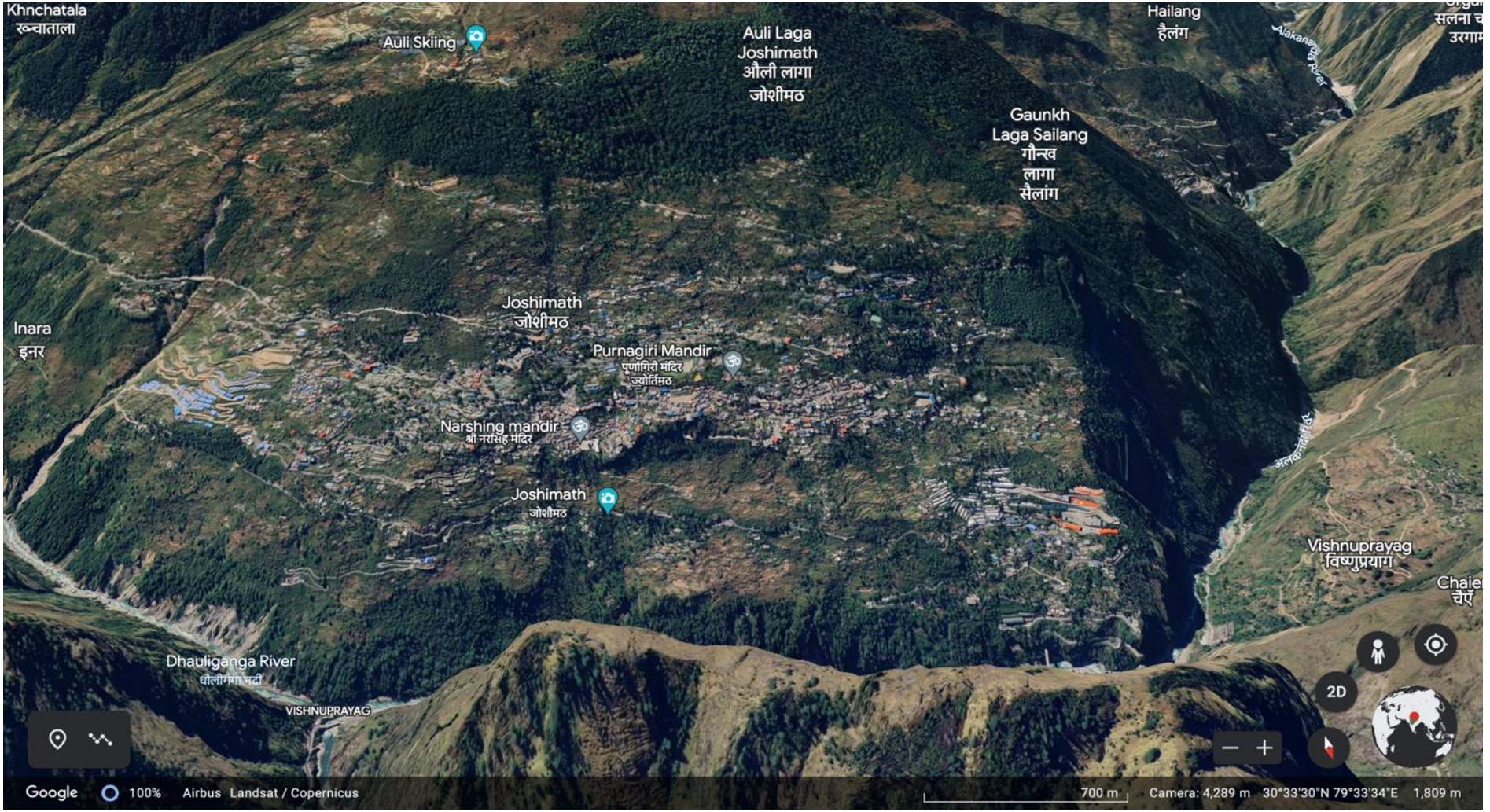
Joshimath Landslide and Subsidence Crisis - 2023

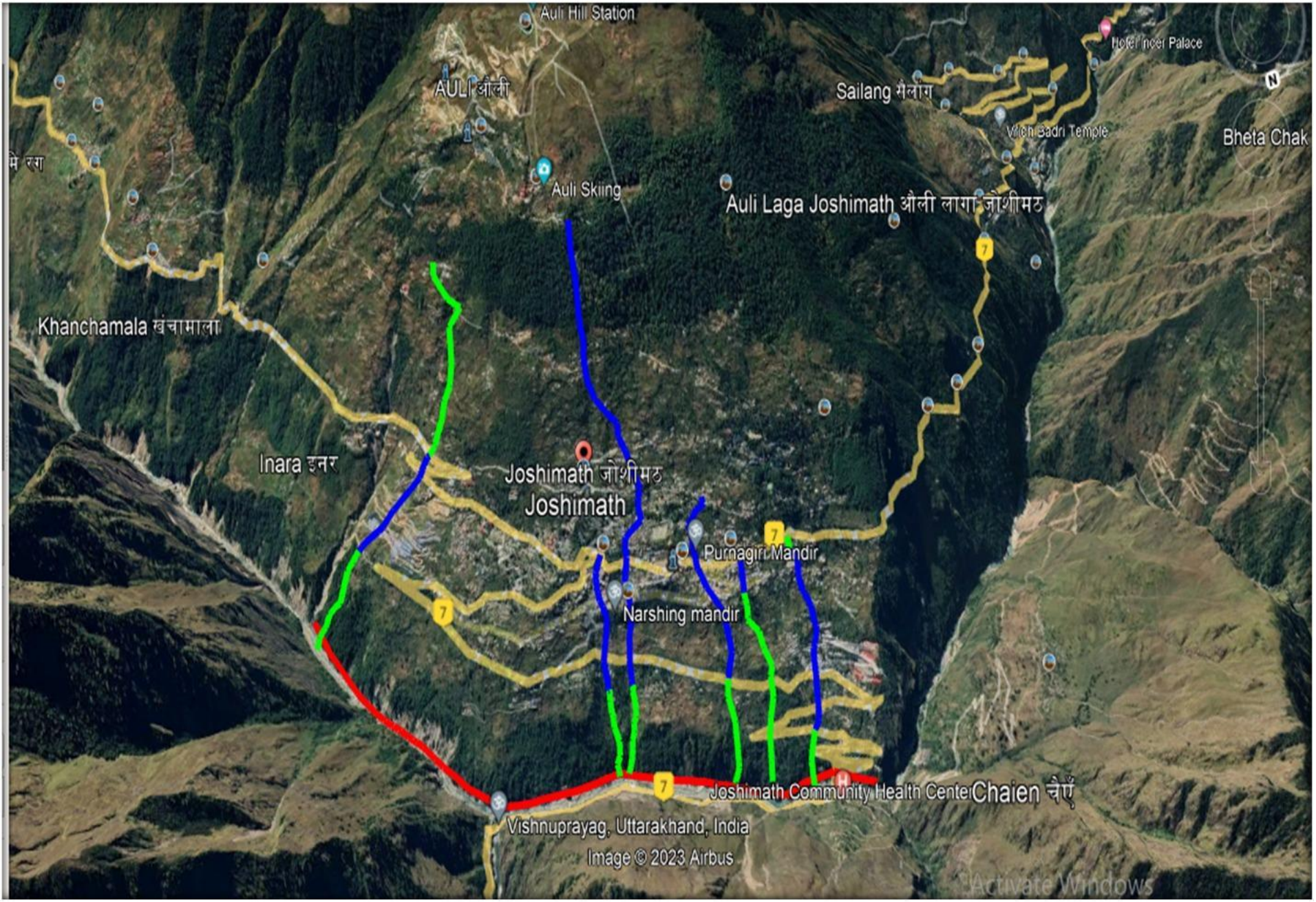


(a) Joshimath during 1890 (picture courtesy Dr. Kurt Boeck, “Himalayan Album”, 1894)
(b) Joshimath during June 2022 showcasing unplanned Development

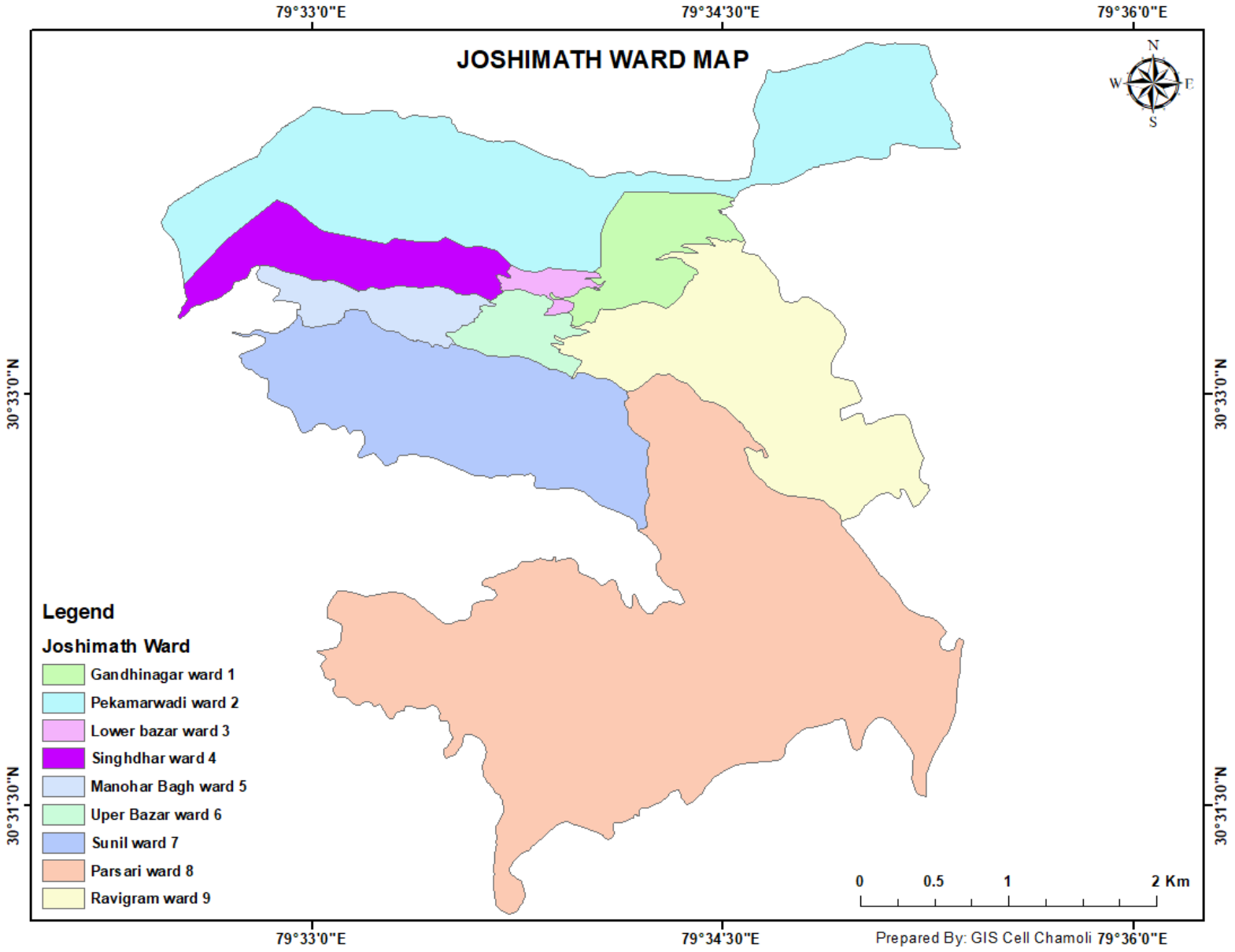
Joshimath

- Located in **Chamoli District, Uttarakhand**
- Average altitude of **1,830 meters above sea level** on the banks of the Alaknanda river
- “Gateway to Badrinath” and winter seat of Adi-shankaracharya
- Largest tehsil, in largest district of Uttarakhand.
- Act as base station for nearby tourist spot - Auli, Badrinath Valley of Flowers and Hemkund Sahib
- Strategic Importance as district shares border with China.(Army and ITBP)


Khnchatala
ख्न्चाताला
Auli Skiing
Auli Laga
Joshimath
औली लागा
जोशीमठ
Hailang
हैलंग
Gaunkh
Laga Sailang
गौन्ख
लागा
सैलांग
Joshimath
जोशीमठ
Inara
इनर
Purnagiri Mandir
पूर्णागिरी मंदिर
ज्योर्तिमठ
Narshing mandir
श्री नरसिंह मंदिर
Joshimath
जोशीमठ
Vishnuprayag
विष्णुप्रयाग
Dhauliganga River
धौलीगंगा नदी
VISHNUPRAYAG
2D
Google
100%
Airbus Landsat / Copernicus
700 m
Camera: 4,289 m 30°33'30"N 79°33'34"E 1,809 m


Auli Hill Station
AULI औली
Auli Skiing
Auli Laga Joshimath औली लागा जोशीमठ
Hotel Ineer Palace
Sailang सैलांग
Vridh Badri Temple
Bheta Chak
Khanchamala खंचामाला
Inara इनर
Joshimath जोशीमठ
Joshimath
Purnagiri Mandir
Narshing mandir
Joshimath Community Health Center
Chaien चैएँ
Vishnuprayag, Uttarakhand, India
Image © 2023 Airbus

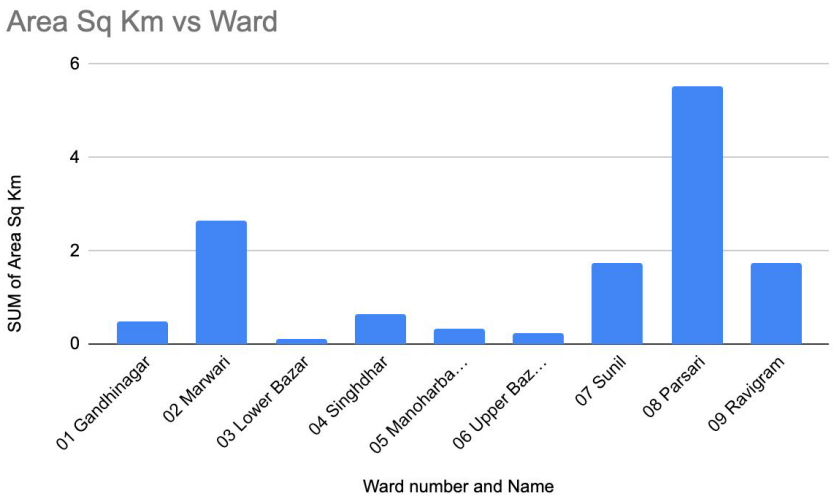
Municipal Wards of Joshimath Town



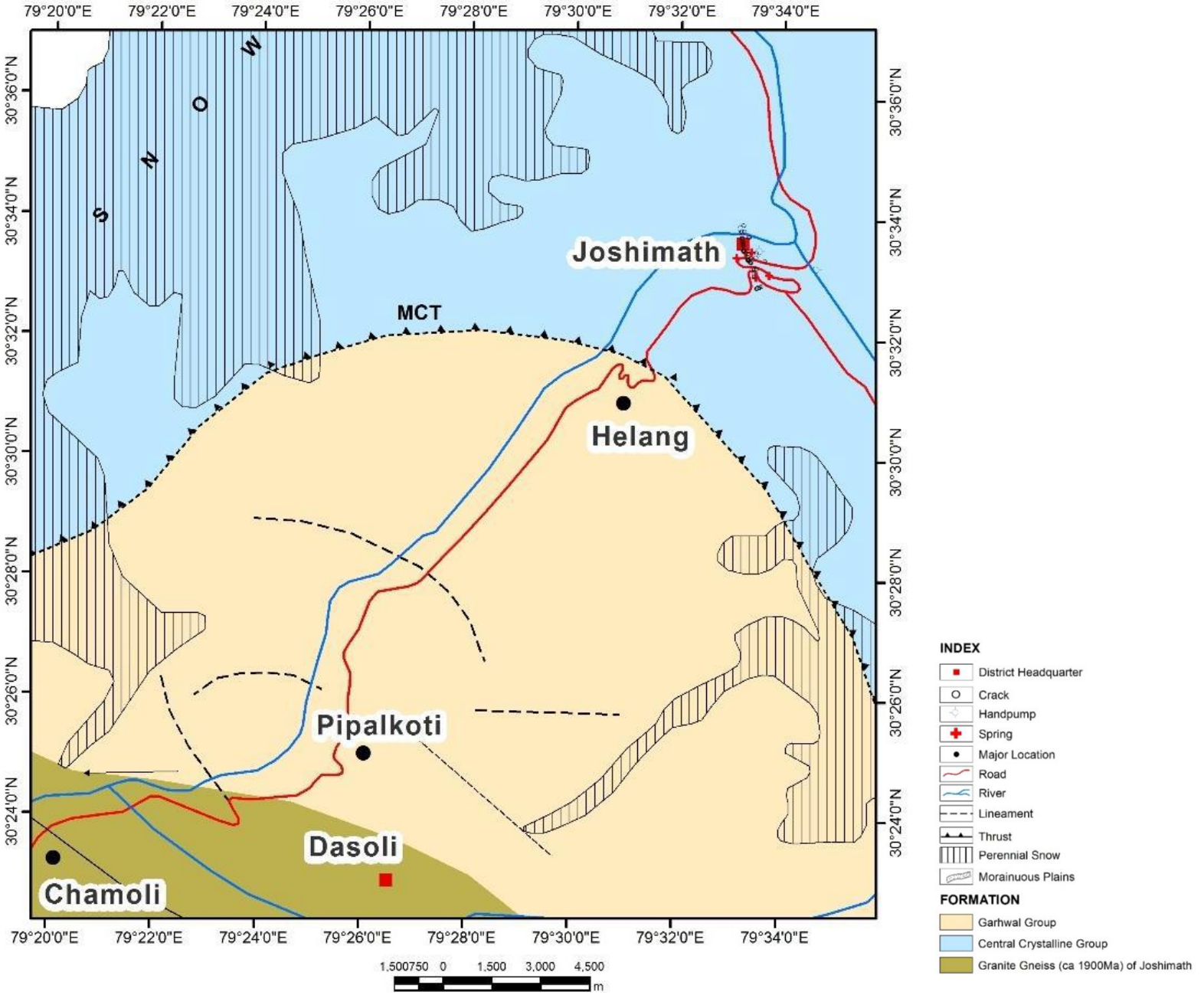
Demography of Joshimath Town

Joshimath Profile (Census 2011)			
Ward Name	**Area (Hectares)**	**Population**	**No. of families**
Gandhinagar	49.4	**3763**	**716**
Lower Bazar	9.71	1472	413
Manohar Bagh	34	1380	354
Marwari	266	1984	508
Parsari	**552**	955	253
Ravigram	174	1766	457
Singhdhar	63	2432	501
Sunil	174	1258	303
Upper Bazar	25	1699	393
Total	**1347.11**	**16709**	**3898**

Joshimath Profile (Estimated 2023)		
Ward number and Name	**Population 2023 (Estimated)**	**Households 2023 (Estimated)**
01 Gandhinagar	3480	696
02 Marwari	1890	378
03 Lower Bazar	1015	203
04 Singhdhar	2335	507
05 Manohar Bagh	1690	338
06 Upper Bazar-dado	2035	407
07 Sunil	**4615**	**923**
08 Parsari	3680	736
09 Ravigram	2655	531
Grand Total	**23395**	**4719**

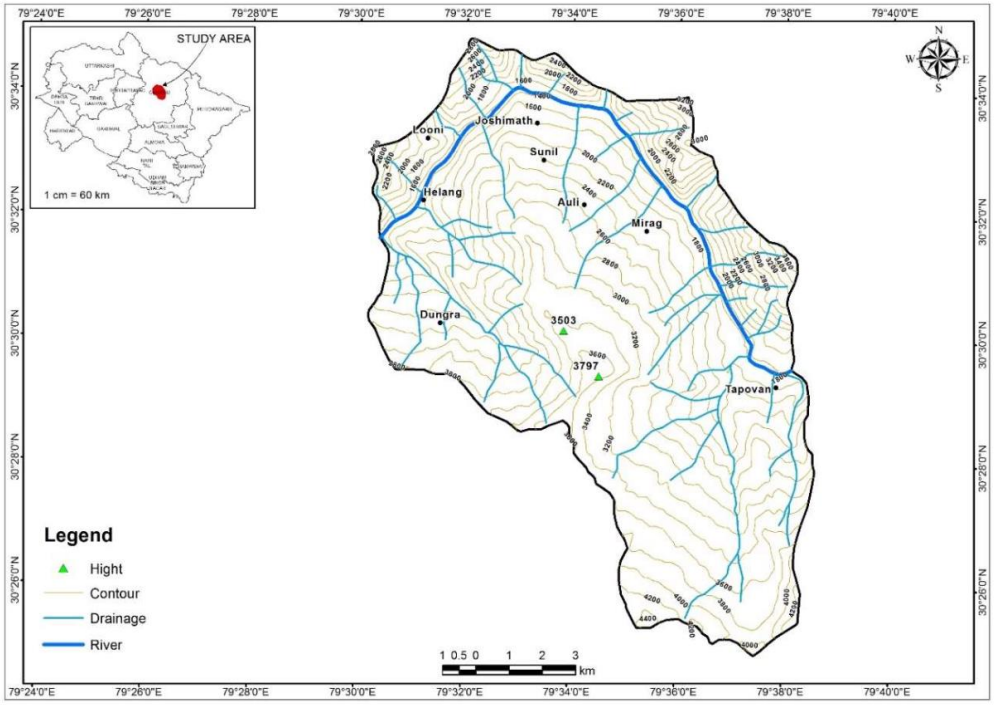


Geology of Joshimath Area



Land-Subsidence Issue

- **2nd January 2023,** Outburst of muddy water observed in Jaypee Colony with a discharge of 600 lpm.
- Between **3rd - 8th January 2023**, major subsidence was observed.
- Situated on an **ancient landslide** made up of **weathered big un-settled boulders** in a loose matrix of fine sandy and clayey material.
- Risk to land subsidence highlighted in **Mishra Committee Report** (1976)
- There is a history of creeping and occasional subsidence in the region.
- The disturbance of aquifers and the hydro-geological environment in the region seems to be the main cause for the sinking of soft-geological strata.
- Subsidence may get accelerated by heavy rains, snow melt, GLOF, ice-fall and earthquakes.

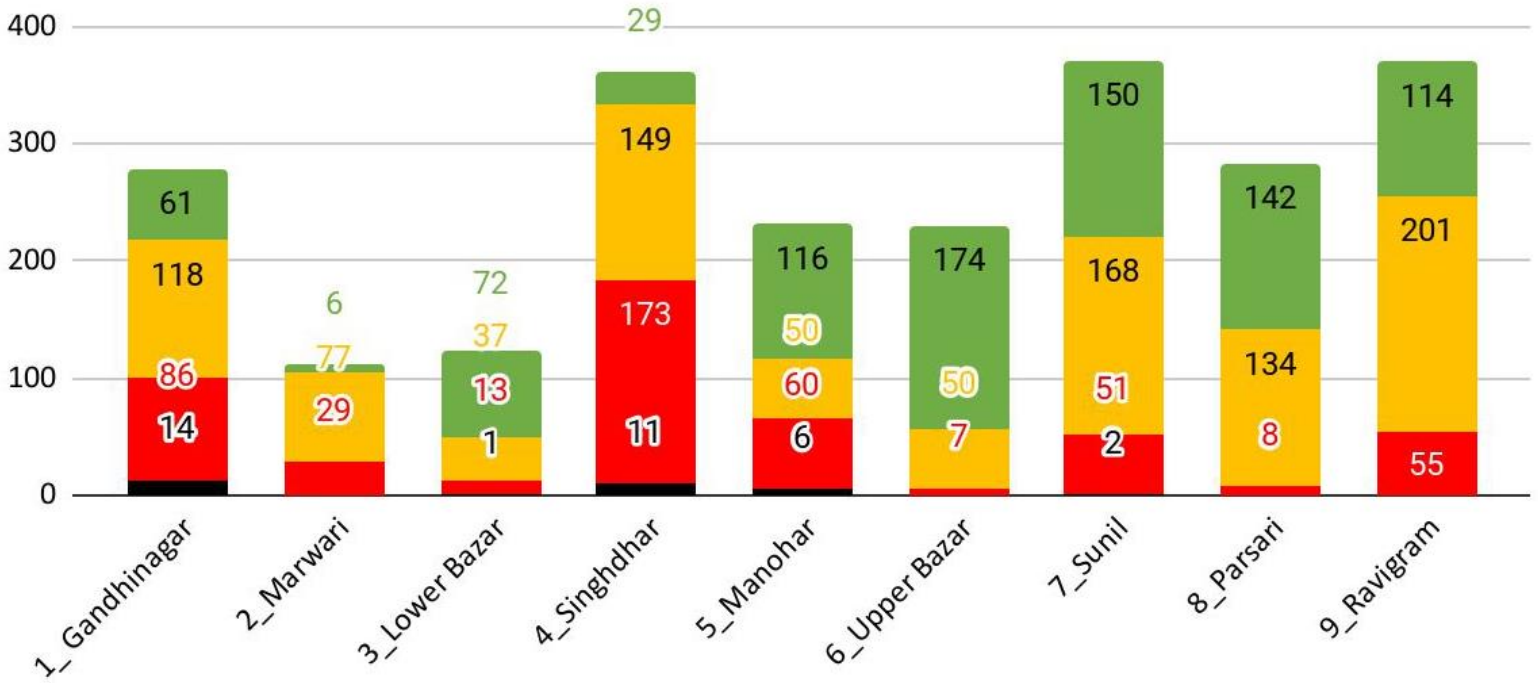


2nd January 2023, Outburst of muddy water observed in Jaypee Colony with a discharge of 600 lpm

1st Week of February 2023, Fresh water observed in Jaypee Colony with a discharge of 5-10 lpm

POST-DISASTER ASSESSMENT

Detailed Damage Assessment of Buildings of Joshimath Town

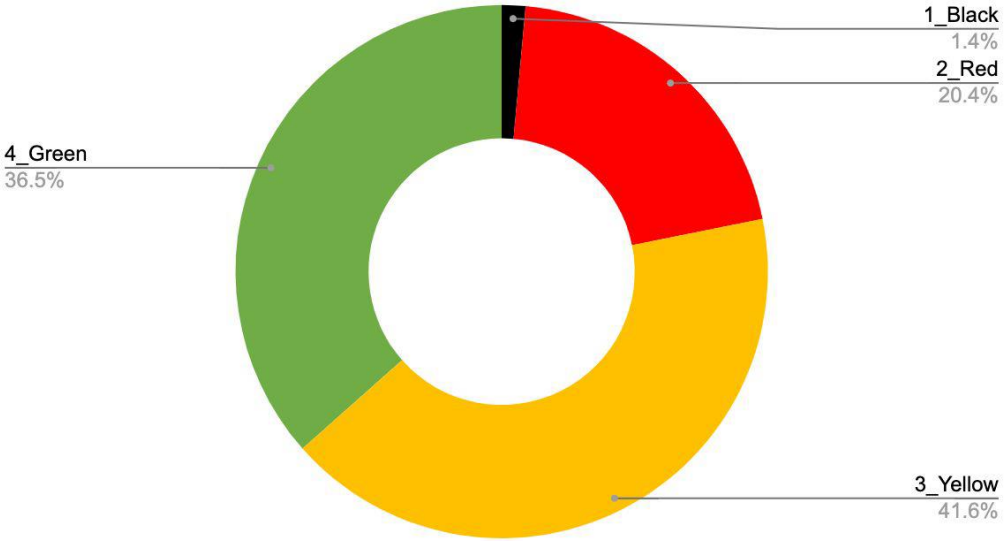


Damage Category	Colour Code	Indication	Suggested Actions
1_Black		Demolish	Demolition of building marked under this category
2_Red		Unusable	Demolition of building marked under this category
3_Yellow		Assess Further	In-Situ Repair or Retrofitting of the marked buildings after further assessment
4_Green		Usable	None

Detailed Damage Assessment of Buildings of Joshimath Town

Final Rating	Number of Building	Total Area (Sq.m)
1_Black	34	4602.46
2_Red	482	71504.23
3_Yellow	984	164871.53
4_Green	864	133410.01
Grand Total	**2364**	**374388.22**

Summary of Building Damages



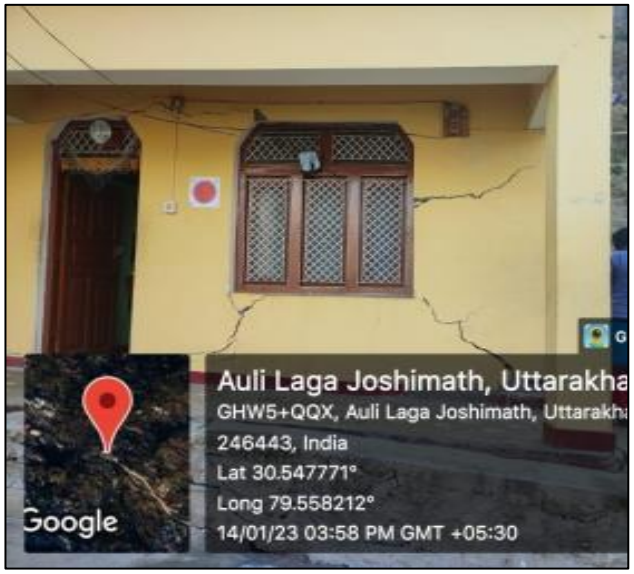
Detailed Damage Assessment of Buildings of Joshimath Town

Sector wise Damaged buildings as per the category

Sector	*Final Rating*	Number of Buildings	Total Area (Sqm)
1_Housing	1_Black	27	3186.54
	2_Red	445	62151.60
	3_Yellow	931	144567.41
	4_Green	749	104945.69
1_Housing Total		2152	314851.24
2_Education, Health and Civic Amenities	1_Black	6	975.92
	2_Red	17	3759.89
	3_Yellow	25	9583.83
	4_Green	42	13397.86
2_Education, Health and Civic Amenities Total		90	27717.50
3_Tourism and Livelihood	1_Black	1	440.00
	2_Red	20	5592.74
	3_Yellow	28	10720.29
	4_Green	73	15066.46
3_Tourism and Livelihood Total		122	31819.49
Grand Total		**2364**	**374388.22**

Failure in Masonry building

Failure of rubble masonry



Diagonal shear Failure of Masonry Infill

Failure of masonry infill

Sliding Shear Failure of Masonry Building

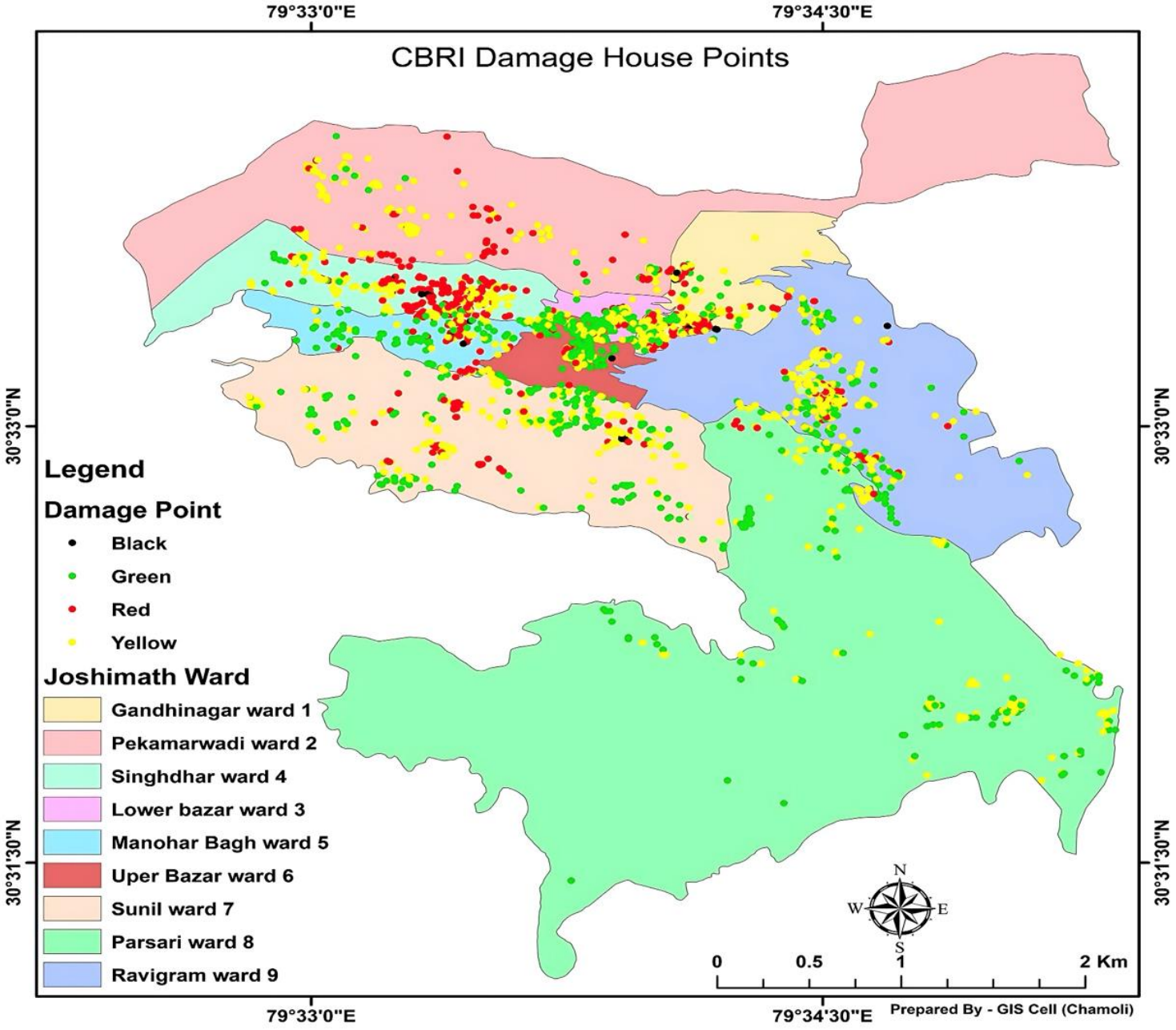
Vertical shear crack along the wall

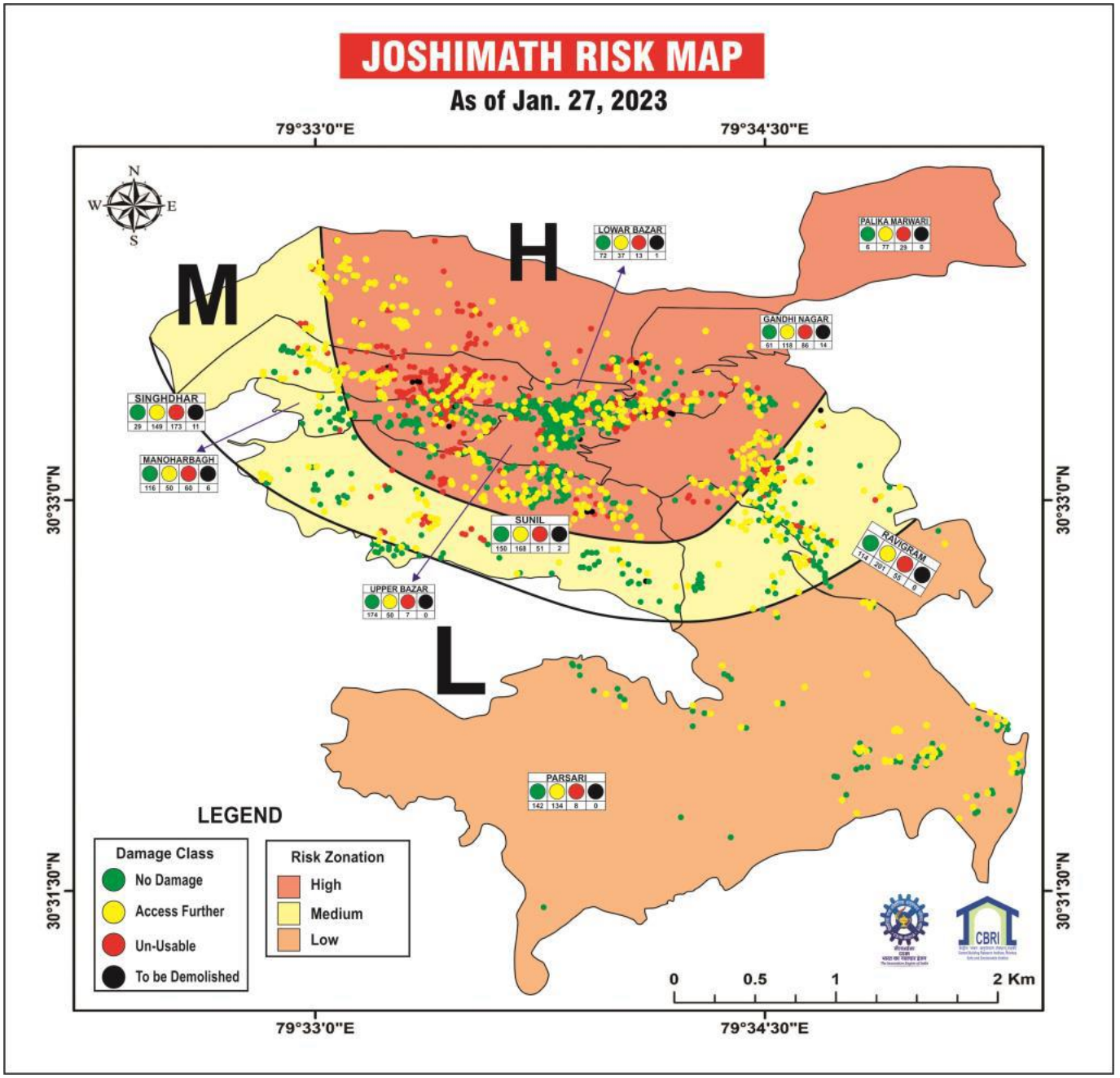
Installed crack meter on the wall

Excessive cantilever projection

Shear Failure at column footing junction

Damage Assessment Distribution of Buildings of Joshimath Town




JOSHIMATH RISK MAP
As of Jan. 27, 2023
79°33'0"E
79°34'30"E
30°33'0"N
30°31'30"N
N
W
E
S
H
M
L
LOWAR BAZAR
72 37 13 1
PALIKA MARWARI
6 77 29 0
GANDHI NAGAR
61 110 86 14
SINGHDHAR
29 149 173 11
MANOHARBAGH
116 50 60 6
SUNIL
150 168 51 2
RAVIGRAM
114 201 55 0
UPPER BAZAR
174 50 7 0
PARSARI
142 134 8 0
LEGEND
Damage Class
No Damage
Access Further
Un-Usable
To be Demolished
Risk Zonation
High
Medium
Low
0 0.5 1 2 Km
CBRI

Drone survey using RGB Photogrammetry sensor (camera) in parts of the affected areas to explore the possibility of interpreting ground based information

Source: CSIR-CBRI

Ortho-mosaic Image (Mission:1)

Resolution: 40 cm

Home Station for Drone Survey

Hotel Malari Inn & Mount View under Demolition

Source: CSIR-CBRI

Orthomosaic Image (Mission:2)

Resolution: 24 cm

Source: CSIR-CBRI

Orthomosaic Images

Mission:3

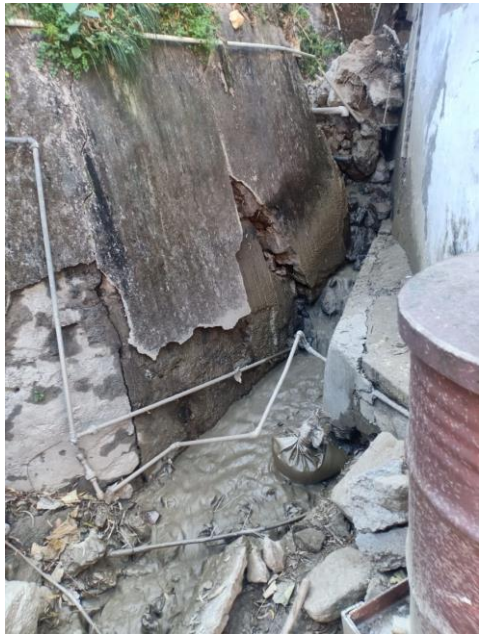
Resolution: 20 cm

Source: CSIR-CBRI

Mission:4

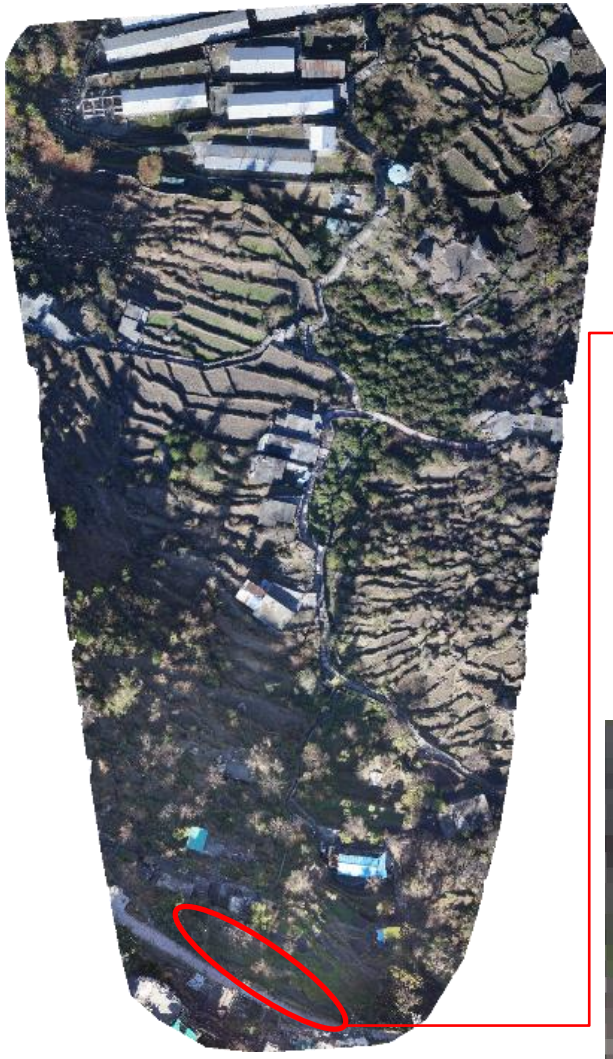
Resolution: 35 cm

Ground Cracks



Source: CSIR-CBRI

Drone based Ground Crack Mapping

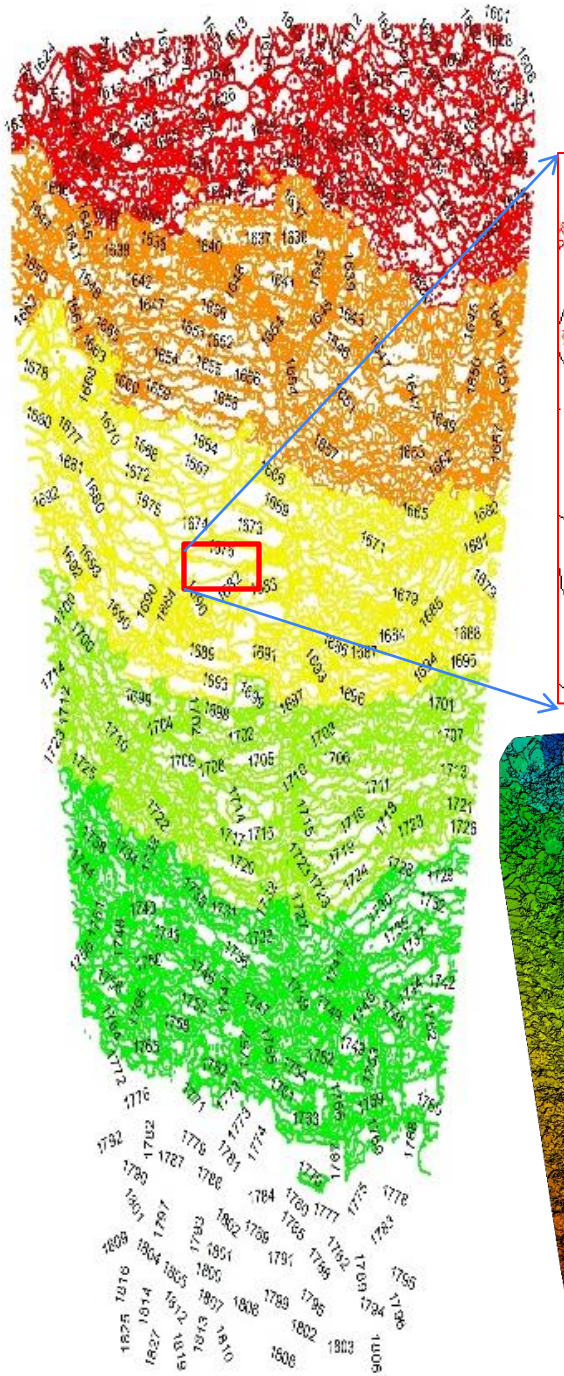


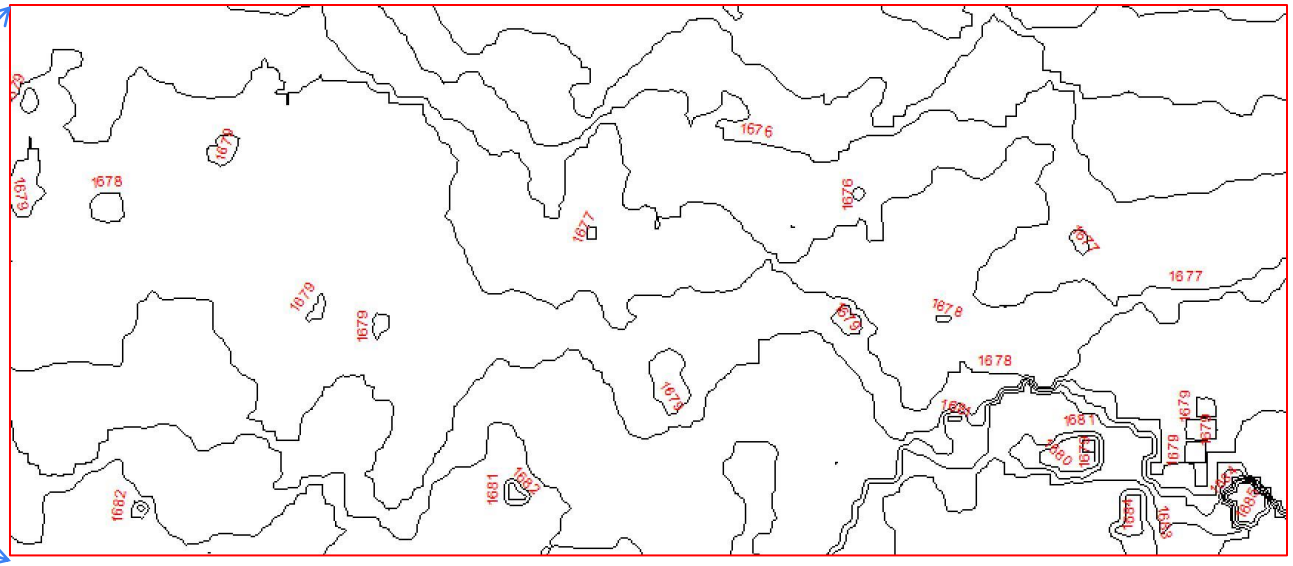
Resolution 20cm

Crack width up to one pixel (i.e., 20 cm)

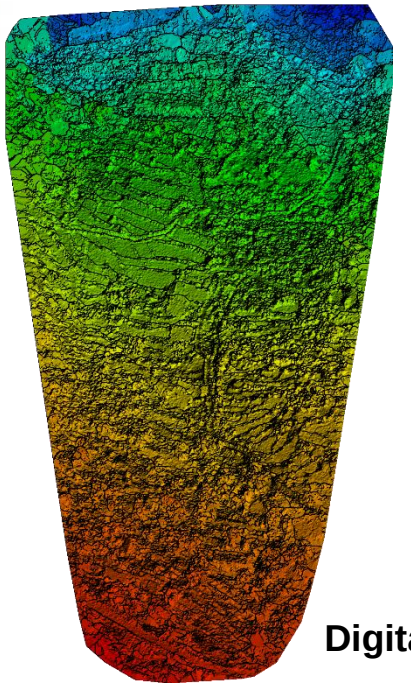
Source: CSIR-CBRI

Drone based Elevation Contouring





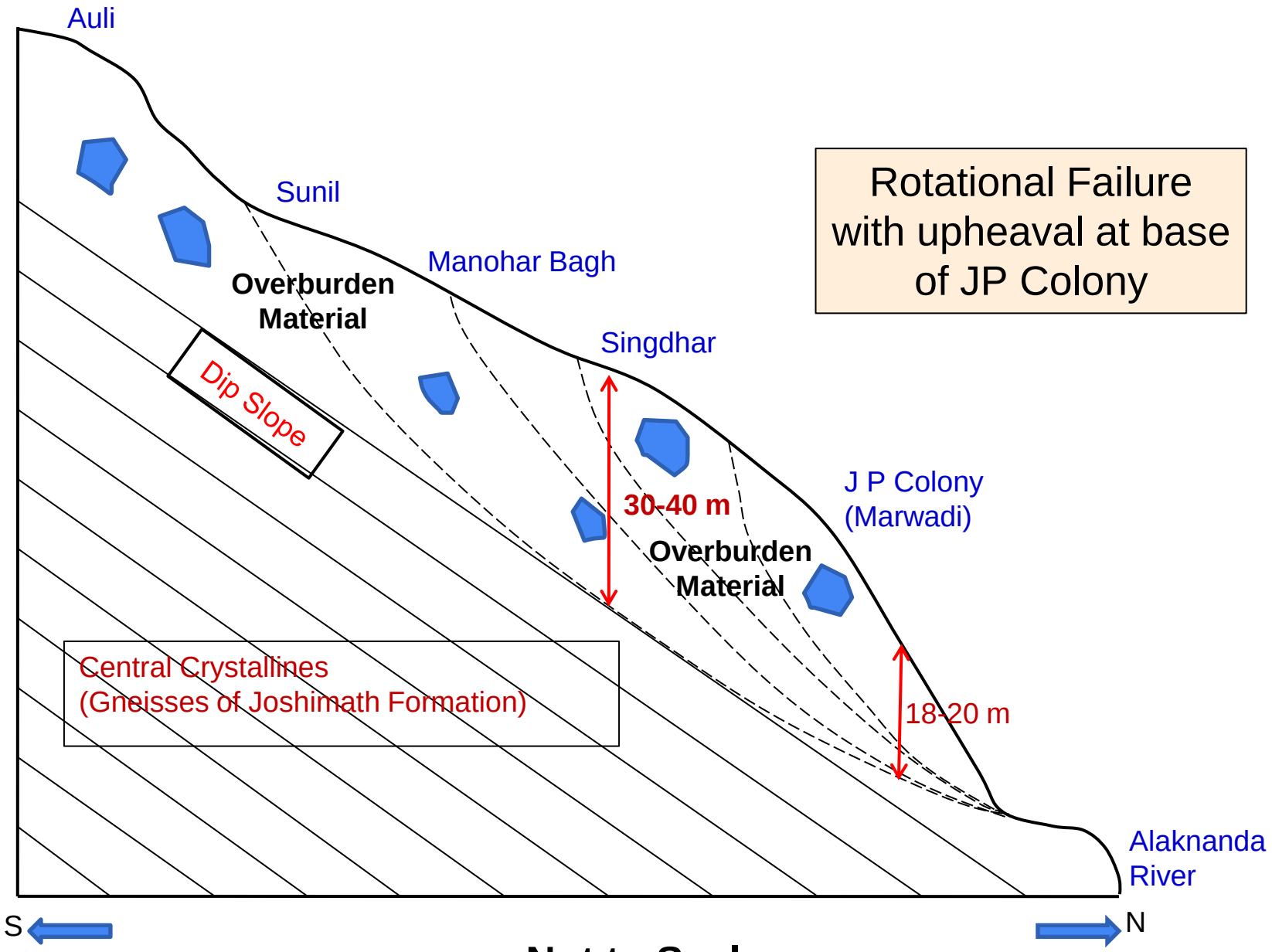
Ground Elevation Contour Map (1 m Contour Interval)



Digital Elevation Model

Source: CSIR-CBRI

Probable Failure Mechanism



Rotational Failure with upheaval at base of JP Colony

Not to Scale

Possible Causes of Instability

Thick Overburden Material

Dip Slope Relation

Hydrologically Active Area

Sub-surface water Saturation leading to Pore Pressure resulting reduction in shear strength of overburden material

Interupted Natural Drainage

Poor/Inadequate Surface Water Channelization

Inadequate Sewerage Water Disposal System

Unplanned construction/loading of vulnerable slope beyond its bearing capacity

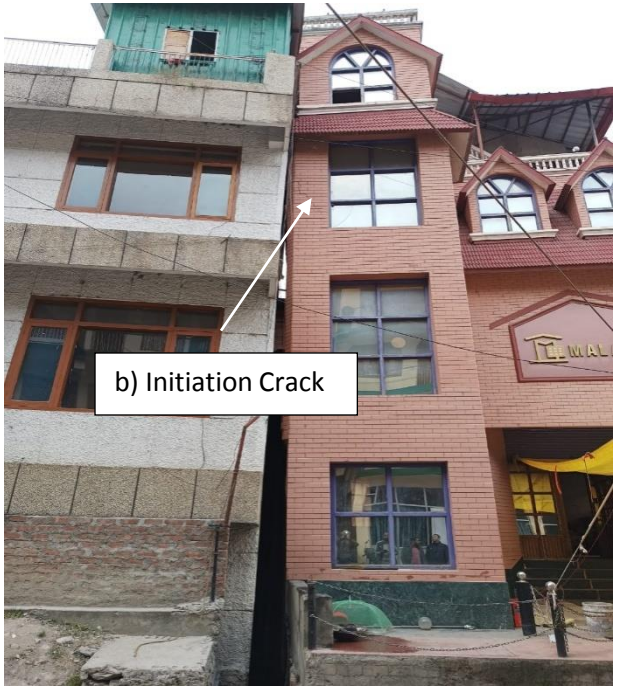
Piping of Finer Material beneath JP Colony through new sub-surface water channel

Pre-demolition Front and Rear Views of Hotels Mount View and Malari Inn

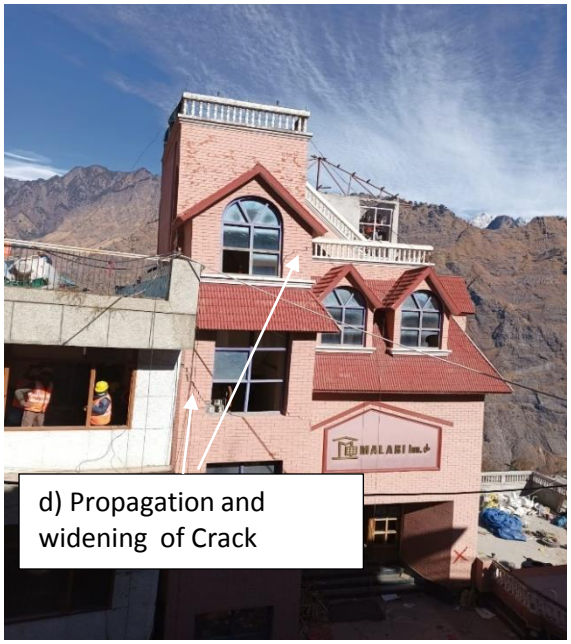
Malari Inn (7 storey including 2 basements)

Mount view (5 storey including 2 basements)


Hotel
Mount View
a) No Crack
Hotel
Malari Inn


b) Initiation Crack


c) Propagation of Crack


d) Propagation and
widening of Crack

To execute the task,

• General guidelines and necessary instructions along with SOPs have been issued to PWD and State Administration.

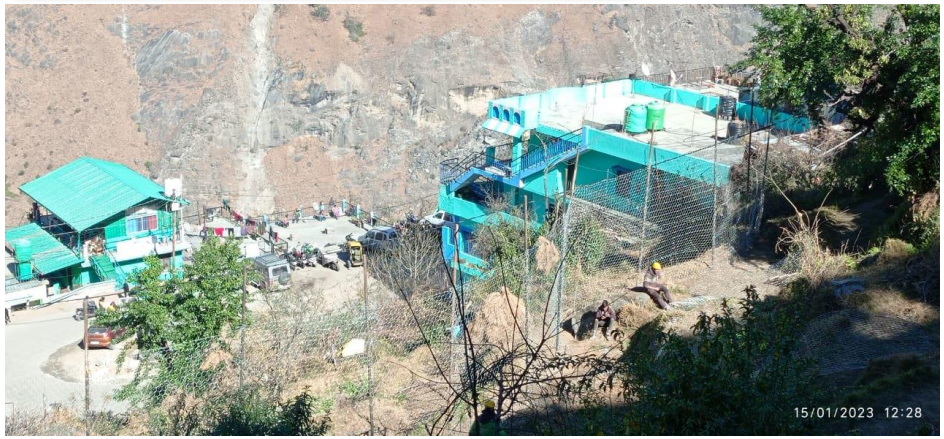
• Safety measures to control the vibration and sudden impact

• It was decided that the two hotel buildings are to be demolished by mechanical means with minimal vibration possible.

• All necessary list of equipment/tools, operators and instruments have been shared with Administration and PWD.

• The administration is requested to deploy SDRF and NDRF with all human safety measures and police force to control the movement of people and vehicular traffic.

Barricading fences on downhill side of hotel buildings to arrest Fly Debris




MALABI Inn.


HYUNDAI

Post-demolition View of Hotels Mount View and Malari Inn

Safe Demolition of PWD Inspection House (RCC Building)

Safe Demolition of Buildings in Manohar Bagh Ward

RCC building demolition

Stone-Mud mortar House under demolition

Safe Demolition of Building in Sunil Ward

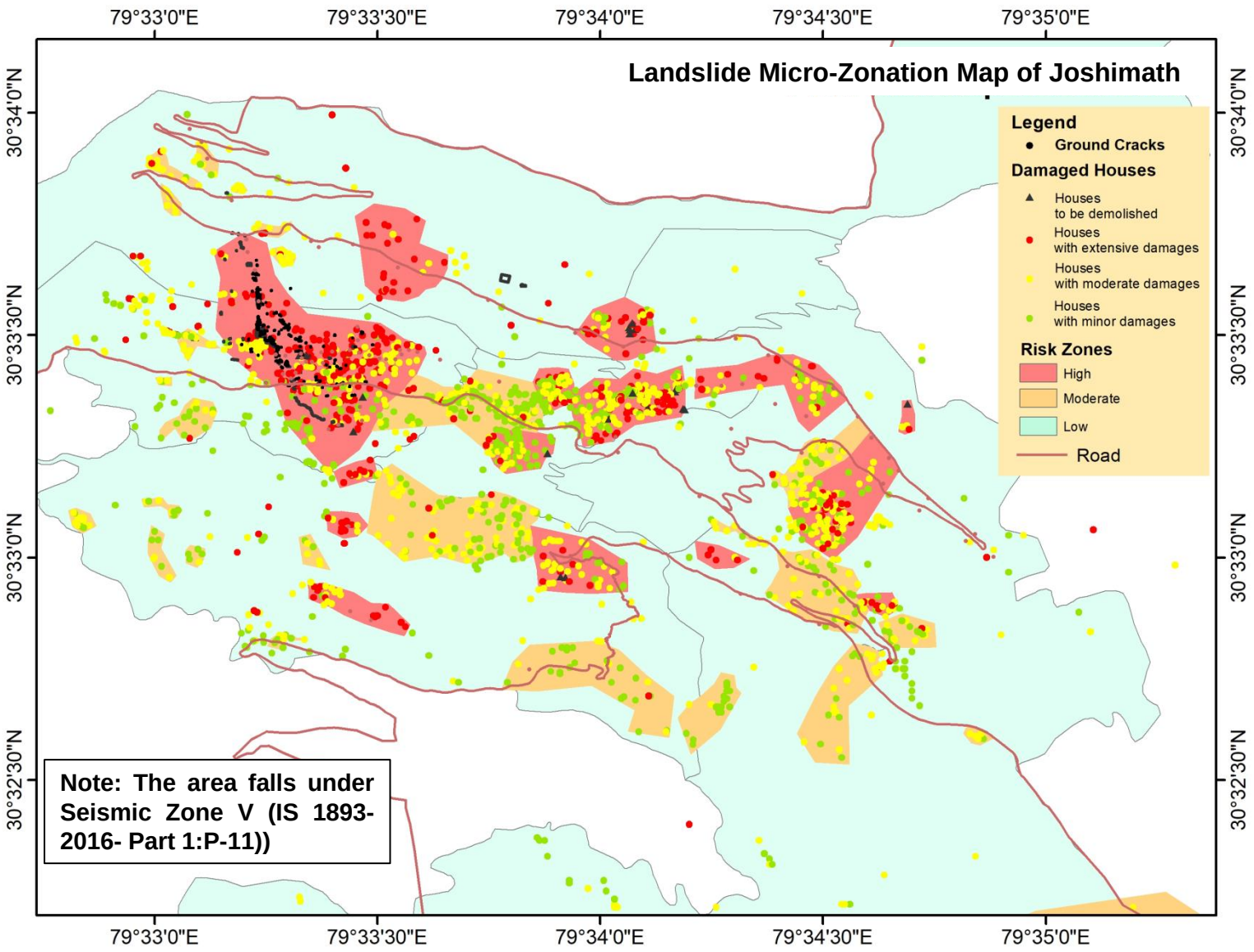
On the spot technical guidance for arresting the huge hanging rock boulders on hill slope in and round the e

POST-DISASTER NEED ASSESSMENT

Disaster Risk Reduction & Environment

- Risk Assessment
- Demolition and Debris Management
- Disaster Risk Reduction Measures including slope stabilization

Risk Assessment



Inputs From:

CBRI, WIHG, GSI, IIRS, NGRI, IITR, NIH,CGWB, ULMMC

IMPORTANT NOTES

The landslide micro-zonation map of Joshimath is prepared based on prevailing ground condition and building damage vulnerability map.

This map is prepared with futuristic perspective subject to reassessment and modification from time to time, specifically in post-monsoon period.

The black (i.e., to be demolished immediately) and red (i.e., unusable) classified buildings are to be demolished on utmost priority and precautions.

The demolition schedule to be prepared and communicated to the owners of the buildings well in advance so that the owners may vacate usable belongings and building materials (door/window panels, water tanks, etc.) from the buildings to be demolished.

The yellow classified buildings in any zone (red/high or orange/moderate or blue/low) are to be strengthened through scientific repair and retrofitting strategies and also to be observed and reassessed during monsoon and post-monsoon period.

Demolition and Debris Management

Sl. No.	Type of Infrastructure	Estimated quantity of Demolition Debris (in cum)
1	Housing	1,14,343
2	Public Buildings	7,311
3	Tourism Infrastructure (Hotels, etc.)	14,582
TOTAL		1,36,236

Recommendation on Demolition of Buildings

The demolition of structures in this populated area should be done under controlled mechanical demolition/dismantling with adequate safety protocol as per the guidelines and SOP provided by CSIR-CBRI.

The District Administration is recommended to prepare a DPR on Demolition Debris Management considering all the environmental safety norms as well as converting demolition waste to wealth adhering to MOEF&CC Construction and Demolition Rules (2016), CPCB guidelines on environmental management of construction & demolition (C&D) wastes (2017) and BMTPC guidelines on utilisation of Recycled Produce of Construction & Demolition Waste - A Ready Reckoner (2018).

The demolition debris may be segregated at demolition site with special focus on reusable building materials which can be utilised in development of resettlement areas.

The District Administration has to identify the debris dumping yards of adequate capacity for dumping all the demolition debris generated from housing infrastructure, public infrastructure and tourism infrastructure with utmost precaution measures such as toe protection wall, surface measures after dumping to void dust pollution and instability of dumping slope, etc.

Disaster Risk Reduction Measures including slope stabilization

Short Term

Crack sealing – The crack sealing may be done with the local material only by side cutting the material from both sides of the crack to maintain material homogeneity. Subsequently, the filled up material may be compacted with hammering by timber/bamboo logs to attain densification. After sealing, the top surface may be levelled and covered either with a layer of bentonite clay slurry or by laying polythene sheets to make the crack section impervious to avoid infiltration of rain water in coming monsoon season.

Channelization of surface water by repairing the damages observed in nalas, cross drains, culverts and their regular cleaning.

Disaster Risk Reduction Measures including slope stabilization

Short Term

Prevention of water ingress through cracks from the sides of the roads.

Proper filling of holes adjacent to the road section.

The shoulders provided on the side of the road should be properly lined with concrete and should be well connected to culvert section to minimise water infiltration.

Removal of deposited debris material on the side drains.

Gabion wall constructed on the valley side to be provided with geotextile at the back face to minimize the loss of fines.

Proper binding of wires and packing of the gabion box.

Disaster Risk Reduction Measures including slope stabilization

Long Term

The DPR has to be prepared prior to the implementation of DRR plans; The DPR must include the followings:

Compilation of all the investigations carried out by different Organisations.

Gap identification for detailed investigation

Detailed geo-investigation including additional topographical, geological, geophysical, geotechnical and hydrological investigations to understand the hill slope and its catchment.

Disaster Risk Reduction Measures including slope stabilization

Long Term

Global stability analysis (both static and dynamic) of different profile sections along the slope using adequate ground parameters to identify stress concentration and weaker portions.

Planning and design of suitable remedial measures

The remedial measures are to be included in different slope profile sections and need to be optimized through stability analysis with adequate factor of safety as per the Indian Standards.

Disaster Risk Reduction Measures including slope stabilization

Long Term

Planning and implementation of drainage management system in the Joshimath area should be given utmost importance to reduce the sub-surface water load on the slope.

Loading through structural measures on the uphill slope must be avoided.

Scientific assessment followed by restoration and conservation of Heritage Zone and Structures in Joshimath area such as Adishankracharya Gaddi, Amar Kalpavriksha, Vasudev Mandir, Nava Durga temple, Gauri Shankar temple, Thiruppirudhi, Ashta Bhuja Ganesh Temple, Maha Laxmi, etc. must be taken up as a DRR initiative.

Disaster Risk Reduction Measures including slope stabilization

Options for Remedial Measures

River training retaining walls at the desired sections of debris overburden.

Pile-pilecap-gabion walls at desired sections where major displacements/deformations have been observed on the downhill side of Joshimath specifically below J P Colony, Manoharbagh and Singdhar.

Flexible retaining structures like gabion walls at desired locations.

Stone walls at desired locations

Provision of rock anchoring for rock slides and rock fall protection measures at desired road-cut slopes with rocky strata.

Disaster Risk Reduction Measures including slope stabilization

Options for Remedial Measures

Drainage Management System

- Proper lining of major 5 nalas
- Repair of cross drains and culverts
- Additional cross drains preferably flexible cross drains with geotextiles and geomembranes.
- Subsurface drainage measures such as perforated drainage pipes rapped with geotextiles to avoid clogging and loss of fines. These drainage measures are to be provided with gabion walls on the road-cut sections to channelize subsurface water to the cross drains.
- Connecting minor natural drainages to the major nalas.

Bio-engineering measures for side slopes of major nalas to avoid soil erosion

Recommendations for DRR

There should be a complete ban on new construction in the entire Joshimath area till the end of coming monsoon. After post-monsoon reassessment of the ground conditions, some relaxation on new construction with prefab light weight structures in comparatively safer areas may be thought of.

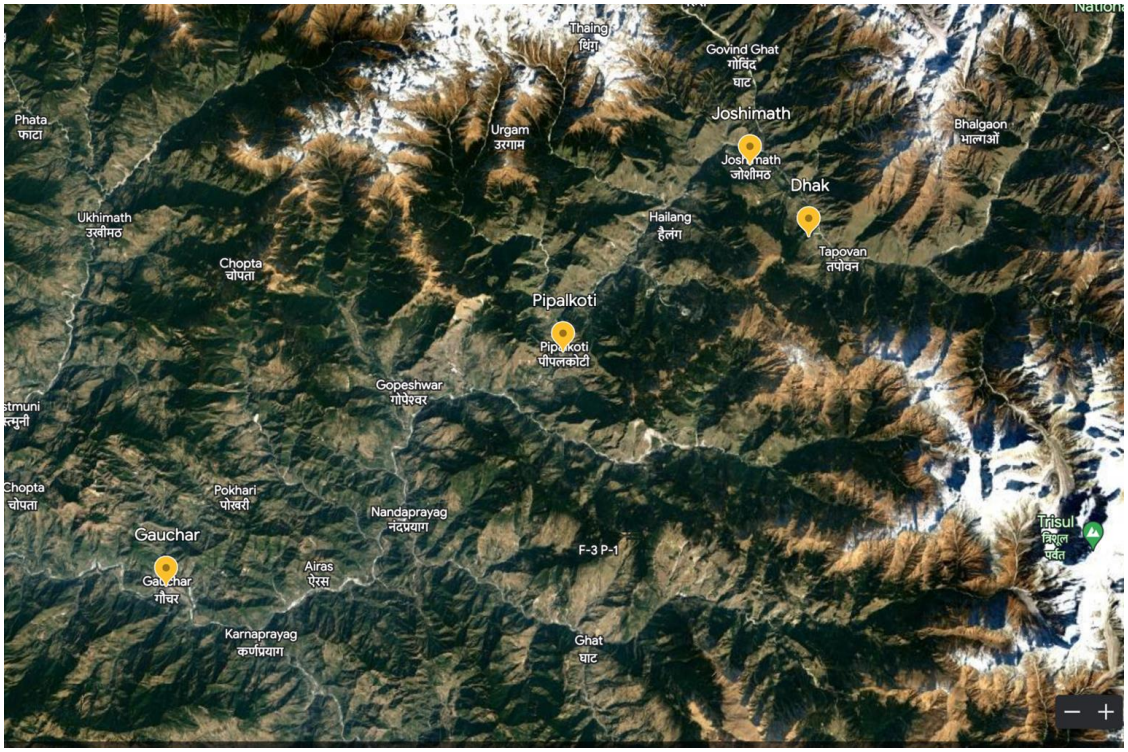
However, retrofitting of the old buildings can be permitted. The permission for single storey public buildings with prefab light weight structures may be permitted for critical emergency services only (Police Station, fire station, hospital, school buildings, etc.).

Proposed Relocation Sites

1. Dhak - 10 Km from Joshimath
2. Pipalkoti - 40 Km from Joshimath
3. Gauchar- 92 Km from Joshimath

Pipalkoti

Dhak



Gauchar Site

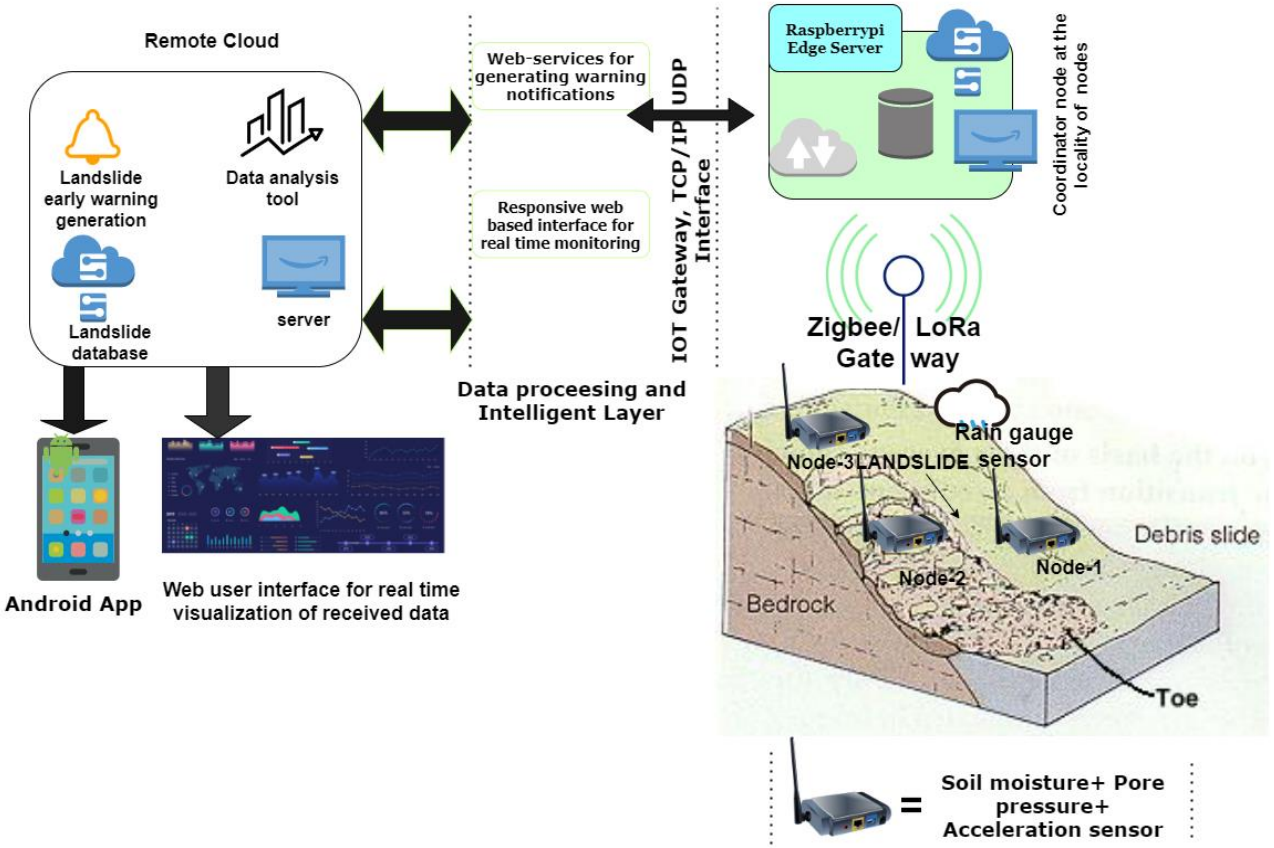
Recommendations for DRR

The base of some of the Ropeway Towers where ground distress has taken place should be examined and suitable measures may be taken to stabilise the area, if possible. Otherwise, realignment of distressed towers to stable and safer locations is recommended.

Assessment, restoration and conservation of heritage structures in Joshimath area must be taken up as a DRR initiative.

Recommendations for DRR

It is highly recommended to monitor the entire area to understand the groundmovement preferably by total station, by installation of ground control points. For long term, a ground-based early warning system is recommended.



Recommendations for DRR

Helang-Marwari bypass also called the Joshimath bypass was proposed to circumvent the circuitous route of the Joshimath township, whose larger part is situated on the subsidence zone. Besides, this bypass will also reduce the length of the highway by 21 km. This bypass will be very important due to its strategic need. It will reduce road distance by 21 km and will help in reducing the traffic load of Joshimath land subsidence area. Moreover, the major part of the proposed bypass road will pass through the stable rock mass zone. Hence, it is recommended to expedite the construction of the bypass road.

NDMA - MODEL OF NLRMP

Identify a Hill city/township/village vulnerable to landslide disasters at District level with a-priori knowledge and history.

Component I

Landslide Vulnerability and Risk Assessment of Infrastructures

Landslide Intensity

Resistance Capacity of Infrastructures

Reduce Intensity

Increase Capacity

Hill Slope Management System

Integrated bio-engineering and drainage management options for landslide mitigation in line with sustainability and socio-economic-environmental acceptability – A Community-based Scientific Approach

Component III

Infrastructure Strengthening System

Repair & Retrofitting strategy to improve the resilience of the built environment

Monitor

Monitor

i) Use of the latest Indigenous science and technology tools/systems available for landslide ground-instrumentation and monitoring to aim at replication and development of a sustainable and reliable early warning systems and

ii) to establish RADAR based and Drone based technologies for landslide monitoring and landform deformity

Component II

Component IV : Awareness Generation & Capacity Building


THANK YOU

Highlights of Mishra Committee Report (1976) – Causes of Landslides in Joshimath Area

- Joshimath lies on an ancient landslide and is situated on weathered crystalline rocks of schistose, gnissic and quartzitic in nature, landslide mass of big unsettled boulders in the loose matrix of micaceous sandy and clayey material.

- The probable causes can be hill wash, natural angle of repose, cultivable and habitated area on old landslide debris, glacial morainic deposits and undercutting by streams.

- Location of cultivable area on slopes will give rise to landslides due to seepage and soil erosion.

Highlights of Mishra Committee Report (1976) – Causes of Landslides in Joshimath Area

- Undercutting by river currents of Alaknanda and Dhauliganga are also playing their part in bringing landslides. River erosion is evidenced by the development of debris slides near Sindhar bridge, village Khon and some other places along the banks of these rivers. Because of the river action, the toe support to the hill is eroded and as a result landslides occur.

- Hill washing and percolation of water take place due to rains and snow melting.

- Heavy construction projects were undertaken in this area after 1962.

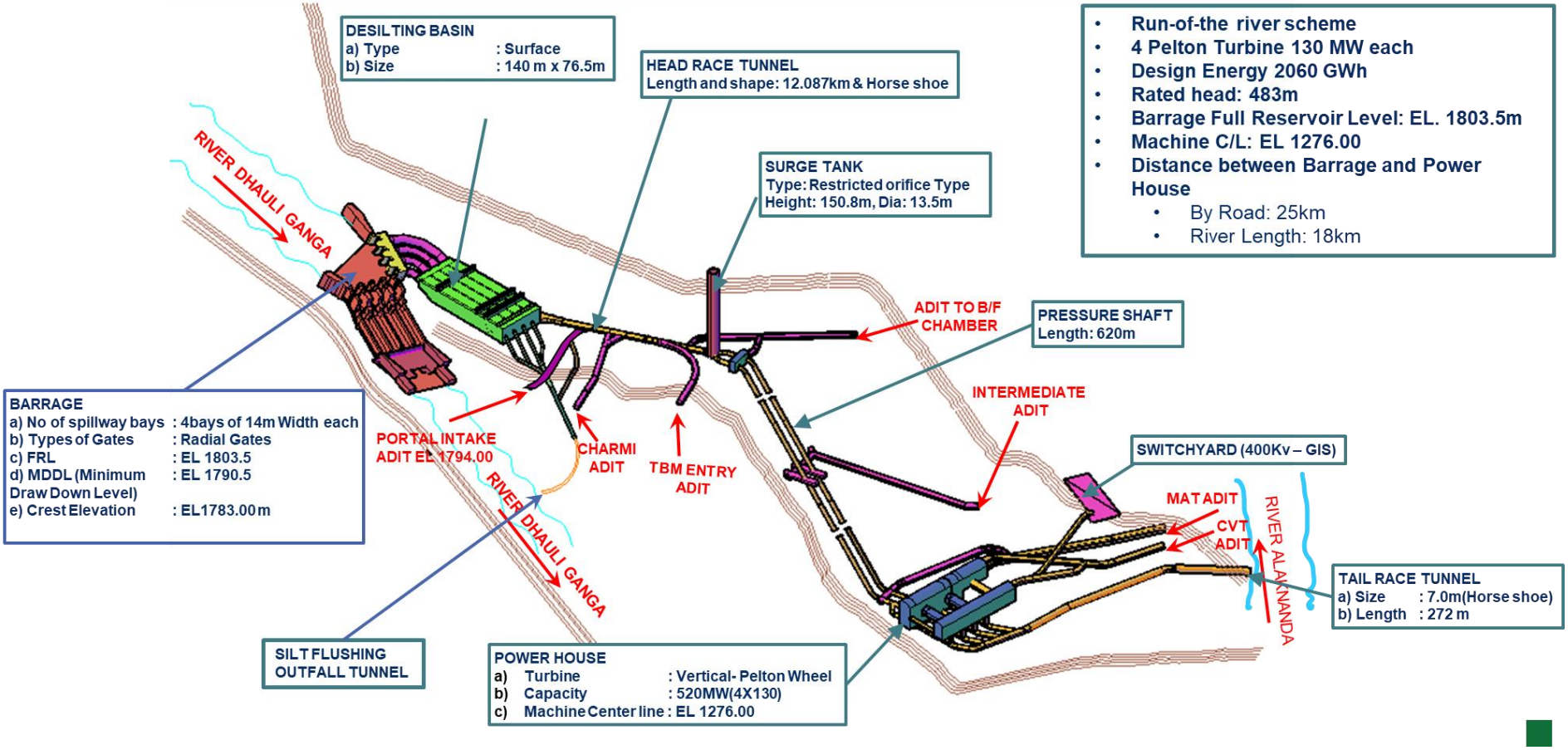
- Indiscriminate felling of trees took place to make the space available for roas and buildings.

Highlights of Mishra Committee Report (1976) – Causes of Landslides in Joshimath Area

- Heavy construction work without adequate systematic provisions for regulated drainage leads to percolation of water which ultimately causes localized shrinkage and landslides.
- Household waste water, rain, nallah, soak pits, katchha drains, unevenness of slopes, presence of cavities, depressions and cracks are also contributing to the problem.
- Blasting has been on the mass scale by various agencies for road and building constructions.
- Construction activity has not only destroyed the biotic factors, but also the natural hill slopes due to removal of established surface cover.
- Lack of proper drainage facilities also accounts for landslides.

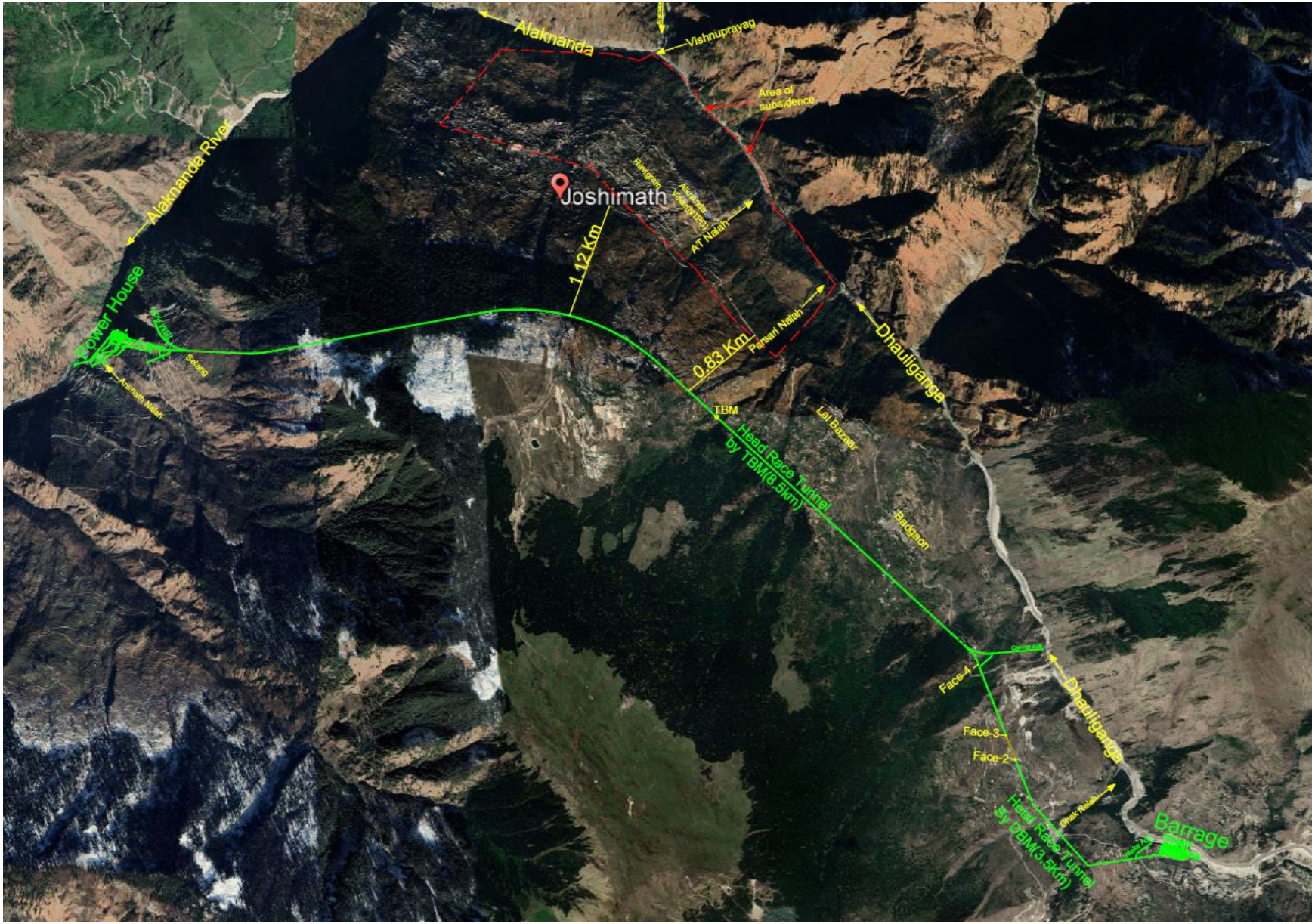
Facts about NTPC HRT with respect to Land Subsidence in Joshimath Area

Project Layout of TVHPP (4X130MW)

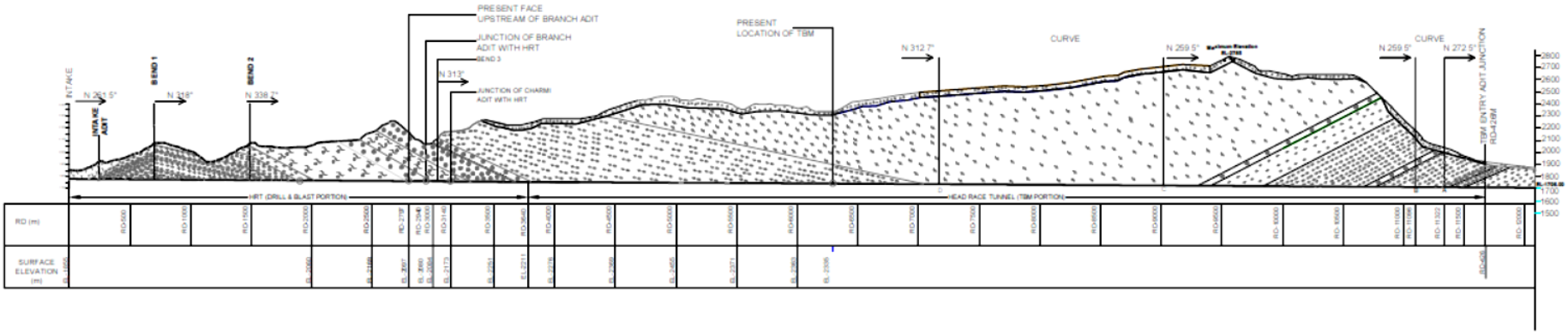


Source: NTPC

Project Tunnel Location relative to the Upper Boundaries of Joshimath



Geological L – Section along HRT



LEGEND - GEOLOGY/ LITHOLOGY INDEX :-

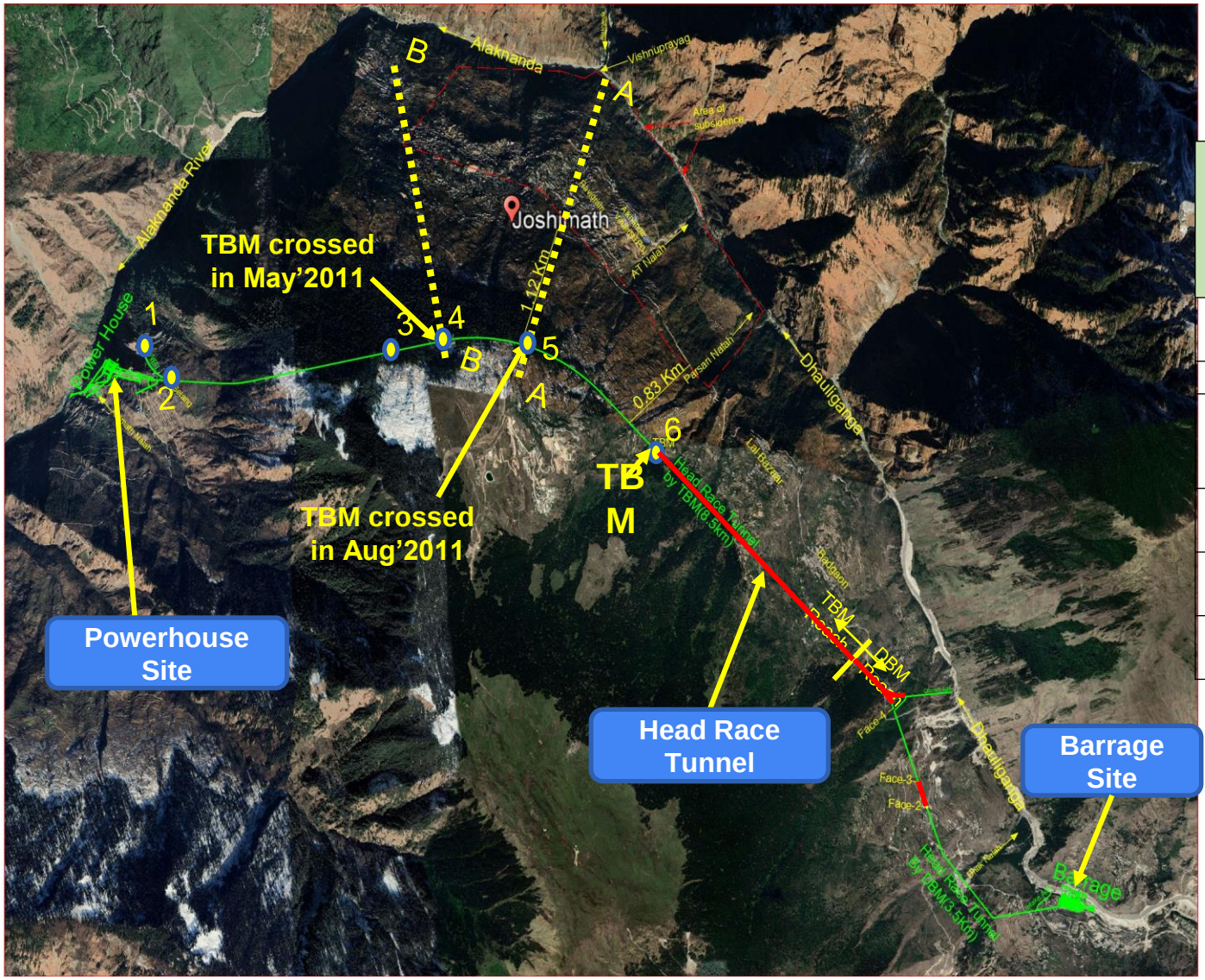
- DEBRIS / OVERBURDEN
- AUGEN GNEISSES
- QUARTZITE
- FINE GRAINED GNEISS
  QUARTZ MICA GNEISS
- BANDS OF QUARTZITE WITH SCHIST/SCHISTOSE GNEISS
- METBASICS
- SHEAR ZONE
- N030/40° DIP DIRECTION/AMOUNT
- FOLIATION JOINT
- OTHER JOINTS

KEY ELEVATION

LEGEND - EXCAVATION INDEX :-

- EXCAVATION COMPLETED
- EXCAVATION TO BE DONE

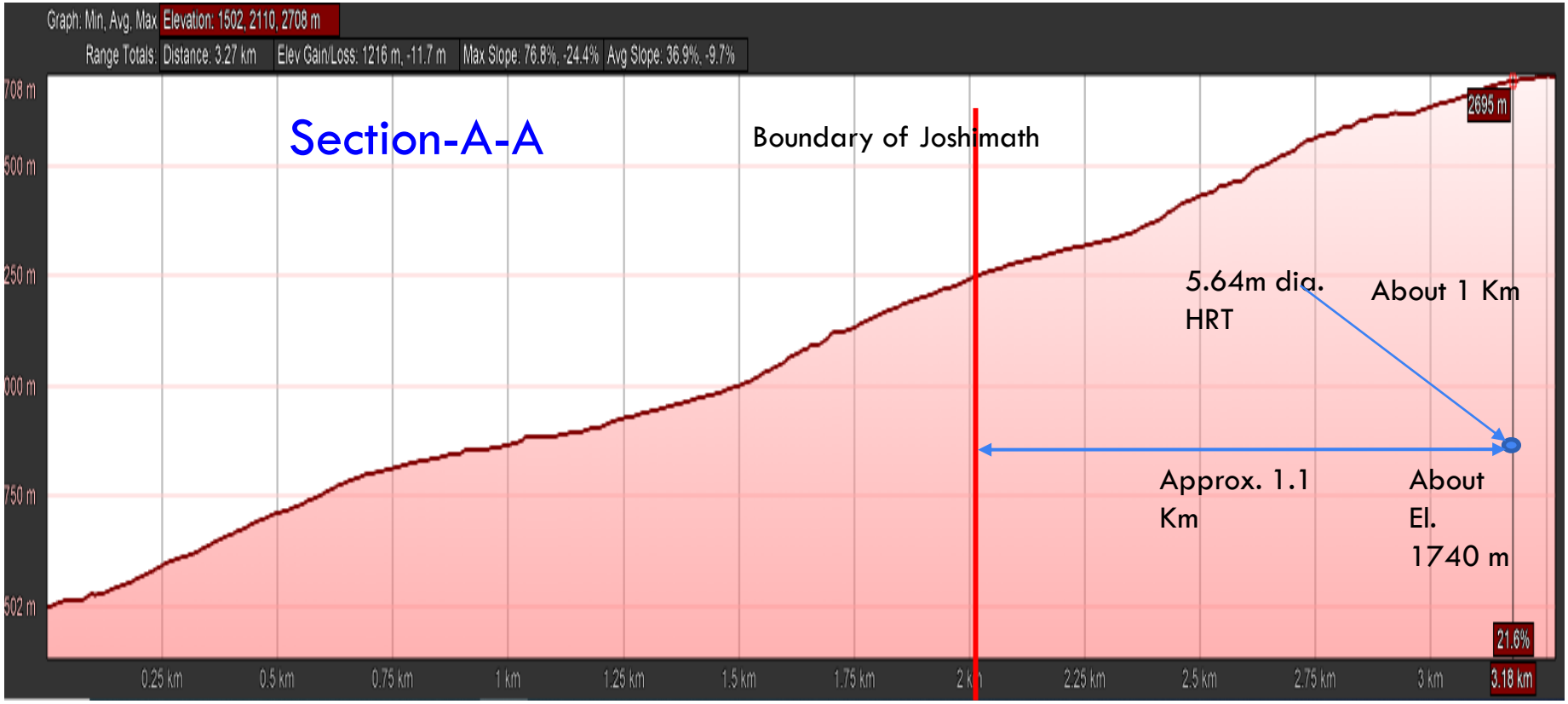
Project Tunnel Location relative to the Upper Boundaries of Joshimath



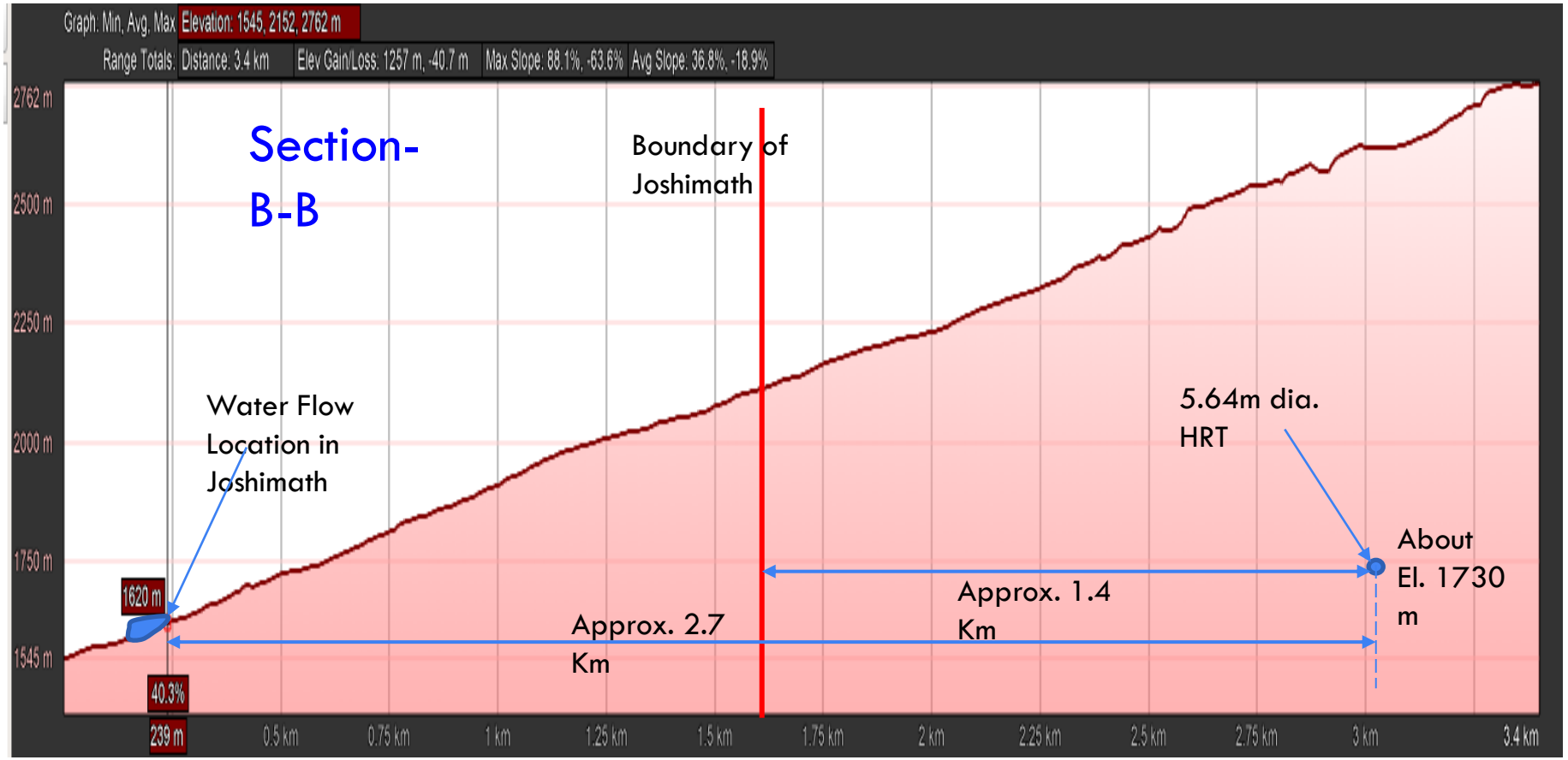
	Location	HRT excavation from Surge Shaft end	Zone crossed in
1	TBM Adit (Start of TBM)		Nov'08
2	Junction	172m	Feb-09
3	TBM Stuck up (Bypass Tunnel constructed)	2785m	Dec-09*
4	TBM crossing Section B-B	2986m	May-11
5	TBM crossing Section A-A	3912m	Aug-11
6	Presnt location of TBM	5659m	Oct-20

* Restart of TBM in Mar'2011

Location of Tunnel and Joshimath



Tunnel and Joshimath Water Flow Location



Sectoral Recovery | Housing and Resettlement

- Building typology Consist of Vernacular Buildings, Masonry Buildings and RCC framed structure
- Almost 99% buildings demonstrate poor quality construction.
- Absence of building permit system and lack of town planning makes the town unsafe in emergencies
- Need for a comprehensive development plan for resilience, water and sanitation, waste disposal, power, access roads, and facilities
- Existing building bye laws need thorough examination for multi-hazard safety compliance

Sectoral Recovery | Housing and Resettlement

- It is Proposed to **Reconstruct the Black and Red category** houses in the resettlement site(s).
- **Repair and retrofit the severely damaged (70% damage category)** buildings in line with BBB principles -in-situ
- **Repair and retrofit the moderately damaged (50% damage category)** buildings in line with BBB principles – in-situ
- The cost of repair and retrofitting was calculated by the **Rural Works Department engineer (AEs)** , as per the **DSR 2018** with an index of 26% for 2023, which is similar to that of the market rates.
- For relocation **1 BHK, 2BHK and 3 BHk houses** of different sizes are proposed depending on size of the previous houses
- Cost component includes **developmental cost** and **infrastructure development cost**

Sectoral Recovery | Housing and Resettlement

- Establish a **techno-legal framework** to **monitor recovery** and provide **technical guidance**
- Local government must release information on risk zones based on damaged buildings.
- Develop **evacuation plan for 700 families,** identify suitable sites for temporary relocation, and **preposition temporary shelter facilities**
- **Consult and Communicate** with citizen groups
- Promote **local construction materials and technologies** along with Prefabricated housing.
- **Safe demolition and debris management** to be given high priority.
- Demolition waste can be **reused for construction purposes.**

Sectoral Recovery | Public Buildings

Sectoral Recovery | Public Buildings

- **32 educational facilities**, 20 government schools, 1 government-aided school and 11 private schools.
- **17 primary schools, 6 secondary schools**, **8 composite schools**, **1 college,** and no training or vocational institutes.
- Enrolled students- **4737, with 2546 males and 2191 females.**
- In the health sector, there are a total of **29 public health facilities,** including **1 community health center** and **3 private clinics.**
- There are no medical college and empanelled hospitals, district hospitals, or sub-divisional hospitals in the district.
- There are also no Ayurvedic hospitals or other health facilities available in Joshimath.
- Other Public amenities consist of police barracks, BSNL buildings, Galla Godown and other government office buildings.

Sectoral Recovery | Public Buildings

- Financial assistance to improve infrastructure and overall quality of education.
- Proposal of a **new Kendriya Vidyalaya Campus closer to Joshimath**, along with transportation facility for students to access the school.
- **Vocational training and skill development courses** to be introduced to provide alternative livelihood opportunities for students.
- Develop a separate **disaster management plan for healthcare facilities** should be emphasized to ensure the safety of patients and medical staff in case of any future disasters.
- Training and capacity building programs for medical staff to deal with disaster situations.

Sectoral Recovery | Tourism

Sectoral Recovery | Tourism

- Tourism is main source of livelihood for the people
- 244 accommodation facilities with a total of 1534 rooms and 4300 beds.
- Total number of rooms and beds available for tourists is significantly less.
- Average tourist expenditure per person per day be INR 1200
- The average revenue turnover for 2022 was estimated INR 101.32 crore.
- Recovery requires assistance for damaged hotels, rebuilding of Auli Ropeway and creating enabling environment for people in the sector.

Sectoral Recovery | Drinking Water and Sanitation

Sectoral Recovery | Drinking Water and Sanitation

- Water Supply network is **47 years** old network with **1086** domestic connection and **149** commercial connections
- Total **31.90 km** of distribution network supplying current water demand at **70 LPCD**
- **3** community toilets and **6** public toilets
- **14.94 kms** of sewage network laid covering 7 of 9 yards **2 STEPs** of capacity 1.08MLD and 2.70 MLD operational.
- Grey water discharged into open drain intercepted and diverted from 5 drains in the city.
- Soak pits for in-situ water management as only **22%** of the total household connected to the network.
- 11.1 Km of pipeline network and 3 storage tanks suffered damage.
- Recovery focuses on providing pipe water supply, sewage connections to all households.

Sectoral Recovery | Water and Sanitation

- Integrate **District Metering Area concept** in water supply network design principles.
- Need for an i**ntegrated approach to water supply and sanitation** in the town to avoid redundancy and inefficiencies in planning and management.
- **Prioritize household sewage connections** in houses marked as yellow in CBRI classification.
- **Revisit capacity estimation method based on population projection** to arrive at a more realistic population growth.
- **Connect military establishments to the municipal mains with the 1.07 MLD Pokhari STP**.
- Implement a **blanket ban on construction of any in-situ sanitation** infrastructure and carry out scientific remediation of existing soak pits in the long run.

Sectoral Recovery | Infrastructure (Roads & Power)

Sectoral Recovery | Infrastructure (Roads & Power)

- Joshimath attracts lot of tourist and roads are the dominant mode of transportation in the Joshimath for both passenger and freight movement
- Four departments manage various categories of roads in Joshimath: BRO (8.4 km of National Highway (NH 7)), PWD (6.2km of SH and ODR), Nagar Palika (8.21 km LMV road) and PMGSY (12km of village roads).
- The peak demand of power supply in Joshimath is 5.86 MW, while the average demand is 3.78 MW.
- The town is served by **3 generation plants (**Urgam HPP, Pandukeshwar HPP and Badrinath HPP) managed by ÙJVNL
- Six feeder stations are present in the town and the transmission network in Joshimath is managed by the Power Transmission Corporation of Uttarakhand (PTCUL).
- The distribution of power to the 11343 customers is being managed by Uttarakhand Power Corporation Limited (UPCL).

Sectoral Recovery | Infrastructure

- Multi-hazard vulnerability and Risk assessment to locate the hotspots and the vulnerable areas.
- Understanding the gaps in the current system and drawing up of a plan for resilient infrastructure
- Immediately seal cracks on the road with bitumen coating treatment.
- Adopt measures to prevent water ingress through cracks from the side of the road.
- Create proper channels to collect excess surface runoff with adequate drainage features.
- **Install cross drains at regular intervals** and construct with proper depth, and ensure regular cleaning for facilitating drainage.
- Provide geotextile on gabion walls constructed on the valley side to minimize the loss of fines, ensure proper binding and packing of gabions.
- Strengthening of Power evacuation system with focus of enhancing reliability of power supply blended with loss reductions.
- Ensure redundancy in the Generation, transmission and distribution system

Sectoral Recovery | DRR and Environment

Sectoral Recovery | DRR and Environment- Debris Management

- Handling debris in congested area and narrow access roads is a major challenge.
- Acquiring and removing the debris to a safe place is expensive, time-consuming, and difficult.
- Recycling and reusing the debris for producing new construction materials would be the best option, considering the cost and the environmental impact.
- Total Debris generated will be **1,34,514 Cum** from all the buildings.
- The estimated total cost for demolition debris clearance- **Rs. 40.3542 crore**, assuming a clearance cost of approximately **Rs. 3000 per cu.m.**
- The District Administration to prepare a DPR on Demolition Debris Management.
- The demolition waste management should adhere to the MOEF&CC Construction and Demolition Rules (2016), CPCB guidelines on environmental management of construction & demolition (C&D) wastes (2017)
- Adequate capacity debris dumping yards must be identified by the District Administration.

Sectoral Recovery | DRR and Environment- Debris Management

Sectoral Recovery | DRR and Environment- Drainage

- As per irrigation records, there are six Nalas draining Joshimath town
  a. Gandhinagar nala – 1617 mts (**45% lined**)
  b. Navganga nala or Auli nala – 5100 mts (**53% lined)**
  c. Tehsil nala – 2971 mts (**66% lined**)
  d. Kamet lodge nala – 2948 mts (**43% lined**)
  e. Dronagiri nala – 2100 mts (**67% lined**)
  f. Ravigram nala – 3050 mts (**20% lined)**

- **Channelise the drain to reduce seepage**
- **Install flow meters** in all drains to assess peak discharge this monsoon before designing the channels
- **Regulation of encroachment** of natural drains and Nalas and allow storm water and base flow to enter the Nalas at regular intervals
- Integrate **slope stabilisation** measures along the drains
- **Integrate regular monitoring** of the drains and aquifer characteristics into the larger monitoring programme

Sectoral Recovery | DRR and Environment- Heritage

- Joshimath is a historic town with the winter seat of Adi Shankaracharya
- Disaster and Rehabilitation will impact the **Tangible and intangible heritage**.
- **Risk Assessments and retrofitting ancient building to be conducted.**
- Cluster of **old traditional buildings to be developed** through a **holistic heritage Management Plan**

Sectoral Recovery | DRR and Environment- Slope Stabilisation

- Adopt **Short-Term like crack sealing** to prevent water ingress.
- Slope Stabilization to be done as long term measures through a detailed **Detailed Project Report** and identifying cost-effective technologies
- Global stability analysis (both static and dynamic) of different profile sections along the slope should be done
- Prepare a master plan for Joshimath and **Town Planning must integrate DRR measures** in town planning.
- Proposal to construct a **Toe wall along River Alaknanda**
- Proposal to develop **Bio-Engineering Works along the drainage channels** and in **demolished area.**