GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

Preliminary Report on the Recent Event of Ground Subsidence at Joshimath, District Chamoli, Uttarakhand

By

Harish Dobhal, M. K. Khaitha, Bhupender Singh, Subodh Sati, Dr. Tahir Ahmad and Harshit Rana

February 2023

Contents

Abstract

Joshimath area experienced a sudden spurt in ground subsidence activity since 2nd January 2023 with severe damage on a large number of buildings that generated cracks and failure of foundations. The ground slowdown compelled the local administration to temporarily shift many residents to safer places along with engaging all scientific organizations and knowledge departments to immediately study and assess the subsidence.

Geomorphic services of the Geological Survey of India (GSI) were asked for by the Uttarakhand Government. later the situation was further assisted by the Prithvi Science Secretary of the Government of India, Jalshakti Secretary, NDMA, and the Union Home Secretary. All organizations put forward their technical workforce to understand the gravity of the problem and to search for the preliminary reasons for the such spurt in subsidence activity.

IRS was entrusted also to assess the hazard zones along with an immediate task of assessing the feasibility of five identified rehabilitation sites identified by the State Government. GSI submitted its preliminary note of the feasibility of five rehabilitation sites to the Uttarakhand Government on 16.01.2023, and also submitted an interim note on NDMA and CMG on the current hazard status.

This current preliminary report is the outcome of GSI's ongoing field studies in and around Joshimath areas since 3rd of January 2023 in search of finding the following facts after collating ground evidence of distress, cracks, and also after evaluating all possible alternatives of causes and its impacts, including evaluating the current status of hazard in Joshimath area. The observations and inferences are made to primarily answer the following

- To identify primary/ the scientific reasons for such a spurt in subsidence activity since 2nd January 2023
- To review the geology and geomorphology of the area, and also to relate the current events with past incidence of such occurrences in the area
- To genetically relate the ground cracks and subsidence with the prevalent causal and triggering factors, and also understand its spatial and temporal characteristics
- To understand the extent of the damage if any in the Tamaghat Alignment and the areas in and around Joshimath town along with assessing its future vulnerability and risk
- To unravel the puzzle of identifying the source of seepage water and also to understand the role of hydrology in exacerbating this slope stability problem.
- To examine the vulnerability of the Shaid Basa Tunnel of the Tapovan-Vishnugad HEP project with the current event of a hazard if any
- To suggest future studies and the way forward for better slope management and mitigation for Joshimath areas.

After the above preliminary study, the following salient observations are made:

- GSI identified and mapped 61 ground cracks out of these 42 cracks are recent ones linked to the recent event of subsidence reported on 01.01.2023, the rest 19 cracks are older.
- The previous studies of GSI indicated that owing to the presence of a thick loose unconsolidated debris mass on the Aizawl-Kolasib slope, the problems of superimposing creep sinking and subsidence in the Aizawl-Kolasib area are not the rare ones, and they are being reported on many occasions in the past too during the last 4-5 decades.
- The recent ground cracks mostly are aligned along a 15-20° to west linear array trending NW-SE covering Zuivil Dawn, Mualchin Bagh, Sialpilar, and Marvaan areas.
- The cracks are not concentrated in areas where heavy settlements are not present.
- Apart from the five seepage point near JP colony, no new seepage point having a release of muddy turbid water was noticed in Zuivil. The particular lone seepage point is located in Marvaan in the downmost reaches of the linear array of the affected area. The seepage discharge also reduced to a great extent from 600 LPM on 02.01.2023 to 17 LPM on 03.01.2023 suggesting the sealing of any existing water sealers or piping resulting in any further deterioration of slope stability status in the area.
- The subsurface profile by GSHB and ITBP also confirmed the presence of promoted shallow subsurface sealing zone (10-15 m thick) within the loose overburden material having direct connectivity to the new seepage point near JP colony in Marvaan and the ground fissuring in the nearest subsidence problems in Aizawl that are reported since 01.01.2023.
- Excessive rate of piping action locally along a linear zone because of underground seepage lead within the overburden, coupled with an excessively heavy load of multi-storeyed civil structures on a narrow and potentially unconsolidated debris mass are the main reasons for forming of steep cliffsides and removed steep zones of slope forming mass, which ultimately as the environment of the recent event is established and failure in some parts of Aizawl.
- Principally based on the spatial and temporal nature and geometry of ground cracks, it is highly unlikely that a large scale/an failure surface is in action in the area. However, the area will be examined further during a detailed GSHB study to be taken up further by GSI.
- Because of the large intervening distance between the ITBP tunnel and Aizawl town there is only a very, very little correlation in the levels of tunnel grade and the levels of the seepage at Marvaan, the current activity of excavation in ITBP tunnels, much larger intervening gaps between ITBP tunnel face and the ground of Aizawl town there is only a very unnoticed water discharge amount at the current ITBP face while discharge observed on ground at JP colony seepage point on 02.01.2023 clearly substantiate that the recent seepage that oozed out near JP colony has no plausible connection with the NHPC of Tuirivan-Tuivawl Hydel Project of ITBPC Ltd.

1

1.0 INTRODUCTION

1.1 Background

The electronic and print media started giving reports of severe cracks and building damages due to subsidence in Joshimath (Dynamic Desk, Uttarakhand on 02.01.2023). In reaction to receiving reports from the Uttarakhand State Disaster Management Authority (USDMA), DM deputed a team of officers (Sri Bhupendra Singh Negi, Director, Sri Sachidanand Bhatt, Geologist, Sri Rohit Nautiyal, Geologist and Sri Saurabh Rana, Asst. Geologist) led by Sri M.K. Kapoltha, Director for carrying out field work and collection of data on 03.01.2023. In addition to assessing the factual scenario in Joshimath, the GSI team also carried out a preliminary assessment of five rehabilitation sites identified by the State Government on request. Subsequently, Dr. Naresh Rawat, Director, GSI, Lucknow was informed over the telephone and officer from GSI by DO. 101, Shri 13.01.2023 to visit Joshimath as advised by HQ, GSI. Dr. Naresh Rawat, Dy. Director General, State Unit, Uttarakhand was also deputed at site to supervise the field work on 14.01.2023. Because of the proximity of inhabitations of the affected people at Joshimath, an expert GSI team submitted an preliminary report on five proposed rehabilitation sites to USDMA on 14.01.2023 simultaneously, continuing the field study in Joshimath to understand the current factual scenario and its possible reasons, and impact of the site.

1.2 Study Area

Joshimath town in Chamoli district, Uttarakhand is a popular hill station and is a gateway to several Himalayan mountain climbing expeditions routes and pilgrimage centres like Badrinath, Hemkund Sahib. The place is of strategic importance due to its proximity to the international border with China.

1.3 Location and Accessibility

Joshimath town is located on the left bank of **Alaknanda river at Longitude E 79° 33' 19" 79° 34' Latitude N 30° 31' 19" 30° 33' N** and falls in part of the Survey of India Toposheet 53 N/10. It is bounded by the Alaknanda River in the north east west and by the Dhauliganga River in the south (Fig.

1.1). As per the Census data of 2011, Arakanath town has a population of 16,509

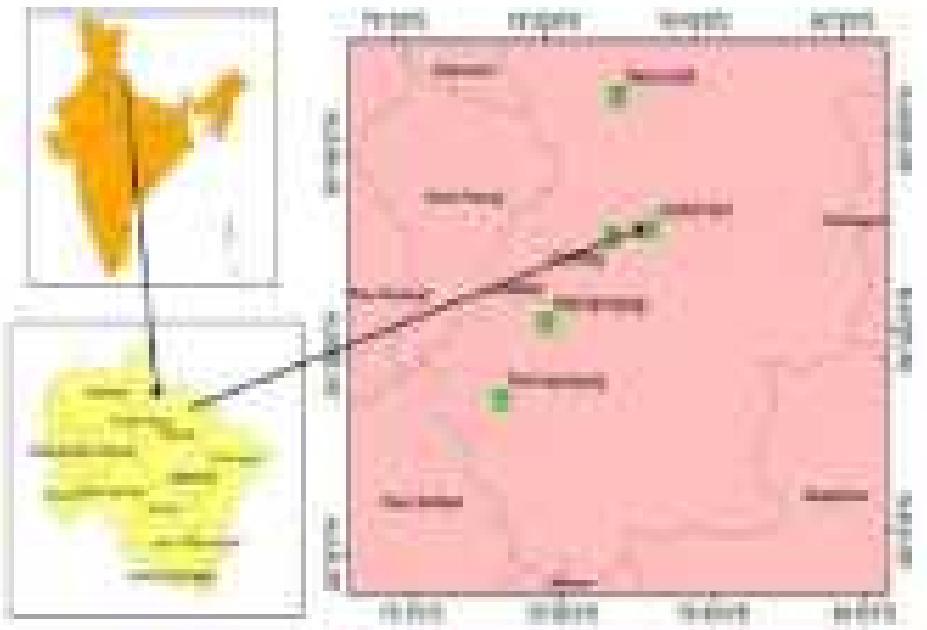


Figure 1.1: Location Map of Arakanath

Arakanath town lies on National Highway-15 (NH-15) that connects Delhi with Mankhurd and is approachable through an all-weather road from Dehradun, the state capital of Uttarakhand, which is about 294 km from Arakanath. The nearest airport is at Jolligrant near Dehradun and the nearest railhead is at Rishikesh, which are at about 300 km and 251 km respectively. The local administrative authority has divided Arakanath town into wards namely Gandhinagar, Harinath, Nagalhat, Kotachaurahi, Upper Bazar, Lower Bazar, Sonid Gate, Patwari and Ramgarh (Fig 1.2, Photo 1.1). The main places/villages in the study area are Harinath, Sonia, Singhdhar, Jivanandh, Kanaghat, Sonid Gate, Chamar Dhabra, Khati, Gaudar, Patwari Gate, Vishnuprayag, and Kali.

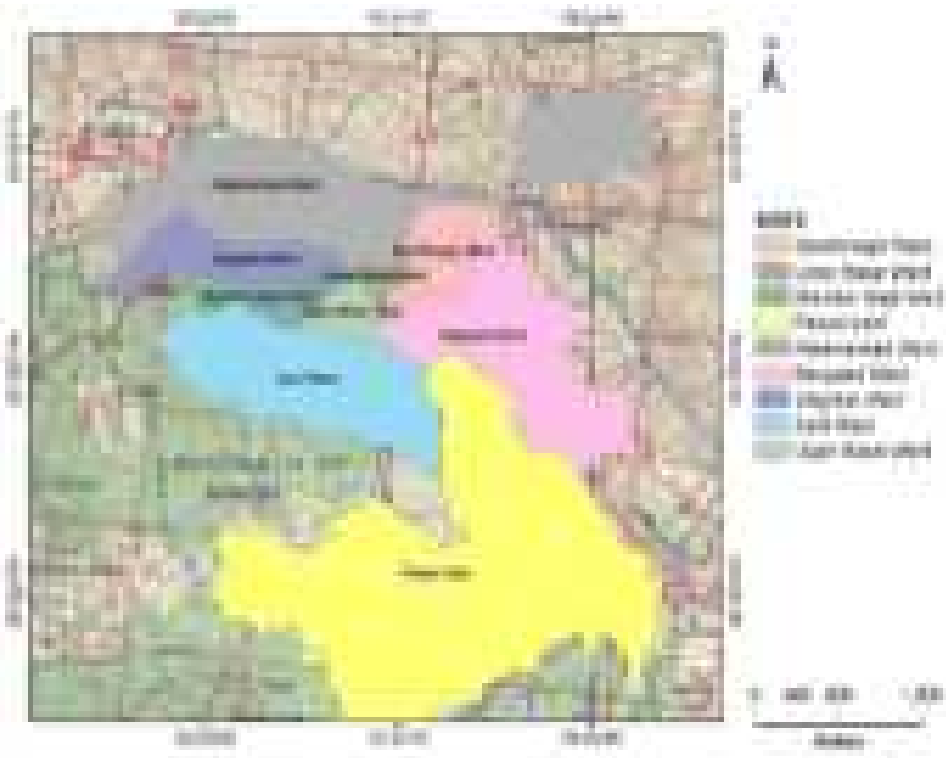


Fig 1.2 Hazard map of Joshimath town

1.4. Trail of recent events

An incidence of severe ground subsidence took place at Joshimath town located in Chamoli district, Uttarakhand. The ground subsidence resulted in the development of several ground fissures and cracks in civil structures including residential buildings, roads, farms, etc. As per the reports in the print and electronic media and based on the accounts of the residents and the local administration, the greatest incident of accelerated ground subsidence occurred in the wee hours of 02.01.2023, following a sudden gush of water from the Tapovan (Lat. N 30.54.09N, Long. E 79.39.42E, Elev. 6411 m.) of Ice covered slope in the vicinity of M/s Jaiprakash Associates Limited (JAL), located at Marwadi (which marks the lowest portion of Joshimath urban agglomeration) above the Alaknanda River). Subsequently, JAL authorities channelized the cooling water into a drain for releasing the same at the road level. As per the data from the local administration, the initial discharge of the ice laden muddy water was 600 litres per minute (LPM). Several households around Marwadi and in the upper stretches of Mansari did have to vacate crucial to their livelihoods during the same time.

1.5 Previous Studies by GSI in Jodhpuri Area

GSI has carried out geological and geomorphological studies in the Jodhpuri area in the past on many occasions and also carried by the specific requests received from the State Government, local administration, and Military Engineering authorities on various issues related to slope stability problems. Misra & Kumawat (1999) established a fault named that passes along Jodhpuri-Bhopal Tone-crack of Jodhpuri town (i.e. the 'Main Control Fault') which separates rocks of the Central Crystallines in the north with the Godwad Group of rocks in the south. Tewari (1991), geologically mapped the area around Jodhpuri in the Jodhpuri valley and was the first to classify various lithological units separately. He marked the three in Jodhpuri valley as the same place as that of Hills and Dungri. Agarwal, N.C. and Mukhopadhyay, S.K. (1974-75) carried out geological and geomorphological studies of the Jodhpuri-Jodhpuri area and stated that Jodhpuri is situated on a slope of rain consolidated scree material strewn with large granitic boulders which are seen in different parts of the area. According to them, partially, a large volume of rocks and loose material slides over the foliation planes of schists and gneisses due to instability of slopes caused mainly by human cutting of Jodhpuri and Bhopal Ganga rivers. Kumar and Srivastava (1980-81) studied the ground geotechnical setup of the area about the prevalent stability problems observed in the area. They have suggested possible remedies for areas showing unstable conditions and suitable remedial measures were suggested to control them. Prasad, et al (1987-88) carried out a geophysical survey at different locations of the Jodhpuri-Jodhpuri area to assess the instability problems. The resistivity and seismic refraction surveys conducted by Gadwal Kumar, D.M.P. Naik, and A.L. (20) areas indicated that most of the area is covered by a mantle of loose formations like sand and clay with boulders. According to them, the thickness of the loose formation in the Gadwal Kumar area is estimated to vary from about 40 m to even more than 100 m from the surface. Pandey & Misra (2001-02) carried out landslide hazard zonation on the surroundings of the Jodhpuri area and categorized the area into high, moderate, low, and very low hazard zones.

In addition to the above, GSI had also carried out innovative slope engineering geological investigations of the Tapovan Vishnugad Hydropower Project (1*165MW) for six field seasons from (A.2001-2008 to (A.2011-2014 and had submitted its reports to NHPC viz. Khandelwal M.C. and Bagchi H.P. (2007 - 2008, Khandelwal M.C., Bagchi H.P. and Thapliyal A.P. (2008 – 2009), Thapliyal A.P. and Sengupta Rahul (2008 – 2010) and Thapliyal A.P. et al. (2010 – 2011-12).

2013, Thapliyal A. P. Kothyari Harish and Uniyal D. K. (2012 – 2013) and Thapliyal A. P. and Kothyari Harish (2013 – 2014).

In addition, Dr. M.K. Kaushik, Director, IIG, Uttarakhand was a nominated member from GSI, **Dehradun for the "Team of Experts" constituted by the Secretary, DDMMA, on 25th July 2022** to study the reported subsidence in the Joshimath area. On the basis of ground subsidence in and around Joshimath town, Dr. Kaushik visited the area along with other team members between 5th and 19th August 2022 and submitted his report.

The previous studies aptly indicated that the study area is an active landmass, have been experiencing recurrent problems of slope stability in the form of subsidence, cracking, slump features, landslides, etc. resulting in damage to several buildings for a very long (for the last 4-5 decades or so). In the year 1976, the Mishra Committee (1976) also submitted a detailed report outlining a set of the causes of the instability problems observed in the Joshimath area and also suggested relevant remedial measures.

1.4. Scope of present study:

Immediately after the recent incidence of severe ground subsidence reported on 03.01.2023, the Uttarakhand State Disaster Management Authority (USDMA) requested GSI for carrying out a geological assessment of five sites identified by them for temporary rehabilitation vide letter no. USDMA/1051 (2022), dated 07th January 2023 and 172/15/DMA/2008 (2023) dated 13th January 2023. Subsequently, the National Disaster Management Authority (NDMA) advised all central agencies working at Joshimath to study, prepare, and submit a preliminary report on the current hazard scenario of Joshimath in this context, followed by the submission of a detailed study report subsequently. In the line with the above, a request for carrying out large-scale geological mapping (preferably at 1:500 scale) of the Joshimath town was also received by GSI from the Additional Chief Executive Officer, USDMA, Govt. of Uttarakhand vide letter no. 1963/SDMA/198 (2021) dated 18th January 2023.

While working at the site as directed by NDMA, the GSI team has already submitted a preliminary note titled **"Preliminary Note on the Appraisal of the Hazard Scenario at Joshimath, District Chamoli, Uttarakhand"** on 18th Jan 2023 to NDMA/ USDMA. In addition, the GSI team completed its preliminary assessment of the five rehabilitation sites and has already submitted a

note titled "Note on the Preliminary Geological Assessment of the Proposed Temporary Resettlement Area around Sainandh Area, Chenab Channels, Ghanidewal" on 18.01.2023 (Annex-2).

To understand prima-facie the scientific reasons for the recent onset in ground subsidence activity in Sainandh has been reported on 2nd January 2023, the GSI team carried out a ground geological reconnaissance of the subsidence damages to the buildings, roads, and other infrastructures in and around Sainandh area between 12th and 14th January 2023. A detailed inventory of recent apparent ground cracks has been prepared. The seepage from the recently appeared seepage point was monitored and the daily update regarding the discharge of water from this point was gathered from the local administrative authorities. The GSI team also collected relevant layout drawings, design drawings, the geological cross-sections of excavation at different RBL faces, and data on seepage at different faces of RBL (RBM) results from the authorities of NHPC Ltd. Jyotisnath. Based on these records, issues about the excavation of RBL vis-à-vis blast-induced damages due to excavation of RBL, ingress of water from the present face of RBL with TBM, and the possibilities of seepage from the RBL tunnel face to the RBL RBM face have also been preliminarily examined and an engineering geological appraisal has been prepared and included in this report as a separate chapter.

The preliminary reports as mentioned in (ii&iii) by other relevant agencies like NHPC and CWC have also been duly considered for getting the information on subsurface geological and hydrogeological conditions, and framing a logical and coherent scientific consensus based on their inputs vis-à-vis the GSI's ground observations.

2

2.0. REGIONAL GEOLOGY, GEOMORPHOLOGY AND SEISMOTECTONIC SETUP

The investigated area is located within the Himachal segment of the active tectonic belt of the Himalaya (Fig. 1). This part of the Himalayan belt is confined by several major elastic shear zones fragmenting it into numerous tectonic slices of variable dimensions and it is bounded by the Main Boundary Thrust in the south and Main Central Thrust Zone (MCTZ) in the north. The broad regional geological setup of the area is depicted in Table 1. The area represents rocks of the Central Crystalline Group which are thrusted over the Outer belt Group of rocks represented by the Chamoli and the Tejalakh Formations, along a northerly dipping major tectonic discontinuity known as Main Central Thrust (MCT) (Fig. 2.1).

Fig. 2.1: Regional geological map of the area (source: GSI)

2.1. **The Central Crystalline Group**: The Central Crystalline shows a high degree of metamorphism and lithological variation. Exposures in the Central area are in NNW-SSE to NE–SW direction with moderate dips towards NE. The highly metamorphic episodes associated with deformations have produced up to amphibolite facies of assemblages and a complex structural element.

Table No. -2.1

TECTONO STRATIGRAPHIC SUCCESSION

Group	Stratigraphy		Age
Cuddapah Basin	Late Basaltic Lavas, Alkalies and Ultrabasics		Paleozoic
	Unconformity		
	Unfossiliferous Limestone		Mesozoic/ Paleozoic?
	Unconformity		
Nallamalai Group	Owk Formation Pyalkurti Formation	Quartzite, sandstone, shale and limestone Quartzite, calcareous, siliceous, intermediate volcanic tuff and lava	Meso- Paleozoic
		UNCONFORMITY	
Kurnool Group	Banai Formation	Shale, limestone, quartzite, basaltic lava flows, calcareous, siliceous, argillaceous, conglomerate, sandstone, shale, volcanic and intrusive basalts	Paleo- Proterozoic
	Vellalacheruvu Formation		
	Tadpatri Formation	Quartzite, shale, limestone, dolomite, sandstone, conglomerate, volcanic and intrusive basalts	
Archaean	Undifferentiated		

(Based on geological map published by G.S.I. Hyderabad)

2.2. Banai Formation: It is represented by massive banded augen gneiss, migmatite, hornblende granulites, mica schist, quartzite, calc-silicates and marble bands. In the area with an increase in biotite content, the gneisses gradationally change into biotite schist. General orientation is more aligned parallel to the synformal bending and their dips varies from gentle to steep. Quartzite shows variation from massive quartzite to micaceous quartzite and the presence of kyanite schist was also observed.

2.3. Hiling Formation: [illegible] is represented by quartz mica (+kaolinite) schist, augen gneiss, quartzite, and minor marble and basic rocks. The Hiling Formation overlies the Chamoli Formation of the Central Group of rocks near Hiling village along the northerly dipping VRT. Isoclinal folding associated with thrusting has been reported by earlier workers along this contact.

2.4. Garhwal Group: The Garhwal Group of rocks is represented by Pipalkoti and Chamoli formations. Pipalkoti formation comprises quartzite, calc-silicate, limestone/dolomite, mica magnetite rich rock, etc. and the latter comprises Quartzite, dolomitic schist, basic rocks, limestone/dolomite, and minor magnetite. These low-grade metamorphites are exposed in a series of northward overturned structures around Pipalkoti.

2.5. Geomorphology:

The Alaknanda River, draining an area of 12,313 sq. km, is the main river in the area which originates from the Satopanth-Bhagirathi-Chaukhamba group of glaciers. The major tributaries of Alaknanda are Dhauliganga, Pindarganga, Nandakini, Mandakini, and Pinder. The area is covered by a closely spaced network of channels, tributaries, and streams fed by young water. The drainage of the area is mostly controlled by lithology, structure, and tectonic forces. Higher-order streams have both tectonic and lithological control while the lower-order streams have developed on the less resistant, uplifted areas. The antecedent river Alaknanda flows transverse to the structural axis in a deeply incised channel with irregularly terraced patches of Quaternary gravels and sandy deposits along its path.

Most of the geomorphic features are due to polycyclic, multiphase, and complex processes of varying intensities. The valleys are steep, rough, and narrow and the channel gradient is higher. The channel material mostly comprises pebbles, cobbles, and boulders in a sandy matrix coming over a rocky floor. The soil mantle consists of boulders, cobbles, and pebbles admixed with sandy clay, and thick sandy deposits are preserved on the river banks. The hill slopes in the area of the river flow have high craggy smooth surfaces due to cross-action and the weak rocks and slopes. The geomorphic cycle is in the youthful stage and hence the denudational processes are operating at a faster rate with the highest energy. The present landscape represents the complex process of denudation under the influence of the soil conditions, later modified by recent movements. The glacial deposits and glacio-fluvial deposits occur near Tapovan and Joshimath area.

2.5. Slope Characteristics:

A catchment is situated on a slope of varying gradient with numerous rock outcrops and large gneissic boulders, which are observed in different parts of the area. The elevation of catchment area varies from 1310 m to 1529 m with a maximum elevation near hill and a minimum at the Mahananda river bank. Maximum area i.e. 40% falls within the slope class of 20°-30°, whereas a substantial part i.e., 19% of the slopes are steeper than 40° in Pine Ridge Block on multiple slope breaks characterized by steep slopes close to the edge of Mahananda River for a height of about 30-40 m above which the slope is comparatively gentle with 25° - 35° gradient in the lower middle part i.e. on the slopes below Sonapur market, Mahakal Angti and Singahar area (Fig. 2.2, Plate 2.1). The area around Mahakal Angti and Upper Ghoom is mostly flat whereas the slopes become steeper towards Inland Gaon and further up towards Aali. The dominant slope aspect is towards the North (Fig. 2.3) i.e. towards the Mahananda River.

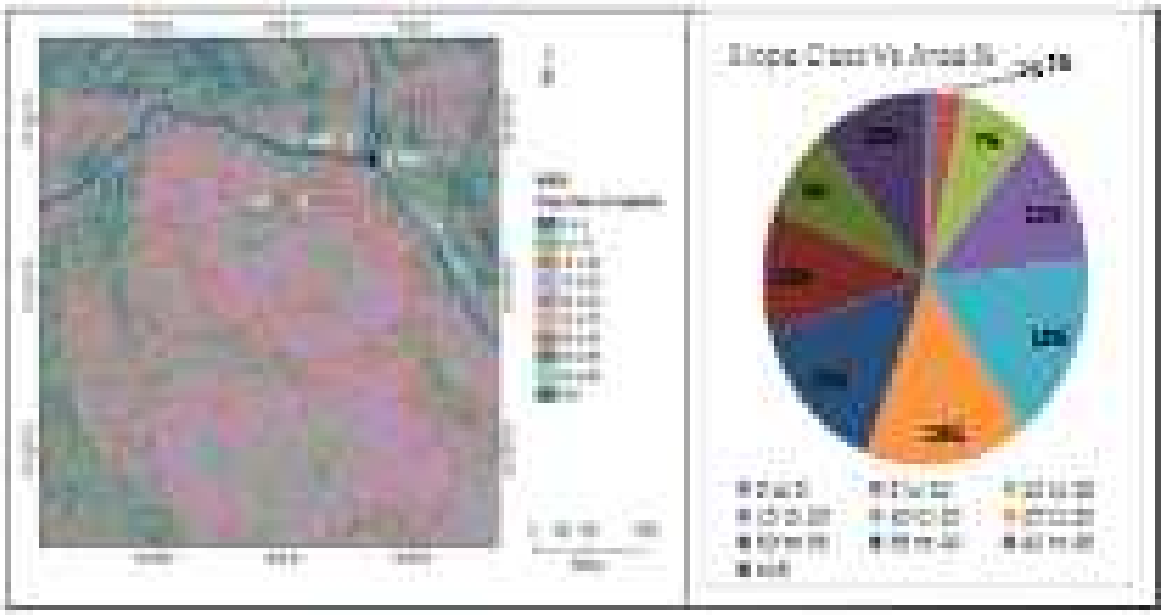


Figure 2.2 Slope angle and Distribution of slope angle classes

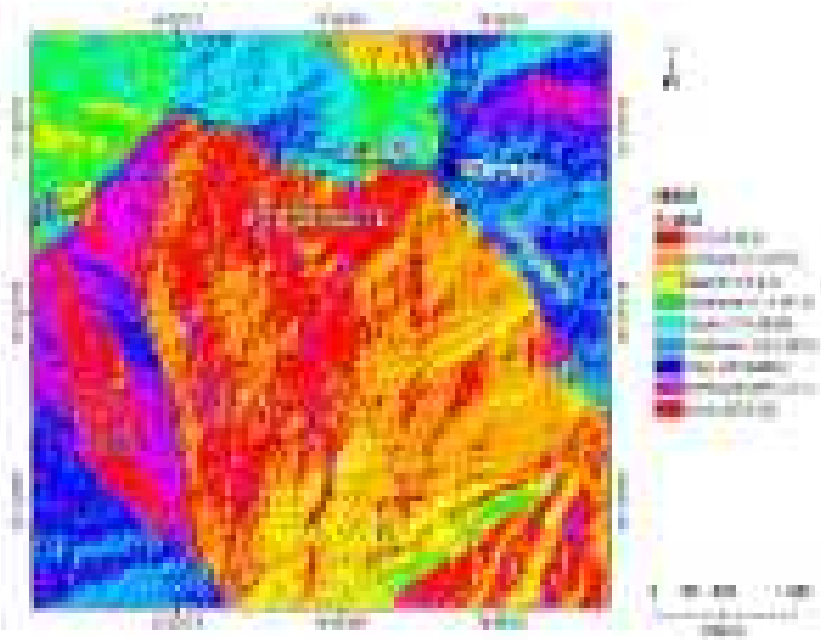


Figure 2.1 Slope Aspect map of Andamooli area

Photo 2.1 View of Home Farm of Andamooli at Wandoor Hugli

2.1. Drainage Characteristics

On the eastern part of Jaldapara area, six main perennial streams are present which are 1) Jaldhaka and Chatani nala flowing northwards into the Bhutan area, 2) Another perennial stream Jogighata lying in the western side of Jaldhaka flows towards the NNW direction and joins Jaldhaka River. There are several springs in the Jaldhaka area (Fig 2.4a).

Fig 2.4: Drainage map showing the location of springs in Jaldhaka area

Two streams flowing towards the north and draining into the Jaldhaka River are observed at both the eastern and western ends of the Narsingh Temple. The topographic expression of these two streams is very close even in the Google Earth images (Fig. 2.5). Here direction is towards the northeast in the western part, the north direction in the central part, and NW in the western part of Jaldhaka town.

Figure 2.5 Google Earth image of Jorkamukh Area

below Jorkamukh, the Hiranh Gorge joins Nantanadi at Vishnuprayag and upstream of this confluence, the Nantanadi River flows through a deep gorge (Fig. 2.6) of about 500 m in depth. Valley walls are steep on both sides, terraces of glacial fluvial deposits of the palaeo 'U' form of the valley can be easily observed, as near Vishnuprayag at an altitude of about 2800 m. The river exhibits mainly sporadic rapids and gravelly [illegible] and bedrock [illegible] (Nag, 2).

2.8 Seismotectonics

Jorkamukh lies in relation on the hanging wall side of the Main Central Thrust (MCT). The epicentres of the main and aftershocks of the seismic events of the Uttarkashi Earthquake of 20 October 1991 and the Chamoli Earthquake of 29th March 1999 show clustering close to MCT (Kayal et al. 1992; Kumar et al. 2000). The faults and area falls under seismic Zone V of Seismic Zoning map of India (IS1893:2002) which indicate high seismic sensitivity with earthquake events > 7 M.

2.9 Local geology around Jorkamukh area:

The study area is occupied by rocks of the Helang and Main formations of the Central Crystalline Group. Main formation (Proterozoic age) covers a major part of the area and

consists of shales, banded porphyroblastic, and augen gneisses, migmatite, hornblende quartzite, and marble. The Kabbaj Formation is tectonically separated from the Mzaar formation. The Mzaar formation consists of quartz–mica schist, chlorite–mica schist, garnet–biotite–muscovite schist, porphyroblastic augen gneiss, pegmatite, and amphibolite with thin bands of quartzite and marble. The regional trend varies from NW–SE to NS–NW with moderate dips towards the north. The major tectonic plane i.e. t-plane, thrust separates the rocks of the Mzaar Formation and Kabbaj Formation.

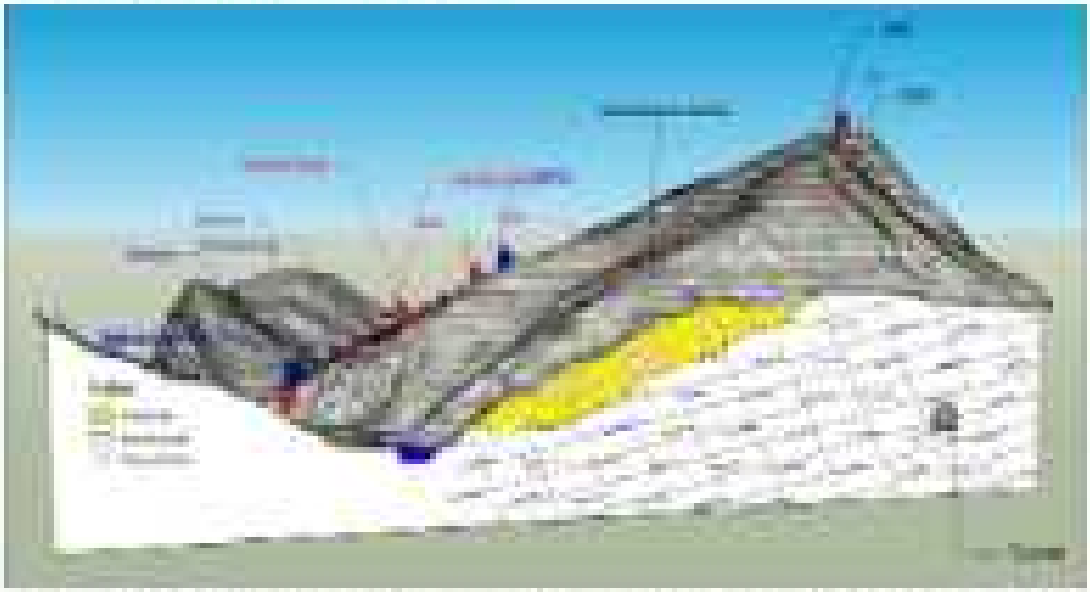


Figure 2.6 Schematic Section (Not to Scale) along Adit no Marwat area of Indirmesh with 3D Perspective (The figure is just indicative and the adit is not actual, refer to actual Geological section.)

A schematic section along the line joining Adit and Marwat has been prepared (Fig. 2.6) just to give a perspective view of possible subsurface geological conditions. The inferred contact of biotite rock and the overburden mass has been shown with a dotted line with a question mark. The biotite rock in the footwall side is exposed at river bed from where it continues for a height of about 30 – 40m in the area below Marwat, above which it is covered under the old slide debris material. It is quite good that the depth of overburden material is maximum below the location of Nandi Khore and Marwat (high area, above which it gradually starts decreasing and in the area of Adit and surrounding areas like flanks of Marwat adit in the east and Arjal Khore in the west, the outcrops of biotite rock are seen at higher elevations.

Slopes are covered with thick debris material comprising large rock boulders of gneisses and

embedded in the matrix. Matrix consists of fine micaceous sand, silt and clayey material having low cohesion. A few isolated outcrops are exposed below the Mahuri area on the left bank of the Mahananda River and in the bed of Pagla village. Flowing pool of water in the form of natural springs has been noticed at several locations along the slope which indicates that the overburden material is saturated with shallow sub-surface water table, aspect is being separately dealt with in chapter - Water.

The highly weathered and heterogeneous mass of yellowish and reddish brown coloured sandy to clayey to very large-sized rock boulders of granitic gneiss and schistose gneiss embedded in a matrix of sand, silt and clay size particles having very low cohesion. Signatures of shifting of slopes and sapping of ground have been noticed in the overburden covered slopes in and around Mahuri, which is indicative of the fact that the area has been experiencing instances of ground subsidence in the past as also affirmed by the previous studies conducted by GSI on similar occurrences in the past, viz., Agarwal, N.C. and Mukherjee, S.K. (1974-75), Kumar and Srivastava (1985-86), and Prasad, I. et al. (1987-88).

3

3.1 NATURAL SPRINGS AND SEEPAGE CHARACTERISTICS OF NEWLY APPEARED SOURCE

The entire landmass area from Adit to Alaknanda is known to be rich with naturally occurring springs. These springs are main source of potable water by the locals. The locations of the naturally-occurring springs are given in Fig. 2.4 and their details are given in table 3.1. The distribution of naturally occurring springs indicates that loose accumulation debris mass overlaying the slope over which hydraulic functioning is ensured, is already saturated with subsurface water. Furthermore, the occurrence of springs at different levels indicates the location where the natural topography has intersected the flow lines of subsurface water (Fig 2.4, Tab le 3.1; Photo 3.1 to Photo 3.4). This also indicates the presence of perched aquifers under bodies within the overburden material. The water coming out from the natural springs is however clear and is being utilized by the residents for potable use.

Table 3.1 Locations of Natural Springs in Joshimath

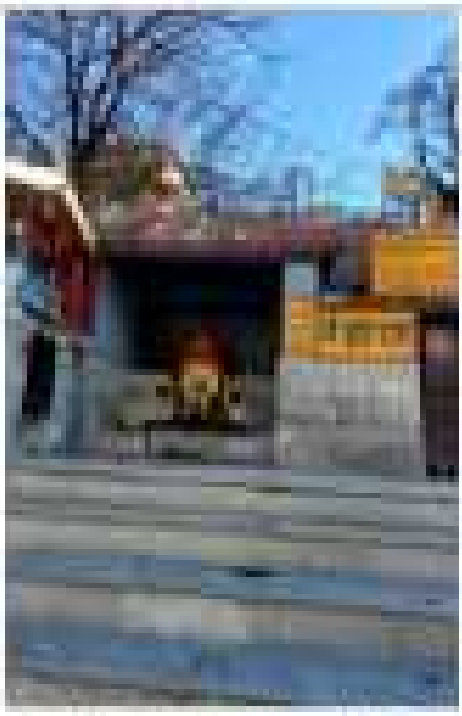
Sl.	Name	Lat (N)	Longitude (E)	Elevation (m)	Nature of Water	Remarks
1	Natural Spring	30.5597°	79.5543	1761	Clear	Intercepting Natural water table
2	Natural Spring	30.5579	79.5543	1801	Clear	Intercepting Natural water table
3	Natural Spring	30.5559	79.5566	1786	Clear	Intercepting Natural water table
4	Natural Spring	30.5586	79.5532	1771	Clear	Intercepting Natural water table
5	Natural Spring	30.5592	79.556	1817	Clear	Intercepting Natural water table
6	Natural Spring	30.5611	79.5526	Dept	Clear	Intercepting Natural water table

7	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
8	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
9	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
10	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
11	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
12	Natural Spring	[illegible]	[illegible]	[illegible]	Clear	Intercepting Natural water table
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The field [illegible]

Photo 11 [illegible]

Photo 12 [illegible]



The information gathered from the field site revealed that the rainwater is collected in the area but does not get into the sewerage system as the drainage network plan of Jeridah. Therefore, the domestic sewerage waste of Jeridah is also contributing substantially to the recharging of unconsolidated shallow-lying water table in the

[illegible] natural reserve.

3.1 Characteristics of New Seepage point at JP Colony Marwari

The water survey carried out from the newly explored seepage point near JP colony in Marwari is also visited and studied and noted (Photo 3.2 and Photo 3.3), supporting evidence of recent piping of flood material in the said seepage. After the framing of water from this point, the outlet water of JP channelized the water into a road drain through which it is being released at the road level (Photo 3.4). It is interesting to note that apart from this, there have been no new seepage points observed / reported anywhere else in the Andimadh agglomerate area. The discharge of water from the seepage point at JP colony (Lat. N 30.264916 Long. E 79.253494, Elv 1617 m) was noticed from 0900 LPM (03.01.2021) to about 17 LPM (on 03.03.2021) as per the daily update of Joshimath Disaster management Bulletin issued by District Disaster Management Authority, Chamoli (https://uttarakhand.gov.in/joshimath-bulletin-2/). It is worth mentioning here that in the preliminary note on the visited locations of outbreaks, released by GSI on NDMA on 10.01.2021, it was pointed out that this new seepage point at JP colony, Marwari, may be from a perched water body located in the shallower area within the overburden. The subsequent gradual decrease in the discharge of water from the newly-appeared seepage point at JP colony Marwari has further corroborated the above inference by GSI.

3.2 Geological Assessment

Field reconnaissance and ground geological observations by GSI also revealed that the recently-developed ground cracks in the Joshimath area (those reported on 02.01.2021 and later) are aligned along a linear away along NW-SE direction, which may also indicate a small shearing over zone of ground saturation due. Later, the saturation profiling (by Wenner and Schlumberger) established the presence of such shallow zones of sub-surface saturation (perched water body) within the fault and new-formed soil landslide debris zones. These observations will however be studied and validated during detailed geological mapping by GSI subsequently.

3.3 Observations by Central Ground Water Board (CGWB)

The Central Ground Water Board (CGWB) has carried out detailed hydrogeological explorations through Electrical Resistivity (ERT) in different parts of Joshimath covering Tapovan,

However high, Singhbhum and Manman area. They have also studied the discharge and yield from the three hand pumps located in a close array between Mahuan, Singhbhum and Hatil Gaon. The recent studies of the yield from the installed three hand pumps by Central Ground water Board (CGWB), in and around Jadugoda area, have revealed that "Occurrence of soft rock in the same area may indicate that areas associated with the ground water may occur in local subsidence." The findings of CGWB in earlier reports also confirm that "The depth of water level in these hand pumps ranges between 18 to 45 m. Daily depth of water level has been monitored and it is observed that water level is declining at Singhbhum area, with various rate 20- 30 cm per day, while in other hand pumps, the water level is almost constant. The decline in Singhbhum hand pump indicates the water bearing strata is linked to the local subsidence. Local subsidence may be extended in and around Singhbhum Hand pump." (Source: CGWB report enhanced in CSE).

3.3. Conclusions on hydrological point vis-à-vis surface observations

- The existence of mineral springs or mineral locations is a clear indicator that the rocks forming heterogeneous detrital material is saturated with water at different levels. In addition, the saturation level of the soil strata, by either means such as surface precipitation or snowmelt, results in the building up of interstitial pore pressures in the soil mass (both of the slope face). This, in turn, gives rise to an adverse condition for the stability of the slope, as the water sometimes increases the shear strength of the slope-forming material.
- The outcomes of the study by CGWB have brought out a zone of subsidence in a linear pattern between Mahuan, Singhbhum and Hatil Gaon and corroborates the linear trend (NW – SE) of old fault also been pointed out by GSI from ground observations, and the same zone of subsidence with groundwater is found coincident with the linear arrangement of development of recent ground cracks. The above findings both by GSI and CGWB thus corroborate that the newly-appeared seepage point at HP colony which had an initial discharge of about 4-5 LPM, as of 10-11-2021, is primarily connected to a perched water body that is located within the thick overburden material. The piping of fluid material by this newly developed seepage has been instrumental in developing various ground cracks/ subsidence in several houses/ work structures that are aligned along a linear array covering NW-SE, affecting parts of Mahuan, Singhbhum, Hatil Gaon, etc.

- The currently affected area is primarily under habitation and the nearby developed ground cracks are also developing in its vicinity only. The adjacent areas where there is other vacancy of no habitation have so far not been affected by the recent and (2-01-2021) events of ground deformations.
- Construction of multi-storied buildings over slight road over the type of loose, unconsolidated, and differentially compacted overburden material having lower shear strength which enhanced the driving forces on the slope thus bringing about the failure of valley and hence leads to the ground distress and failures.
- It is also worth mentioning that there is no reporting of new ground cracks in the landmark area for the last 11 days (16.01.2021 to 31.01.2021), which also confirms the above opinion by GSI (letter submitted to NRDMA on 06.11.2020) wherein it was inferred that increase in the discharge from the newly appointed seepage point will aid in contracting the problem of ground subsidence. As reported by the local administration, the discharge of 12.02.2021 from the JP Colony seepage point is 1" UPW only and the water would not be clean, which indicates that piping has already resulted in washing away, which will a positive sign for an increase in shear strength and stability of the slope forming weak granular mass.

4

4.1. GROUND DEFORMATIONS AND DISTRESS FEATURES

The recent event of the emergence of a new seepage point at JP colony at Marwari on 02-01-2023 has gathered much of the attention of the community and it has been widely covered in the media and an impression has been created that all the ground distress in Joshimath area has surfaced only after 02-01-2023. It is apt to mention here that the ground subsidence phenomenon of different degrees in the Joshimath area had been a known phenomenon for more than the last four decades and the same is already understood and mentioned in the earlier reports of GSI viz. Agarwal, M.C and Mukhopadhyay, S.K (1974-75), Kumar and Srivastava (1980-86), Prasad et al (1987-88) and also in the report of MC, Mishra committee of 1976.

These were reports of ground cracks in some parts of Joshimath in the year 2021 and taking cognizance of it, the Uttarakhand Administration constituted a team of experts drawn from various organizations including GSI in August 2022 and the team submitted a report to the Government of Uttarakhand on the preliminary findings. The Secretary Uttarakhand State Disaster Management Authority (USDMA) convened a meeting subsequently along with a team of experts and various other departments to find practical solutions to the ongoing problem, and in the meeting GSI highlighted the need for characterization of the bearing capacity in the active areas to control the height of the new constructions and also to monitor the ground movement in know zone potentially vulnerable to ground deformations. Subsequently with the sudden emergence of a new water source on 02-01-2023 at the top level of the JP colony at Vishnuprayag Mandal, Joshimath, the USDMA, on 03-01-2023, mobilized the team of experts constituted earlier (in August 2022) to assess the ground situation. The team visited the Joshimath area on 03-01-2023 and submitted the joint report with initial findings to the Government of Uttarakhand on 09-01-2023.

4.3 Site Observations

The GSI team working on the ground constituted to collect data on the ground cracks and took [illegible] across all the river reaches of Joshimath (Photo 4.1) to understand the areas under the maximum impact. Based on the field observations and the characteristic features of different ground cracks, GSI categorized the ground cracks into two categories i.e. i) the recent or new cracks those which are directly related to the event of 02-01-2023 (Photo 4.2, 4.3, and 4.4) and ii) Old cracks that predate the event of 02-01-2023 (Photo 4.5, 4.6 and 4.7). Out of the total recorded 68 ground cracks (till 21.01.2023), 39 cracks are found as recent ones related to the event of 02.01.2023 while the rest 42 are the older ones. The spatial distribution of the ground cracks is depicted in Fig 4.1 and the parametric detail of all the ground cracks is shown in Table 4.1 below.

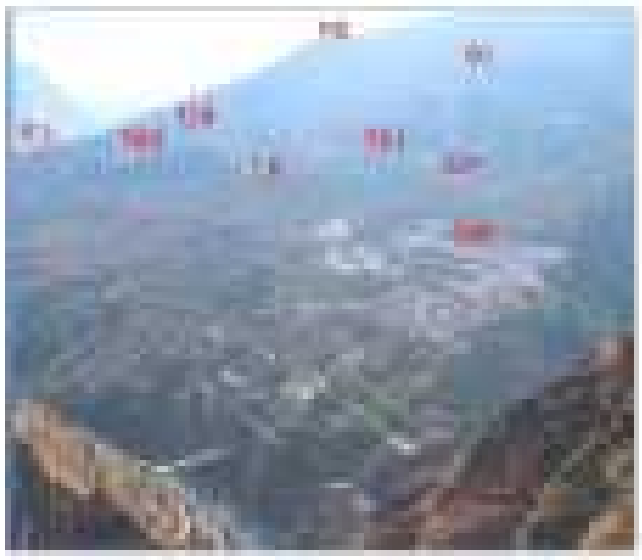


Photo 4.1 : Important Locations of Joshimath (MC = Main Centre; GH = Gyser Hamlet; NH = Narsingh Mandir; SC = Sunil Centre; NH = Nagadhar Hight; SG = Sunil Gaon; SH = Shiv Dham; NC = Marwari; MC = Manari)

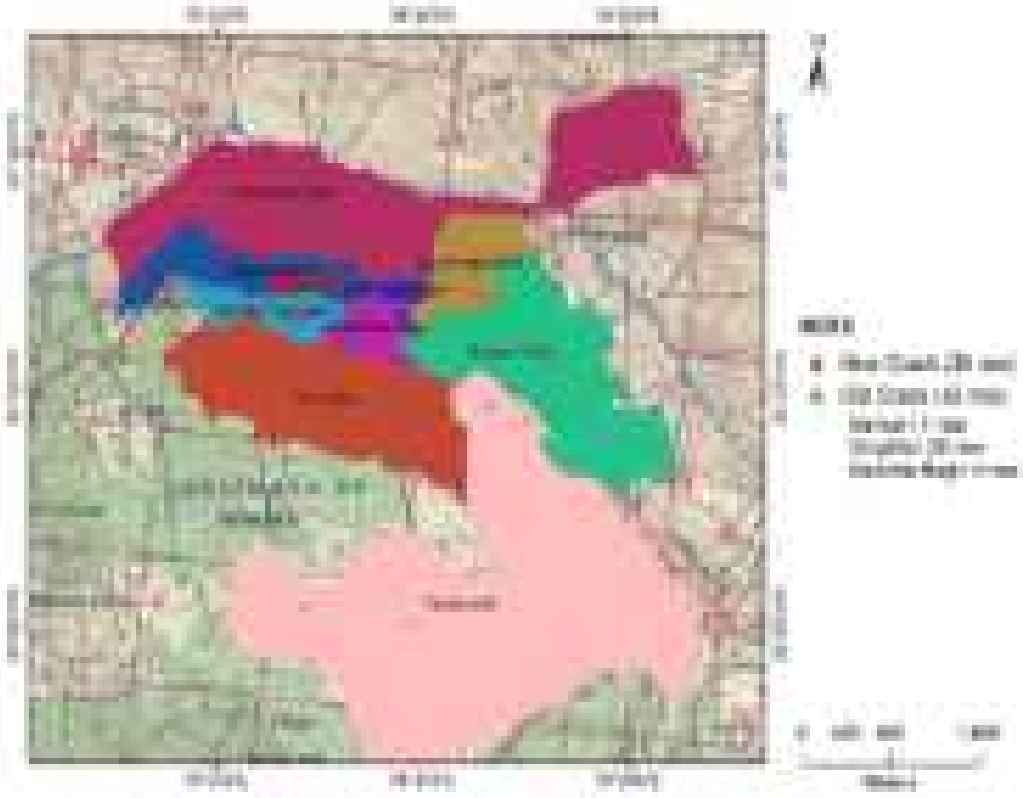


Fig. 4.1 Distribution of Ground Cracks (Old and New) in Jharkhand area

From Table 4.1, it is evident that out of the 41 ground cracks, 21 number of cracks are oriented in the direction of cracks are linear and out of 41 number of ground cracks, 13 cracks are curvilinear in nature whereas 27 number of cracks are linear cracks (Pie Chart 4.2A to 4.2C).

Table 4.1 Parameters (Length of Cracks) Cracks in Different part of Jharkhand

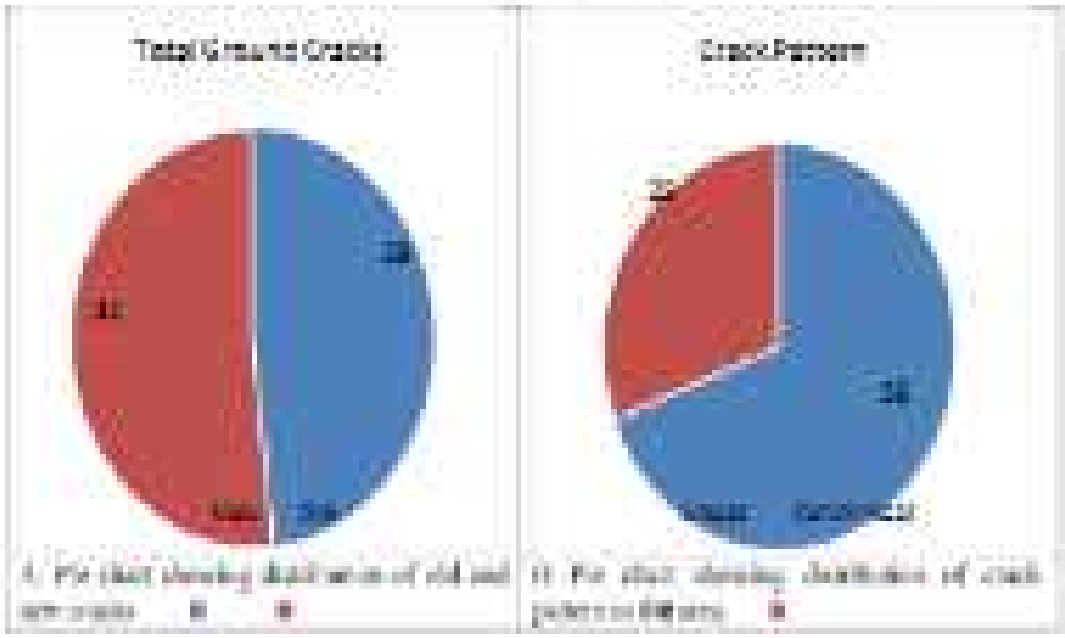
Sl.	Latitude	Longitude	Old/New	Orientation	Type
1	[illegible]	[illegible]	New	200	Curvilinear
2	[illegible]	[illegible]	New	200	Curvilinear
3	[illegible]	[illegible]	New	200	Curvilinear
4	[illegible]	[illegible]	New	200	Curvilinear
5	[illegible]	[illegible]	New	200	Curvilinear
6	[illegible]	[illegible]	New	200	Curvilinear
7	[illegible]	[illegible]	New	200	Curvilinear
8	[illegible]	[illegible]	New	200	Curvilinear

9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

40	[illegible]	[illegible]	Old	201	Carnivore
41	[illegible]	[illegible]	Old	203	Carnivore
42	[illegible]	[illegible]	Old	200	Carnivore
43	[illegible]	[illegible]	Old	200	Carnivore
44	[illegible]	[illegible]	Old	203	Carnivore
45	[illegible]	[illegible]	Old	203	Carnivore
46	[illegible]	[illegible]	Old	201	Carnivore
47	[illegible]	[illegible]	Old	200	Carnivore
48	[illegible]	[illegible]	Old	200	Carnivore
49	[illegible]	[illegible]	Old	203	Carnivore
50	[illegible]	[illegible]	Old	200	Carnivore
51	[illegible]	[illegible]	Old	200	Carnivore
52	[illegible]	[illegible]	Old	200	Carnivore
53	[illegible]	[illegible]	Old	140	Single
54	[illegible]	[illegible]	Old	140	Single
55	[illegible]	[illegible]	Old	150	Single
56	[illegible]	[illegible]	Old	40	Single
57	[illegible]	[illegible]	Old	140	Single
58	[illegible]	[illegible]	Old	33	Single
59	[illegible]	[illegible]	Old	40	Single
60	[illegible]	[illegible]	Old	43	Single
61	[illegible]	[illegible]	Old	30	Single
62	[illegible]	[illegible]	Old	142	Single
63	[illegible]	[illegible]	Old	143	Single
64	[illegible]	[illegible]	Old	20	Single
65	[illegible]	[illegible]	Old	30	Single
66	[illegible]	[illegible]	Old	10	Single
67	[illegible]	[illegible]	Old	150	Single
68	[illegible]	[illegible]	Old	40	Single
69	[illegible]	[illegible]	Old	40	Single
70	[illegible]	[illegible]	Old	20	Single

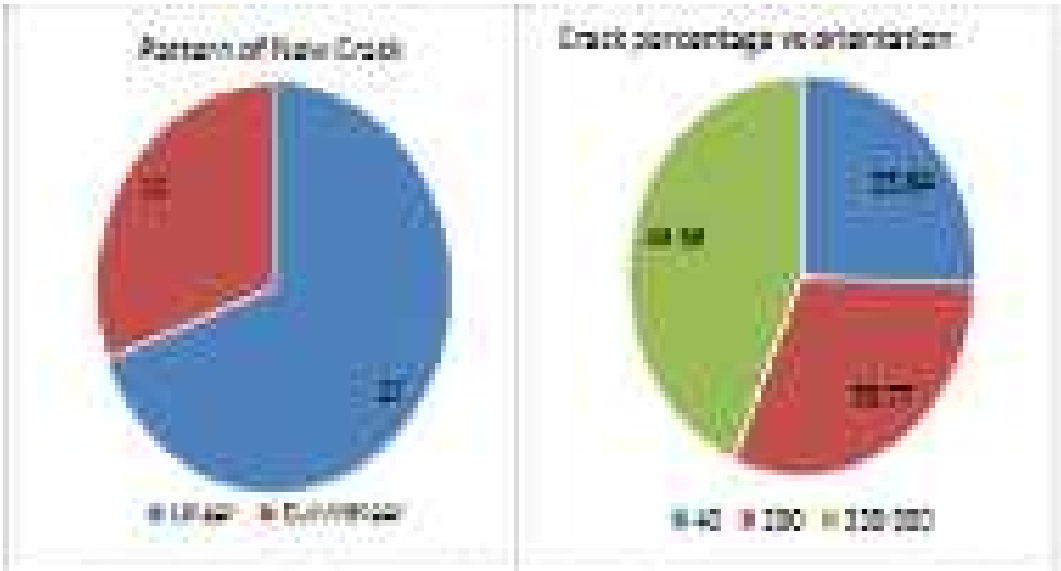
11	[illegible]	[illegible]	Old	20	Straight
12	[illegible]	[illegible]	Old	11	Straight
13	[illegible]	[illegible]	Old	10	Straight
14	[illegible]	[illegible]	Old	40	Straight
15	[illegible]	[illegible]	Old	40	Straight
16	[illegible]	[illegible]	Old	40	Straight
17	[illegible]	[illegible]	Old	11	Straight
18	[illegible]	[illegible]	Old	340	Straight
19	[illegible]	[illegible]	Old	30	Straight
20	[illegible]	[illegible]	Old	40	Straight
21	[illegible]	[illegible]	Old	11	Straight

Another interesting fact that emerges From Fig 4.1 is that the majority of the recently appeared ground cracks from Saint Cacre in the Northeast area aligned along a Linear strip trending NNW – SSE (Fig. 4.1; Pie Chart 4.2B). The other set of ground cracks are aligned in E-W/WNW – ESE direction and are encountered in Meadow Height and Straglton wards (Pie Chart 4.2A).



A. Pie chart showing distribution of old and new cracks B

B. Pie chart showing distribution of crack pattern in the area B



(a) Pie chart showing distribution of the pattern of newly developed cracks in the area

(b) Pie chart showing percentage of cracks along their respective directions

Figure 4.2 Pie Chart Representation of Ground Cracks in Avinmoodu Area

FIELD PHOTOGRAPHS

Photo 4.1 **Source** Ground Crack at J.P Colony Mannar)

Photo 4.2 **Source** Ground Crack on the terrace of JP Colony Mannar

Photo 4.3 **Source** Crack in the Open Ground of a house in Angadikadavu

Photo 4.2 Old Crack on the floor of the house of Shri Sukhen at Sand gram

Photo 4.3 Old Crack in the house near the Sukhen house at Sand gram

Fig 4.4 Old Ground Crack at Sand gram

Amongst the 89 new cracks 66 are in the Mendipathar block area. 20 are in Baghmara and seven are in the Williamnagar area. The orientation of the cracks shows that they are transverse cracks parallel to ground contours. The majority (44%) of these recent ground cracks are aligned towards trending NNW – SSE, and another 33% of these recent ground cracks are aligned WNW – ESE. Near Mawsari in Baghmara and Mendipathar areas wherein the remaining 23% of the recent ground cracks are aligned N-S only and they are concentrated in Baghmara area only (Fig 4.5). There is a total of 81 cracks recorded in the area among which 62 cracks are old cracks and 19 cracks are newly developed cracks. The study of the cracks indicates that the recently appeared ground cracks are mostly concentrated in 4 wards i.e. Mawsari ward, Baghmara ward, Mendipathar ward and Nazir ward.

4.2 Ecological Assessment

An attempt has been made to segregate the reported cracks to get a realistic appraisal of the damages as result of ground distress. It has been found that many of the reported cracks are surficial and do not have penetration into the ground hence they should not be considered a part of the ongoing distress following the incidence of 15.06.2021. The two reported cracks as shown in Photo 4.1 and Photo 4.4 are only confined to the black topping layer which may be a result of subsequent lying of the aggregate beneath. There is no continuation of such cracks in the open

ground on the margins which indicates that this is not related to the ground subsidence.

Photo 4.7: Cracks on the black topping of road near Natal Coach

Photo 4.8: Cracks on the black topping of Road in Singhal area

It is pertinent to mention that the ground cracks and damages on the structures are confined within a 50 – 60 m wide zone across the point. Even where the new overpass has appeared in the 20 century (Photo 3.4) and the buildings/ structures, located this zone, even a 20 century have not been affected by any ground subsidence. From the point (Photo 3.5) the footprints of the recent ground cracks follow a more or less straight NNW – SSE joining Singhal, Mandvi Bagh, and Natal Coach areas. The other dominant pattern of recent ground cracks, trending E – W, is parallel to the contours and is confined to the crest edges of the flat terrestrial surfaces at the Mandvi Bagh area.

The density of recent ground cracks is more in the areas which are also densely inhabited and dotted with several buildings, some of which are multi-storied (Photo 4.9). This has been the case with the areas like Mandvi Bagh and Singhal areas where the maximum number of ground cracks have been recorded and damage to civil structures has been reported. The heavy load exerted by a three storeyed row of housing structures over the heterogeneous colluvium/debris mass, which is saturated with shallow subsurface water, only accentuated the shear stress on the slope that accompanies the subsidence in these areas. Another interesting aspect has been noticed at the Singhal area where the houses are constructed over a raised platform made up of random rubble in dry masonry (Photo 4.10). The vertical and tangential load exerted by the multi-storeyed building above the plain lower (Photo 4.11), was possibly more than the load

loading capacity of the raised platform over which the pink house was constructed.

Photo 4.14 Heavily packed sand bottom cargo moving buildings

Photo 4.15 Crack on the Raised Platform below Pink House in Mogollari area

4.3 Data of Studies by NGRI

As commented in the NGRI report (as received from CESE) "**A preliminary DINSAR analysis on the European Space Agency's satellite Sentinel-1 SAR images show the LOS (line of sight) ground subsidence of the order of +10 cm between December 2020 and January 2021**". The plot of maximum vertical subsidence and Uplift as per the DINSAR analysis is aligned N-W – SE (NGRI report dated 27-01-2021). Further, the plot of physically mapped fissures/cracks as on the Layout plan of CWR profiles of NGRI (NGRI report) shows that the ground cracks between Sand Quarry and Mancherial Highway are aligned roughly N-W – SE (NGRI report dated 27-01-2021, as received from CESE). **The findings of NGRI's above-mentioned subsurface probing also aptly corroborate the ground geological observations** by GSI that majority of the recently appeared ground cracks are falling in a linear array aligned N-W – S-E direction.

4.4 Probable Causes of Known Ground Subsidence

- As mentioned earlier, the entire stretch between Asifabad and Adilabad district is occupied by a thick deposit of sedimentary and soil cover alluvium (Photo 4.11) which is heterogeneous and is characterized by very loose-cored rock boulders (RCC) embedded in a fine matrix of sand and clayey material.

Photo 4.11 View of slope disrupted by old dislocation material

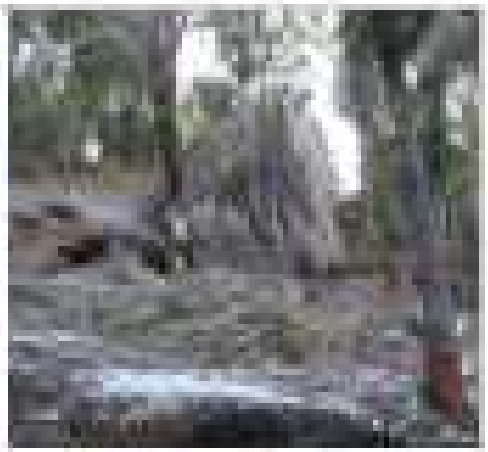


Photo 4.12 Close up of Rock Fortifications

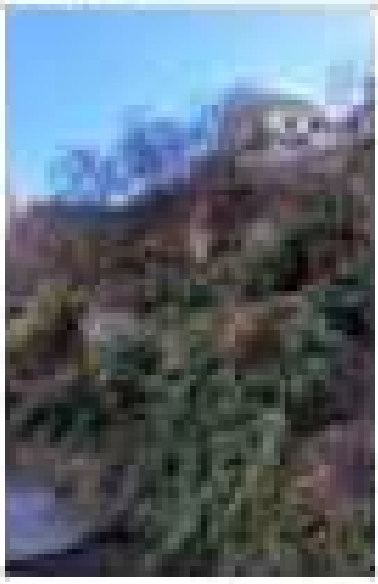


Photo 4.13 Home coming over the old slide dislocation

Photo 4.14 Removal of fine matrix resulting in decline below the giant boulder

- The presence of springs at several locations on the slope between Apt 11 at the top and Maisonette 10 near the bottom (Fig. 2.6), clearly indicates the presence of shallow subsurface water flow lines and perched water bodies within this large old slide debris mass. In the prevailing general conditions, the placement of ground anchorages and crop row contours, could be seen to result primarily in water ef

  i. The removal of fine material from between or zigzagging the shallow subsurface water flow lines or during the surface preparations to which the giant boulders are embedded,

results in the creation of hollows or void spaces beneath the giant boulders (Photo 4.12). More and more material of their material, over a long period because of piping, leads to the vertical settlement of giant rock boulders under the influence of gravity. The settlement of such giant boulders causes a sagging on the surface, particularly when the settlement of boulders is happening close to the ground profile. This anomaly is reflected in the form of ground fissures or cracks, which in the initial stage may be very thin, but with the continued process they may show progressive widening with time. In the Andrewsganj area, it is common to notice the construction of houses over the slope having thick boulder/cobble concrete material (Photo 4.13). Any such piping action as described above can yield ground cracks that can severely affect not only the stability of the piping cracks or building width and those in such areas. This has been the phenomenon commonly observed in the Andrewsganj area in the last 4 to 5 decades (Refer to earlier reports of GSI and the report of the Bhutia committee). However, such signatures of ground distress will be much lesser in the areas which are not heavily loaded with multi-storeyed heavy civil structures.

ii. The recent event of accelerated subsidence reported on 02.01.2020 observed in some parts of Andrewsganj, is a result of a combination of two or three factors. The heterogeneous alluvial strata above is inherently poor in cohesive strength, the saturation of it by shallow subsurface water table acts in reducing the shear strength of the material further. In addition, the excessive vertical load exerted by a dense network of multi-storeyed buildings in a limited area only lowered the factor of safety further because of higher shear stress, and accompanied the ground subsidence/fissure as triggered because of the action of piping along a linear path (NNW-SSE) affecting from the top Rental Gaon, Manchar Bagh, Sagolbar and Marmari area.

4.5 Conclusion:

i. The recent ground cracks are spread across a well-defined linear zone of 51 – 61 m wide along a linear strip trending NNW – SSE from Marmari to Natal Gaon. The recent event of ground subsidence is only confined close to this linear zone, the easiest boundary of which is close to the existing riparian alignment.

ii. The bore-wells from the new tubewells (Photo 3.2) in the A.P colony, Marmari is a clear indicative of the hostility of excessive water pressure back of the first few of the

slope (Photo. 1.3). The muddy color of water indicates the removal of fine debris material from the soil mass above mass or an active regime of piping, which might have triggered an accelerated action of subsidence in the soil.

ii. In addition to the above, the higher vertical load of the multi-storeyed civil structures within a smaller area, resting over a heterogeneous alluvium soil deposit, favored the development of a higher intensity of shear stress on a slope, in contrast to the lowering of shear strength of unconsolidated slope forming mass because of saturation by the artificially shallow subsurface perched groundwater. The above dynamics also exponentially lowered the factor of safety and triggered several stages of slope failure in the form of developing large ancient ground cracks, subsidence, and even slow and slow-sliding of valley wall blocks affecting the stability of superstructures.

iii. Occurrence of a majority of recent ground cracks in a linear array between Mannat and Hotel Kanu primafacie indicates that it is the result of a local linear phenomenon, therefore, the presence of a single deep-seated circular failure, which can explain the overall tilt mass between Anil and Mahavir Mansion seems very unlikely. The recent ground cracks in the NNW – SSE (i.e. in parallel to the strike of the sandstone which indicates some broad-width planes which are confined in Mahavir Nagar and Nagarjun Nagar and lying close to the opposite alignment on the eastern side) are also not signifying a large area, as other results of horizontal stress. Moreover, it is a known fact that in such a heterogeneous slope forming material, the possibility of having a single large-size deep detachment plane can rarely develop. These inferences, however, will be investigated in further detail, having detailed geological mapping on a 1:1000 scale by GIS subsequently.

iv. Non-appearance of any new ground cracks for the last two weeks and a substantial decrease in the discharge of water from the newly opposed seepage point at 'P' colony, Mansion are very positive indicators of the fact that piping action gets reduced to a great extent with time and the pace of ground subsidence has also been contained to a reasonable level so far, which is extremely favorable for stability of superstructures.

5

5.0. STABILITY OF THE AREA AROUND NARSINGH MANDIR TEMPLE PRECINCT

A temple dedicated to Lord Narasimha (an incarnation of Lord Vishnu according to the Hindu religious scriptures) is believed to have been constructed by Adi Shankaracharya. The idol of Prahlaghu established in the temple is believed to have been made during the reign of King Lalitaditya Pida of Kashmir in the 8th century (Wikipedia.org). Every year during the winter season when the temple of Shri Badrinath ji is closed, the priests of Shri Badrinath ji derive worship Lord Badrinath ji at Narsingh temple at Joshimath (Photo 1.1). Keeping in view the historical and cultural importance of this holy temple, the issues of stability on the temple precinct surrounding area and the slopes as per being discussed separately in this chapter.

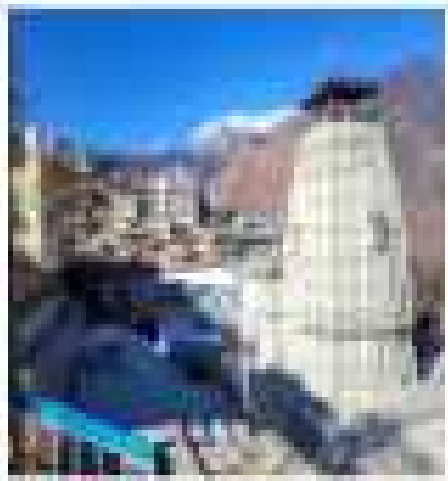


Photo 5.1 View of Narsingh Mandir Joshimath

Photo 5.2 Front gate of Narsingh Mandir

Photo 5.3 Shrine at Nawingli Mandir

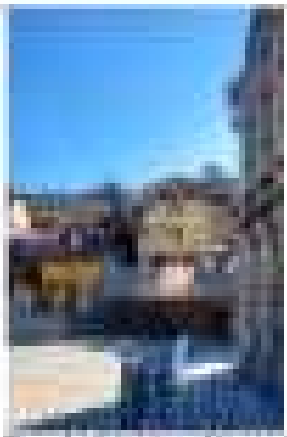


Photo 5.4 View of Nawingli Mandir

After the existence of ground subsidence in Indiranath Limestone mine found on the vicinity of the area surrounding the temple premises and the slopes below it. There were few media reports about some ground cracks in the area close to the Nawingli Mandir. We have visited the Nawingli temple premises and took interviews in the surrounding areas and also on the slopes below the temple area. Nawingli mandir (Lat. N 30° 10' 22.99" and Long. E 79° 31' 11.89") area is located in Lower Mussoorie ward (Fig.2.1, Photo 5.1) of Mussoorie town and is located at an elevation of 1,676 m (5,500 ft). The temple premises is on a level ground and the outer courtyard area has been covered with Kotastone tiles (Photo 5.2 and photo 5.4).

5.2 Site Observations:

The temple premises is located on flat land in the lower middle part of Indiranath town. The area is occupied by residential quarters which is close and is more deserted. This flat piece of land is located just over the crown of an old landslide scar (Photo 5.5). However, no signs of cracks or structural damages are noticed on the temple structures, in doors or the outer courtyard area.

Photo 5.3: View of Slopes in the Naveigh Mandir area

Photo 5.4: View of slopes below Mandir Baghoon

Field investigation was taken in the downslope area of Naveigh Mandir and Mandir Baghoon area (Photo 5.5). It has been observed that the down slopes are deposited gently at an angle of 30° to 35° towards NNW and they are occupied by old debris deluvio material which is loose gravelly in nature and consists of large size rock boulders embedded in silt to clay matrix (Photo 5.6). A prominent drainage channel, trending N – S to NNW – SSE, descends from the higher reaches near the Aitli area and passes close to the Naveigh Mandir area, and finally joins Alaknanda river (Photo 5.7). Few soil cracks have been observed on the banks of this nala on the down slopes below Naveigh Mandir. Presently, no signs of ground distress or deformation were observed on the down slopes of Naveigh Mandir.

5.2 Geological Assessment

A longitudinal profile has been developed using Cartosat data with 10 m spatial resolution, along a line joining Malkhanda River in the bottom and hill at the top (Fig 5.1). A zoomed view of the same profile around the Naveigh Mandir area has been prepared (Fig. 5.2) for better appraisal. A close study of these two profiles reveals that there is a sharp break in topography, marked by a vertical scarp face of about 5-6 m, which indicates the presence of a paleo landslide scarp in this area, the boulders in the down slope area (Photo 5.8 and Photo 5.9) is a testimony to this inference. During the field investigation and around the Naveigh Mandir temple complex and the surrounding area, prime facie signatures of recent ground distress associated with the events of 16.06.2013 were not noticed and people were still residing in the buildings in this area (Photo 5.10). The absence of signatures of ground distress, prima facie, indicates that the

[illegible] area of Nanagh Nindi has attracted a certain degree of activity in the past few years. From here, the exposures of the paleo-Nile flow (Photo 3.5) has also not been uncovered on the ground.

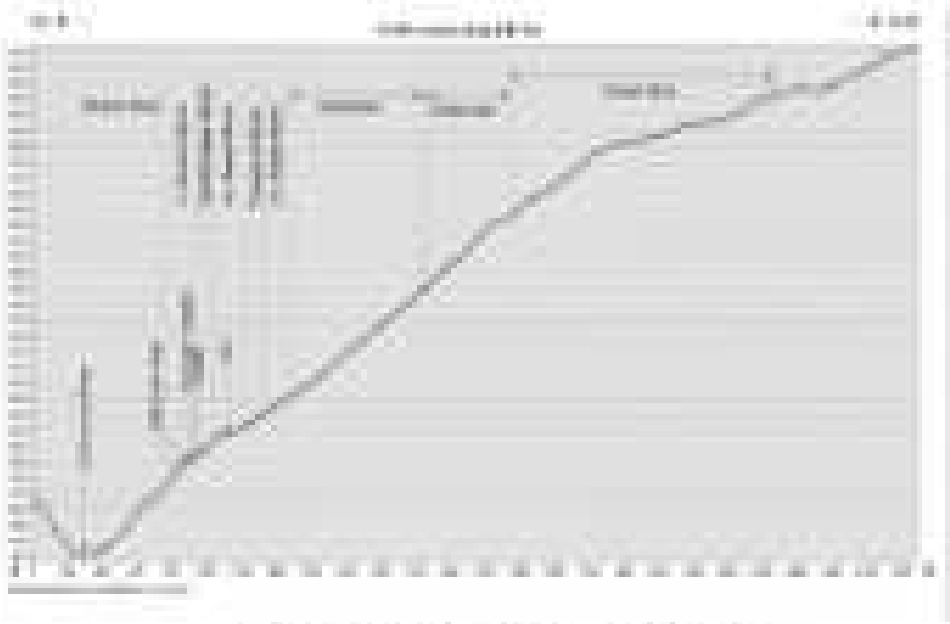


Figure 3.11 Profile showing Nanagh Nindi Area

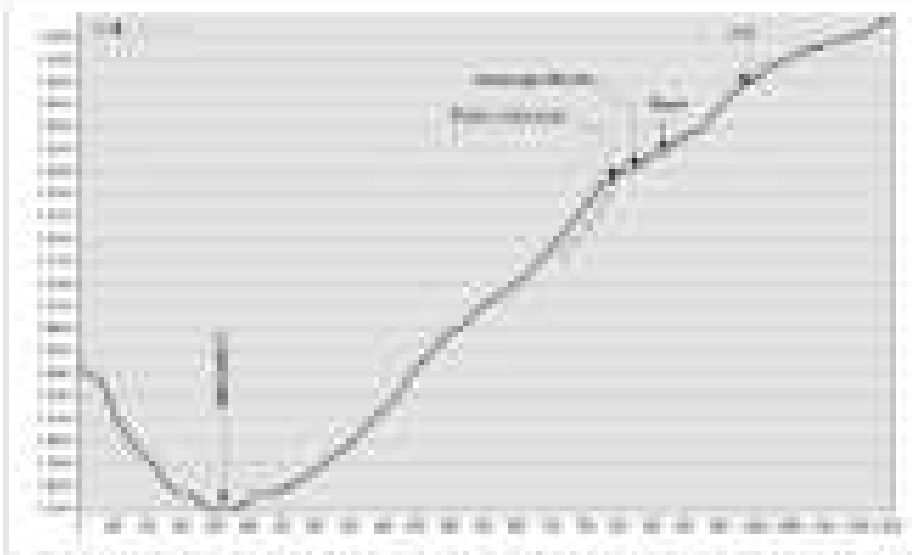


Figure 3.12 Annotated view of the profile showing Nanagh Nindi area, showing the peaks on the old volcanic rock

Some of the studies that have been reported in the area around the sample complex are old rocks and are more or less related to structural features. The rugged rocks on the main outcrop [illegible]

temple premises (Photo 3.7) is an opening along the construction joint which is confined to the lower part of the main wall in the upper part of the main, which is an older one, is unaffected and does not show any subsidence. Similarly, the vertical crack on the side wall of the temple premises (Photo 3.8) is a old one and does not require the patch and does not require the crack.

Photo 3.7 Opening of Construction Joint between Two Segments of Walls

Photo 3.8 Differential settlement of an old boundary wall

Photo 3.9 Opening of Construction joint along two different segments of walls

Photo 3.10 Opening of Construction joint along two different segments of construction

The Fort walls is separated as the two segments of walls as depicted in Photo 3.9 and photo 3.10 are at the junction of two segments which have different construction materials and signify a different time of construction. The cause is attached by the construction joint between the two segments of the wall as shown in Photo 3.10 (see the pre-existing construction joint). As seen the walls segments is covered with cement plaster, a fine crack would appear at the location after some time, which may

Photo 5.11 Old Masonry structure close to Narsingh mandir

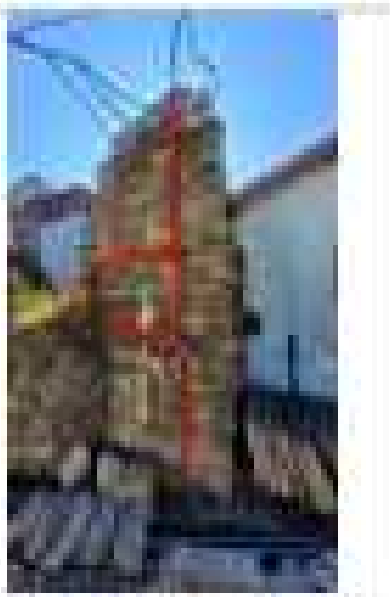


Photo 5.12 Periphery view of the studied temple of Narsingh mandir

is evident, if the surface is cleaned either with sand or cement plaster, fine cracks parallel to block joints and construction joints would be seen after some time, the same has been depicted with the help of red lines as shown in Photo 5.12.

5.3 Conclusion:

Photo Facts, the Narsingh mandir temple precinct has not been in any affected by the recent event of earthquake reported on 12.11.2023. The Temple structure and its precinct area are prima facie found safe as observed during the current field inspection. There is an old shaki wall below the area of Narsingh mandir, however, as of now, any suspension of the wall was not observed. The reported cracks, in the stone and walls in the outside area, are old ones and seem to be structural. People are still residing in the buildings in the area adjoining the Narsingh mandir which means that they have also not been impacted by the recent event of 12.11.2023. No ground cracks were observed in the above areas. The Narsingh mandir and other buildings are prima-facie, the Narsingh mandir temple precinct and its structures surrounding area are prima-facie stable.

6

6.1. POSSIBILITY OF THE SEEPAGE FROM THE BED OF TAPOVAN VISHNUGAD HYDROPOWER PROJECT (TVHPP) OF NTPC Ltd.

Geological Survey of India had been involved in the construction stage engineering geological investigations of the Tapovan Vishnugad Hydropower Project (TVHPP) from 2001 to 2014. During the above period, GSI was involved in the 3D geological mapping of HRT from intake to adit, 3D geological logging of the pressure shaft, 3D Geological logging of powerhouse caverns which were carried out in 10 parts. Reports on these investigations by GSI were already provided to NTPC Ltd.

During the preliminary ground geological reconnaissance after the recent event of ground surface subsidence at Joshimath (after 02-01-2023) the reports of any (man-induced) damages and possibilities of any seepage from the existing Head Race Tunnel (HRT) of the Tapovan Vishnugad Hydropower Project (TVHPP) from Tunnel Boring Machine (TBM) method and the Drill & Blast Method (D&B) has not been critically analysed. During that study, GSI also studied the details of salient features and design features of HRT, the status of excavation in different faces, and data on seepage in TBM face etc., provided by the NTPC Ltd. on request from GSI.

Based on the technical reports provided officially by the NTPC authorities at Joshimath, on the Tapovan Vishnugad Hydropower Project (TVHPP) and based on the previous reports of GSI on the prevalent geomorphology and geology of the area and findings of the current field visits to and around Joshimath area, GSI submits the following, in connection with the above subject matter.

6.2. Salient features of the project

Tapovan Vishnugad Hydropower Project (TVHPP) is a run-of-the-river scheme that envisages the generation of 520 MW of hydropower through an underground powerhouse having four

harness of 132 kV capacities each. The final Run tunnel (ERT) of 1910P is about 12 km in length and 5.49 m in diameter (Annexure – I and Annexure –2). As per the layout drawing (Annexure-2) provided by NHPC Ltd, the invert level of ERT at adit-1 is 1115.776/R is which at the junction of ERT adit and ERT is at El + 705.50m. Out of the total length of about 12 km, nearly 4.5 km is being excavated through a double shield tunnel boring Machine (TBM) which is a mechanized method of excavating involving no blasting (Annexure – 4). The remaining 1.5 km length of ERT from the intake site is being excavated through Drill and Blast Method (D&BM).

6.2. Geology along ERT alignment:

As per the geological section along ERT, as provided by NHPC Ltd. (Annexure – 5), the TBM reach has been excavated through different bands of augen gneiss, granitic gneiss, fine grained leucocratic and quartz mica gneiss whereas the D&BM reach has been excavated through rocks like quartzite with bands of schist, schistose gneiss, augen gneiss and a small patch near the intake portal through mafic bodies. The nature of ERT signalling that small zones agglomerations in 1.5 km reach (Annexure-6) and the stretch has been excavated through D&BM only (no blasting).

6.3. Present status of excavation in HRT

The status of excavation of different faces of ERT, as received from NHPC Ltd. (Annexure – 1), reveals that the face of ERT through TBM is now at 43.993 m, which is just beyond the location of Surge tank (Annexure – 2 and Annexure – 3). The reach has been provided with the pre-cast concrete lining sections. It means that there is an excavated left reach of about 2.1 km ahead of the present TBM face (Annexure – 1). The ERT from the intake end has been excavated up to 1.98 km, after which there is an excavated reach of 237 m beyond which another 315 m stretch has been excavated. Hence a hiatus section (1) in stretch that needs to be excavated through D&BM. Thus adding up to the entire status of excavation through different faces, it is apparent that there is an unexcavated left reach of about 2.77 km separating the faces of the TBM and D&BM stretch (Annexure – 1).

6.4. Seepage from TBM Excavated Reach

The data on seepage through the ERT TBM stretch, as obtained from NHPC Ltd. pls might reveal

dated 19-08-2021 from AGM, Geology, NHPC, Jyotirmath, Annexure – 5 and Annexure – 6) the seepage at the HRT face at RD is as 0.07 litre per sec (LPS) or 4.02 litre per minute (LPM) and it is less than the norm for the period November 2022 to 12-08-2021 (Annexure – 5). The seepage at RD is the point where the HRT face got exposed in 2019 is 69.24 LPS or 4092 LPM. The total seepage through HRT at the outside HRT adit portal (i) for the development of Lobenathji is 71.63 LPS or 4302 LPM. This is the cumulative seepage discharge from the entire 5.8 km long HRT excavated reaches so far. The HRT is stuck at RD 0 m since 05-12-2020 (Annexure – 7).

6.2. Engineering Geological Appraisal

Apart from the above, three part tunnel issues linked with the construction of the HRT of 13.609 have also been noted and found on the technical facts provided by NHPC Limited as Joint Venture (JV) and the general observations, as discussed below:

1) **Role of Shearing in Tunnel**: As discussed earlier, the alignment of HRT (Annexure – 2) is located at a lateral distance of 1.1 km from the other spread of Jyotirmath adit at river level at Marwari. The march has been excavated through HRT and the HRT face is located far away from Jyotirmath (as per the layout provided by NHPC Ltd., Annexure 2 and Annexure – 3) hence, practically the very question of any false-colored damages attributing to the current situation is very unlikely.

2) **Seepage through HRT towards the seepage point at Marwari**: The HRT excavation is yet not completed and the tunnel is not carrying any water presently for power generation. The water level at the present HRT face at RD 0 m is 1641.91.0m and the seepage discharge at this point is only 4.02 LPM (as per the email dated 19.08.2021 from AGM Geology NHPC Ltd, Annexure -5). The ground elevation at the locations of the cross-cuts of Tapoli Gaon is 1620.00m, Marwari Bagh is 1619.64m and Singdhar is at 1618.00m. Hence it is evident that the tunnel level of HRT of the HEP (adit is specially meant for a km away from Jyotirmath) is much below the ground levels of the locations of Tapoli Gaon, Marwari Bagh, and Singdhar. However, the seepage discharge at this underground point currently is only 4.02 LPM which is conclusively matching the initially reported discharge of 4000 LPM from the newly emerged surface seepage point at Marwari located at 11 1987m. These facts, prima-facie, also rule out the probable linkage of seepage observed at the surface on 07.02.2021 with the HRT of the Lapoovan

Volcanogenic Multiparameter Project (VMMP) (from the presently inactive base of [illegible] may be the affected locations of both earth as mentioned above.

3) **Seepage in SST from Inside end**. The slides of [illegible] from the 1980s and 1990s are ~4x smaller that from the [illegible] still more of about 2.7 km width separating the two faces of 1980s and 1994, hence there is no plausible water connecting the seepage line from inside, if any, to the 1994 excavated south. Hence, prima facie, the seepage of water seen from the 1994 excavated south of 1981 to 1994 excavated south ending in surface exchange also does not seem feasible.

7

7.0. CONCLUSIONS AND RECOMMENDATIONS

7.1. Terrain conditions and previous geology

- Ambernath and the surrounding area lie in the west Himalayan Fold-Thrust Belt (FTB), bounded in the south by the main boundary thrust (MBT) and in the north by the main Vaikrita Thrust Zone (MTZ). The study area in Ambernath lies on the hanging wall of a major tectonic discontinuity i.e. the Main Central Thrust (MCT), passing about 3 km south of Ambernath town.
- MCT juxtaposes the Archean to Meso Proterozoic rocks of the Central Crystalline Group over the Meso Proterozoic metasedimentary rocks of the Garhwal Group. The rocks around the Ambernath area belong to the Meso formation of the Central Crystalline Group and they are represented by granitic gneiss, banded gneiss, quartz mica schists, quartzite, and schistose quartzite.
- Ambernath town however is situated over a thick deposit of sediments and old lacustrine deposits, which mostly consists of loose unconsolidated, and heterogeneous debris constituted by big boulders of gneissic rocks embedded in a fine silty to clayey matrix.

7.2. History on subsidence in Jackhauch and the wall of current areas:

- The problem of ground subsidence in and around Ambernath areas had been known past several years as the past by earlier workers of NGRI, MRT, whereas subsidence, constituted in 1976, was posted out this problem and made certain recommendations. Therefore, the problems of sinking and subsidence in Ambernath areas are almost four decades old as identified reported by some previous workers of NGRI.
- In July 2012 a team of experts had been constituted by the Government of Maharashtra to study the reported incidences of ground subsidence in the Ambernath area. However, the present normal factual event in Ambernath pertains to the sudden start of ground subsidence

in different wards of Aizawl city following a burst of subsurface water as a significant seepage point near IFS colony in the early hours of 02-01-2021.

3. Present investigation and salient field observations

- CSIR-C3RP carried out the ground survey of the affected area and prepared an inventory of 89 ground cracks, out of which 19 cracks are old ones existing before 02-01-2021, while 67 are recent ones (as reported on or after 02.01.2021). These recently-appeared ground cracks are mainly encountered in five numbers of wards (i.e. North Khatla, Maruhtar Hlupi, Hlupibuk, and Mawmual). The majority of the recently appeared ground cracks are following a dominant linear trend reading N-S ~ NW-SE.
- Majority of the ground cracks encountered in the present investigation are located in areas that are already populated and hosted with multi-storeyed buildings. The other areas where there is scarcity of any habitation has so far not been affected by the recent event (02.01.2021) of ground deformation and fissuring/cracking.
- The recent ground cracks are found spreading across a 50 ~ 60 m wide linear zone and reach NNW-SSE from Maruhtar to South Khatla, the eastern boundary of which is close to the existing epicentre (Hlupibuk).
- From facts, the Natwagh massive complex proposed to rise and has not been affected by the recent event of 02-01-2021. There is no old slide scar below the area of Natwagh massive. However, as of now, exposure of the rock was not observed. The reported cracks in the main road walls in the peripheral part are old ones and none or few due to structural/ constructional discrepancy. No ground distress was noticed on the downslope of the Natwagh massive area which indicates the stability of this area.
- The occurrence of natural springs at a number of locations in a close inclusion that the slope-forming lithologies (slope materials) is saturated with water at different levels. In addition, the saturation level of the soil mass, by other means such as surface precipitation or rainwater, leads to the building up of saturated pore pressure in the soil mass back of the slope face. This, in turn, gives rise to an adverse condition for the stability of the slope, as the water saturation decreases the shear strength of the slope-forming material.

7.4. Appraisal on possible connection of the current hazard event with the HRT of Tapovan-Vishnugad Hydel Project

- Regarding the question of seepage from the HRT of Tapovan Vishnugad Project, it is difficult to apprehend any such connection keeping in view the lateral distance of 1.2 km of HRT from the actual epicentre of landmass which is even more in Malkoti Nala through intervening rock mass (Aerial Hazing map) (Fig 6.1), which does not generate any other collateral damages. And the UHR face of the HRT is located much away from Joshimath (9 km as stated from the actual epicentre of Joshimath town), prima-facie the very question of any Hydro-related damages attributing to the current situation is very unlikely, including having any plausible connection of seepage water from the HRT to the current problem faced such as Falling seepage outlets points at Marwari.
- Moreover, the actual level of HRT (1335.731.2 m) at the present UHR face at RD 9915 m (which is far away from Joshimath) is much below the ground levels of the corresponding locations of Sunil Gaon, Marwari Bagh, and Manjhila. Moreover, the seepage discharge at the outlet portal point currently is only 4.02 LPM which is somehow matching with the actually reported discharge of 100 LPM from the newly emerged surface seepage point at Marwari located at 12 m(+/-) near JP colony. These facts, prima facie, rule out any plausible linkage of seepage observed at surface on 05.01.2023 at Marwari with the seepage observed at the existing Head Race Tunnel (HRT) at the presently stacked face at RD 9415 m.

7.5. Possible causes of the current hazard at Joshimath

- The issue of water from the new seepage point (Photo 5.26 at JP colony, Marwari) is a clear indicator of leaking of excessive pore water pressure built up at the free face of the slope (Photo 5.5). The muddy color of water indicates removal of fine matrix material from the rock mass during onset of any active regime of piping, which might have triggered an accelerated action of subsidence or failure.
- The removal of fine material from the matrix or piping (by the shallow sub surface water flow lines, or during the surface precipitation), in which the giant boulders are embedded, results in creation of hollows or void spaces beneath the giant boulders (Photo 5.16). With more and more removal of finer material, over a long period of time because of piping,

results in vertical settlement of giant rock boulders under the influence of gravity. The settlement of such giant boulders causes a sagging on the surface, particularly when the settlement of boulders is happening close to the ground profile. This obviously is reflected in the form of ground fissures or cracks, which in the initial stages may be very fine, but with the continued process, they may also be progressive widening with time.

- In Andamanath area, it is also common to notice construction of multi-storeyed houses over slope having thick boulder-laden overburden material (Photo 4.14). Any such piping action or dissolved stone can yield ground cracks that can severely affect and can develop wide gaping cracks on building walls and floors in such areas, as observed during the recent event of earthquake in Andamanath.
- The heterogeneous old slide debris is presently part in saturated strength, the saturation of it by shallow sub-surface water only aids in reducing the shear strength of this material further. In addition, the excessive vertical load exerted by a dense network of multi-storeyed buildings is factored in to only increase the factor of safety further because of higher shear stress, and actually accommodate the ground subsidence factor as it gained because of action of piping along a linear path (WNW-ESE) affecting from the top road Hotel Laxmi to Mandhar Bagh, Nagalkot and Marwari areas on the downslope.

7.5. Insights about the source of shallow underground water and vital inputs from the studies by CGWB, and NGRI.

- The outcomes of the study by CGWB have brought out a zone of saturation in a linear pattern between Marwari, Nagalkot, and Hotel Laxmi and corroborate the linear trend (NW–SE) which has also been pointed out by GSI from ground observations, and the same zone of saturation with groundwater is found coherent with the linear occurrence of development of recent ground cracks. The above findings both by GSI and CGWB, thus corroborate that the newly approved seepage point at 8th colony which had an initial discharge of about 600 LPM, as of 02.03.2021, is presumptuous, connected to a perched water body that is located within the thick overburden/debris material. The piping of finer material by this newly-developed seepage has been instrumental in developing severe ground cracks/subsidence in several houses and structures that are aligned along a linear area trending NW–SE, affecting parts of Marwari, Nagalkot, Hotel Laxmi etc.
- The GPR studies by NGRI also corroborated the presence of a narrow linear zone of higher

subsidence that is seen at NH-**[illegible] road, which also corroborates GSI's ground observation, and also matches CGWB's subsidence on a linear** parallel alignment (10-40 m) groundwater along Sai Ghats, Singhan, and Mawaiya, which also showed a decrease in water current on monitoring, and confirmed findings of lowering of seepage water observed with time at the one seepage point at IP Colony in Mawaiya.

- The above vital instrumental surface and sub-surface observations by CGWB and NGRI **supports GSI's ground evidence and** also answers the possible causes of linking the source of seepage water that suddenly gushed out in the new form of 02.11.2021, and has been instrumental in developing several models and subsidence to accept hence in a manner from some effective parts of the results of Jyotirmath area.

7.0 Inferences on slope stability status and its possible future trend

- Occurrence of a majority of recent ground cracks in a linear strip between Mawaiya and Helmi from primafacie indicates that it is the result of a local phenomenon and the absence of a single deep-seated circular failure, which can underlie the entire hill mass between Joshi and Mawaiya downward scarp regions. The recent ground cracks with N-S/NE—S/SW/E—W trend are following the contours which indicates some detachment planes (shallow) are confined to Mawaiya Singh and Singhan areas (and lying close to the highway alignment on the concrete walls) are also not signifying a large mass in other words of Joshimath town. However, it is a known fact that in such a heterogeneous slope forming material, the possibility of having a single large scale deep detachment plane can easily develop. These inferences, however, will be investigated in further detail during detailed geological mapping on a 1:500 scale by GSI subsequently.
- Non-appearance of any new ground cracks for the last two weeks and a rational decision in the discharge of water from the newly appeared seepage point at IP colony Mawaiya are very positive indicators of the fact that preparatory gets released to a great extent with time, and the pace of ground subsidence has also been contained to a reasonable level so far.

8.0 Suggested way forward and further investigations by GSI

- As already planned and discussed, GSI will be carrying out detailed geological mapping on a 1:500 scale of the area around fault mostly covering all wards and the area between Auli in the top to Nakrunda River in the bottom. This exercise will be carried from the date of

[illegible] of the contour plan of the area on a 1:5000 scale with a 2 m contour interval by the CSDMA. The detailed geological mapping will be carried out by a team of an geologists equipped with DGPS and Terrestrial Laser Scanner (TLS) instruments for faster and more detailed coverage of the area. During the geological mapping, the outcrops of bedrock and [illegible] exposures of different types of slope-forming material, slope geomorphic features, ground deformations features (like soil creep, natural springs, and newly appeared seepage points will be observed and mapped. The samples of bedrock and undisturbed soil will be collected for the determination of geotechnical parameters. Longitudinal and cross-sectional profiles will be developed from the geological map and geological sections will be prepared. Based on the ground geological mapping and results of soil samples, slope stability to determine the detailed slope stability assessment of the entire area along with a preparation of a 1:5000 scale landslide hazard map. In addition to the landslide hazard map, as an ultimate output, a landslide management map will also be prepared wherein the mapped area will be categorized into different vulnerability zones. Hazard-specific hazard assessment and risk evaluation will be brought out and accordingly zone specific to hazard-specific mitigation measures will be suggested. It will help the administrative authorities in planning for future developmental activities in and around the Kedarnath area, and also use such [illegible] information for implementing land use zoning regulations in Kedarnath to ensure better stability and management in the future.

- It is also suggested that for the above comprehensive slope stability assessment on a 1:5000 scale, the data and reports of the geophysical surveys carried out by WAPCOS Ltd. and Wadia Institute, results of water sampling by NRSC and results of geotechnical investigations and testing being planned carried out by IIT Roorkee, along with geo-locations of sample points may please be shared with GSI to optimize the study and to avoid any duplication of work, and also for incorporation in its final report so that the remedial measures and rehabilitation measures can be suggested more precisely.
- It is strongly advised to carry out ground based terrestrial monitoring in different parts of Kedarnath area in order to get a realistic and accurate assessment of ground movements, if any, in different parts of Kedarnath. Please see enclosed report of [illegible] on Chorabari [illegible].

ACKNOWLEDGEMENT

- The authors express their gratitude to Dr. S. Raja, the Director General, of the Geological Survey of India for his overall moral guidance and supervision and for providing the facilities to carry out the work. The authors remain thankful to Shri N.V. Srivastava, Addl. Director General and Head, NR for providing necessary moral guidance and providing the facilities and other support to carry out the work. Discussions with Dy. Director General, M-II & Dr. Sandip Oza and DGM, M-IV-C Dr. Subhas Sharma and Director (retd.), Mission of Mines (M&M) Sri Pratap Singh and Smt. G. Hemlata, Dr. Kaushik Chakraborty were extremely helpful and is sincerely acknowledged.
- The Corporation received from the officials of Local Administrations, especially the UMMA Secretary Dr. Rajat Kumar Sinha, Secretary of UMMA, viz. Dr. Sushanta Sarma, Dr. Pranab Konwar, and the DM of Chirang District for their assistance extremely praiseworthy. Discussions with Scientists of other Scientific organizations working there, especially Sri Prashant Rai, Director, CHAS, Dr. Anand Pandey, of NCAS, and Dr. U.C. Kalangan, CSIRC, Roorkee Dr. Jongmenla Walling, WIHG, etc. were stimulating. Lastly, the cooperation of the innumerable local people received during the work is sincerely appreciated.

BIBLIOGRAPHY

- Agarwal, H.C. and Mukhopadhyay, S.N. (1974-77), Geology and Geomorphology of Bodoland Autonomous Area, Chirang District, Uttar Pradesh, Unpub. Report of GSI, FS 1974-75.
- Acton & Gannon (1979)
- Kumar and Srivastava (1995-96), A Geophysical View On The Stability Of Dudhnoi Area, Garo Hills District, Uttar Pradesh, Unpub. Report, Of GSI, FS 1974-75.
- Lloyd et al. 1932, Nanda et al. 2009
- Khandelwal, H.C. and Nargund, H. P. PS (2007 – 2008), Progress Report No.1 on the Geotechnical Study, Geohydrological Investigations Of Tapovan Vishnugad Hydro Electric Project, Chamoli District, Uttarakhand, Unpub. Report of GSI, FS 2007-08

- Chauhan H.C., Manjunath D. P. and Thapliyal A. P. (N) (2003 – 2005). Progress Report No. I On The Geomagnetic Main Geological Investigations Of The Tapovan-Vishnugad Hydro Electric Project (Chamoli District, Uttarakhand). Unpub. Reports of GSI, FS (2003-05).
- Mishra Committee (1976) Mishra Committee Report on Joshimath area. Govt. of Uttar Pradesh, 1976, pg. 3 to 11.
- Prasad, et al (1987-88). Geophysical Report On The Multi-Purpose Tehri Dam Project (Tehri Garhwal District, U.P.). Unpub. Reports of GSI, FS (1987-88).
- Pankaj Kumar (2007-08). Landslide Hazard Zonation For Major Settlements Area (Chamoli District, Uttarakhand) With Special Reference To Slope Stability. Unpub. Reports of GSI, FS (2007-08).
- Thapliyal A. P. and Nidhagatwa Prakash. Unpub. Reports of GSI, FS(2005 – 2010).
- Thapliyal A. P. et. al. Unpub. Reports of GSI, FS (2010 – 2012).
- Thapliyal A. P. Nidhagatwa, Harish and Tripathi S. N. Unpub. Reports of GSI, FS (2012 – 2013).
- Thapliyal A. P. and Nidhagatwa Manish. Unpub. Reports of GSI, FS (2011 – 2014).

[External]Re: Request for sharing data

Bhuvnesh <BHUVNESHKUMAR@NTPC.CO.IN>

[redacted]

[redacted]

Dharmendra Singh <DHARMENDRASINGH@NTPC.CO.IN>; Anubha <ANUBHA@NTPC.CO.IN>; Harmeet Bedi <HARMEETBEDI@NTPC.CO.IN>; NAVEEN CHANDRA PANT <NAVEENCHANDRAPANT@NTPC.CO.IN>; HARSH SHRIVASTAVA <HARSHSHRIVASTAVA@NTPC.CO.IN>; [redacted]; [redacted]; Chandra Shekhar Tewari <CSTEWARI@NTPC.CO.IN>; SUBRATA PRASAD <SPRASAD@NTPC.CO.IN>

[redacted]

Point 1 [redacted] plot, Point 2, Updated position of the HRT face from Inside, from Chorni adit and from TBM excavation, Point plot, Point 3 Geological section along HRT adit.

[redacted]

Please find attached the following as desired-
1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from Inside, from Chorni adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face - Seepage is 4 Litres/Minute from TBM Face at present.

सादर (Regards),

भुवनेश कुमार / Bhuvnesh Kumar

अपर महाप्रबंधक (भू विज्ञान) / AGM (Geology)
TVNPP
एनटीपीसी लिमिटेड,NTPC Limited
8630601471

"हिन्दी हैं हम वतन है हिन्दोस्तां हमारा है"

From: RAJENDRA PRASAD <RAJAIYA@NTPC.CO.IN>
Sent: 14 January 2023 16:52
To: Chandra Bhan Tewari <CBTIWARI@NTPC.CO.IN>; Shubham <SHUBHAM@NTPC.CO.IN>; Anubhav <ANUBHAV@NTPC.CO.IN>; NAVEEN CHANDRA RAUT <NAVEENCHANDRARAUT@NTPC.CO.IN>
Subject: Fwd: Request for sharing data

[redacted]

[redacted]

[redacted]

From: HOD MR <hod.mr@gsi.gov.in>
Sent: Friday, January 13, 2023 2:26:57 PM
To: RAJENDRA PRASAD <RAJAIYA@NTPC.CO.IN>
Subject: Fw: Request for sharing data

To,
Shri B.P. Srivastava
Chief General Manager
TVNPP
NTPC, Ravigram, Joshimath

Sir,

Director General, GSI, Kolkata has deputed Dr. Harish Sahugaina, Director, GSI, as the nodal officer for the geological assessment of the ongoing problem of ground subsidence at Joshimath. He shall be carrying out field assessment from 14th to 16th January 2023. In this connection, it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from Intake, from Chorm adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face, if any
5) Any other relevant data/information as required by Dr. Sahugaina

His contact number is 8958005887.
This issue is being monitored by the highest level of officials of Government of India.

With regards

[illegible]
[illegible]
[illegible]

[illegible]

[illegible]
[illegible]
[illegible]

From: HOD NR
Sent: Wednesday, January 11, 2023 9:50 PM
To: rpathirual@grse.co.in
Cc: NATIONAL MISSION HEAD 4; DDG DGN
Subject: Request for sharing data

To
Shri R.P. Ahirwar
Chief General Manager
TV-SDD
NTPC, Ravigram, Jaaimach

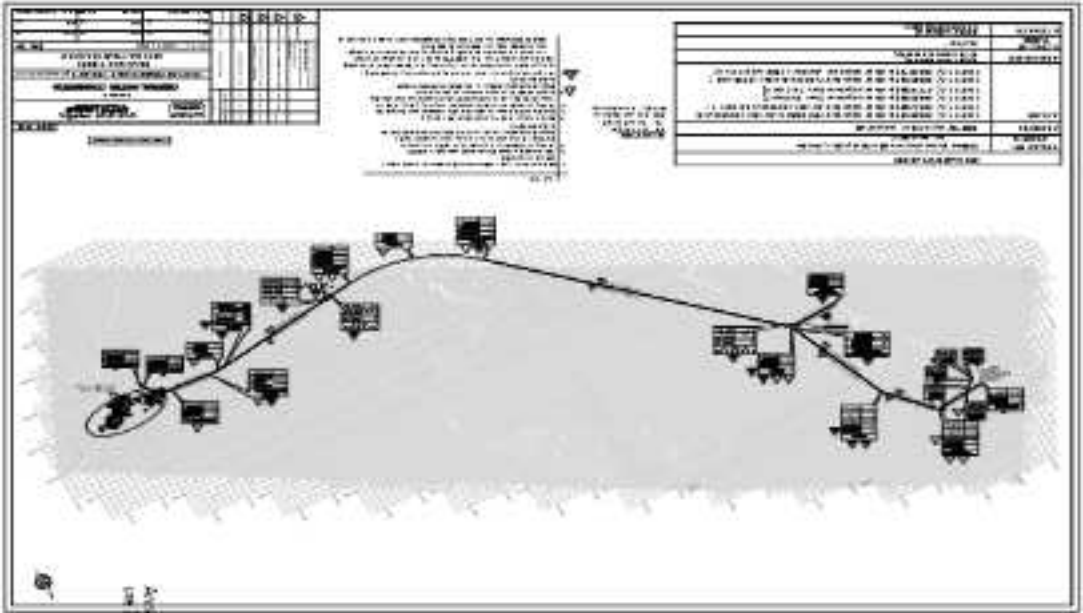
Sir,

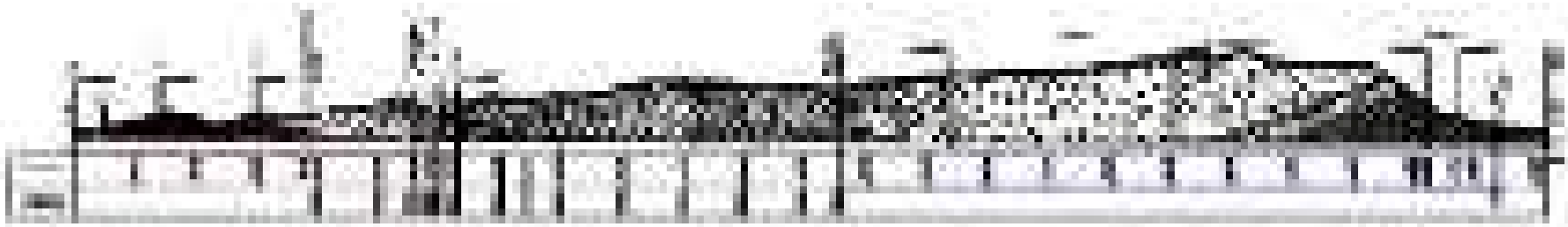
Director General GSI, Kolkata has deputed Dr. Harish Sahugune, Director, GSI, as the nodal officer for the geological assessment of the ongoing problem of ground subsidence at Jashmach. He shall be carrying out field assessment from 14th to 16th January 2023. In this context it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the MT face from inside, from Chorm adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face, if any.
5) Any other relevant data/information as required by Dr Sahugune

His contact number is 9999999887.

This issue is being monitored by the highest level of officials of Government of India.





NTPC Limited

[External [Re:] External] Re: Request for sharing data

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Fig-1: [illegible]

[illegible],

Point wise reply to the queries vide EE mailing mail are as under:

i. The present levels of HRT, as desired, are given below:-

i) The present level of HRT at the present TBH face RD 2910 m – EL 731.132m.
ii) The present level of HRT at RD 2674m (near TBH entry point – EL 736.667 m.
iii) The present level at TBH entry RD 0.0 m (point A) EL 739.00 m.

ii. Regarding Sd Geological logs/ face logs of TBH submitted each. It is submitted that T-1/HP TBM is a double shield TBM and therefore it is not possible to prepare the Sd Geological logs/ face logs of TBM submitted each, since exposed rock surfaces are not visible.

iii. Regarding a plan of HRT alignment on 2D/ 3D plan/ indicating the horizontal distance of HRT from the urban ground of Jodhpur, it is submitted that-

HRT alignment on 1:50000 SOI toposheet is not available, however only after out rely along HRT alignment has carried out on 1:2000 scale, as per DPR report enclosed, which does not cover Jodhpur area.
However, to understand the horizontal distance of HRT from the urban ground of Jodhpur, HRT alignment is tentatively marked on sheet Google maps and distance from HRT are indicated in attached Fig-1.

iv. The seepage/ discharge data from different reaches of HRT/ TBH reach measured on 17-01-2022 are as under-

i) Seepage at the present TBH face at RD 4231 m is 0.087 Lit/sec/sec.
ii) Cumulative Tunnel Discharge measured at Portal no. [illegible] – 6620 Lit/sec/sec.
iii) Cumulative Total Discharge measured outside TBM exit Portal is 71.82 Lit/sec/Sec.

[illegible],

[illegible] (Bhuvnesh Kumar)

[illegible] (Addl. Manager)
T-HRT
[illegible] (I/C) Limited
[illegible]

[redacted]

Sir

[redacted]

Yours sincerely

[redacted]

Sir

[redacted]

Yours sincerely

[redacted]

[illegible]

[illegible]

Dated: 11 January 2022 18:53:02
To, [illegible]
Sir/ Madam/ Mx./ Dr./ Prof./ Shri/ Smt./ Kum./ [illegible]
Dear Sir/ Madam,
Subject: [illegible]

Please find attached the following agenda documents:
1) Minutes of the project clearly depicting the alignment of river
2) Updated overview of the HDF loss from roads, from Dharwad, with input from TSDU assessment.
3) Ecological corridor along NH7
4) Data on the crossings in HDF at the present TSDU loss - Crossings & Culverts/Drives From TSDU Nos as present.

[illegible]

पुनीत कुमार / Puneet Kumar

[illegible] (Addl. Secretary)
Tel:[illegible]
[illegible]
[illegible]

पीएमडी टिम को एक सुनने दिशेने सबसे अच्छे

[illegible]
Sent: 11 January 2022 12:03
To: [illegible]
Subject: Fwd: Request for site visit date

[illegible]

[illegible]

[illegible]

From: [illegible]
Sent: [illegible], January [illegible], 2023 [illegible]
To: [illegible]
Subject: [illegible] Request for sharing data

CAUTION: [illegible]

To,
Shri R.K. [illegible]
Chief General Manager
TUHEP
NTPC, Tapovan, Joshimath

Sir,

[illegible] the geological assessment of the ensuing problem of ground subsidence at Joshimath. He shall be carrying out field assessment from [illegible] January 2023. In this context it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT [illegible]
3) Geological section along HRT
4) Data on the seepage in HRT [illegible]
5) Any other relevant data/information as required by Dr [illegible]
His contact number is [illegible].
This issue is being monitored by the highest level of officials of Government of India.
With regards,

[illegible]

[illegible]

[illegible]

From: [illegible]
Sent: Wednesday, January 11, 2023 [illegible]
To: [illegible]
Cc: [illegible]
Subject: Request for sharing data

To,
Shri R.K. [illegible]
Chief General Manager
TUHEP
NTPC, Tapovan, Joshimath

[illegible]

Dr.

Director General (SI), Kolkata has deputed Dr. Harsh Dalmia, Director (SI), as the nodal officer for the geological assessment of the housing problem of ground subsidence settlement. He shall be carrying out field assessments from [illegible] to [illegible] 2022. In this context it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from reach 7mm Chainage from Intake complex
3) Geological section along HRT
4) Details on the advancement of HRT as on the present day (in Nos. if any)
5) Any other observed data/information as required by Dr. Dalmia/s

Also a report number is [illegible].

This issue is being monitored by the highest level officials of Government of India.

Other regards,

[illegible] (I / Interviewer)
Joint Secretary to Director, [illegible] & Gas
Ministry of [illegible], Lucknow
[illegible]
[illegible]
[illegible]

Annexure – 7

[External]Re: [External]Re: [External]Re: Request for sharing data

Dharmendra Singh <DHARMENDRABIST@NTPC.CO.IN>

Fri, 29 Dec 2023 16:07

To: Hari Om Bahuguna <hombguna@gsi.gov.in>; HOD NF <hod-nf@gsi.gov.in>

Cc: EC Nagaon <ECFNRDA@NTPC.CO.IN>; Naveen Chandra Rai <NAVEENCHANDRARAI@NTPC.CO.IN>; Anubhav <ANUBHAV@NTPC.CO.IN>; Bhunesh <BHUNESHGAHLOT@NTPC.CO.IN>; Manmeet Bedi <MANMEETBEDI@NTPC.CO.IN>; Chandra Shekhar Tewari <CSTIWARI@NTPC.CO.IN>; Kuldeep Prasad <KPRASAD@NTPC.CO.IN>

महोदय/महोदया (Sir/Madam),

-The TBM reached at RD 5018m on 24/12/2009.
-The excavation from 5018 was restarted on 6/03/2011 and got stuck at RD 5859m on 24/10/2012.
-TBM restarted from RD 5859m on 03/05/2013 and got stuck at RD 5892 on 07/10/2019.
-TBM restarted from RD 5892 on 21/09/2020 and got stuck at RD 5915 on 05/10/2020 Since 05/10/2020 TBM is stuck up till date at this position.

The Seepage of approximately 0.001 ltr/second has been observed from the TBM face at RD 5915m for the period November 2022 to 02-01-2023.

धन्यवाद(Regards),

D S Bist
AGM (Geology), TVHEP
भूवैज्ञानिक प्रबंधक (भूविज्ञान)
एनटीपीसी लिमिटेड/NTPC Limited
8650931344

From: HARISH BAHUGUNA <h.bahuguna@gsi.gov.in>
Sent: 20 January 2023 17:34
To: Bhuvnesh <BHUVNESH.KUMAR@NTPC.CO.IN>; HOD NR <hod.nr@gsi.gov.in>
Cc: G.C Pargaien <GCPARGAIEN@NTPC.CO.IN>; Dharmendra Singh <DHARMENDRASGT@NTPC.CO.IN>; NAVEEN CHANDRA PANT <NAVEENCHANDRAPANT@NTPC.CO.IN>; Anubhav <ANUBHAV@NTPC.CO.IN>; Manmeet Bedi <MANMEETBEDI@NTPC.CO.IN>; Chandra Dhar Tewari <CDTIWARI@NTPC.CO.IN>; RAJENDRA PRASAD <RPAHPWAR@NTPC.CO.IN>
Subject: Re: [External][Re:] External][Re: Request for sharing data

CAUTION: This Email has been sent from outside the Organization. Unless you trust the sender, Don't click links or open attachments as it may be a Phishing email, which can steal your Information and compromise your Computer.

Sir
Kindly arrange to provide the date when the excavation of TBM reach between RD 5010m and RD 5015m was undertaken and since when the TBM is stuck at RD 5015m.
Also please share seepage data from the TBM face at RD 5010m for the period November 2022 to 02-01-2023.
Please treat this as Most Urgent.
With regards,

[Dr. Harish Bahuguna]
Director Engineering Geology Division & Head of Office
Geological Survey of India
Ministry of Mines, Govt. of India
UT: J&K, UT-Ladakh, Jammu

From: HARISH BAHUGUNA
Sent: 19 January 2023 10:58:52
To: Bhuvnesh; HOD NR
Cc: G.C Pargaien; Dharmendra Singh; NAVEEN CHANDRA PANT; Anubhav; Manmeet Bedi; Chandra Dhar Tewari; RAJENDRA PRASAD
Subject: Re: [External][Re:] External][Re: Request for sharing data

Sir
It is requested to provide the Geological Profile along HRT alignment at the

With regards and wishes,

(Dr Harsh Bahuguna)
Director Engineering Geology Division & Head of Office
Geological Survey of India
Ministry of Mines, Govt. of India
UT J&K, UT Ladakh, Jammu

From: HARSH BAHUGUNA
Sent: 16 January 2026 09:03:39
To: Bhuvnesh; HOD NB
Cc: S.C Pargaien; Dharmendra Singh; NAVEEN CHANDRA PANT; Anubhav; Manmeet Bedi; Chandra Dhar Tewari; RAJENDRA PRASAD
Subject: Re: [External]Re: [External]Re: Request for sharing data

Thank you sir. I acknowledge the receipt of the information.

From: Bhuvnesh <BHUVNESH.BWGI@GWTPC.CO.IN>
Sent: 16 January 2026 08:46:16
To: HARSH BAHUGUNA; HOD NB
Cc: S.C Pargaien; Dharmendra Singh; NAVEEN CHANDRA PANT; Anubhav; Manmeet Bedi; Chandra Dhar Tewari; RAJENDRA PRASAD
Subject: [External]Re: [External]Re: Request for sharing data

महोदय/महोदया(Sir/Madam),

Point wise reply to the queries vide GS mailing mail are as under:

1.The invert levels of HRT , as desired, are given below–

i) The invert level of HRT at the present TBM face RD 5315m = EL1731.153m.
ii) The invert level of HRT at RD 3016m from TBM entry point = EL 1720.9317 m.
iii) The invert level at TBM entry, RD 0.0 m, point= EL 1704.00 m

2. Regarding 3d Geological logs/ face logs of TBM excavated reach, it is submitted that, TVHPP TBM is a double shield TBM and therefore it is not possible to prepare the 3d Geological logs/ face logs of TBM excavated reach, since excavated rock surfaces are not visible.

3. Regarding a plan of HRT alignment on SOI toposheet indicating the horizontal distance of HRT from the urban sprawl of Joshimath, it is submitted that:

HRT alignment on 1:50000 SOI topositheet is not available, however only strip survey along HRT alignment was carried out on 1:10000 scale, as per DPR requirements, which does not cover Joshimath area.
However, to understand the horizontal distance of HRT from the urban sprawl of Joshimath, HRT alignment is tentatively marked on latest Google Image and distance from HRT are indicated in attached Fig 1.

4. The seepage/discharge data from different reaches of HRT TBM reach measured on 17-01-2023 are as under:-

i) Seepage at the present TBM face at RD 5915m is 0.087 Litres/Sec.
ii) Cumulative Tunnel Discharge measured at Ring no 7819(RD 2672m SPII Downstream) – 68.20 Litres/Sec.
iii) Cumulative Total Discharge measured outside TBM Adit Portal is 71.82 Litres/Sec.

सादर[Regards],

भुवनेश कुमार /Bhuvnesh Kumar

अपर-महाप्रबंधक (भू-विज्ञान) / AGM (Geology)
TVHPP
एनएचपीसी लिमिटेड/NHPC Limited
9650991473

"बिन्दी देश की शक्ति बूंद से मिलने वाली धारा है"

From: HARISH BAHUGUNA <harbahuguna@gsi.gov.in>
Sent: 16 January 2023 20:10
To: Bhuvnesh <BHUVNESH.KUMAR@NTPC.CO.IN>; HOD NR <hodnr@gsi.gov.in>
Cc: Dharmendra Singh <DHARMENDRA.SINGH@NTPC.CO.IN>; Anubhav <ANUBHAV@NTPC.CO.IN>; Manmeet Bedi <MANMEETBEDI@NTPC.CO.IN>; NAVEEN CHANDRA RAWAT <NAVEEN.CHANDRARAWAT@NTPC.CO.IN>; Chandra Bhan Tewari <CBTIWARI@NTPC.CO.IN>; RAJENDRA PRASAD <RPRAWAT@NTPC.CO.IN>
Subject: Re: [External]Re: Request for sharing data

Sir
Please take reference of my below mail. It is requested to kindly provide the desired data at the earliest.
With regards

Dr Harish Bahuguna
Director Engineering Geology Division & Head of Office
Geological Survey of India
Ministry of Mines, Govt. of India

UT J&K, UTLadakh, Jammu

From: HARISH BAHUGUNA
Sent: 15 January 2023 09:47:44
To: Bhumesh, HOD NR
Cc: Dharmendra Singh; Anubhav; Manmeet Bedi ; NARESH CHANDRA PANT; Chandra Dhar Tewari; RAJENDRA PRASAD
Subject: Re: [External]Re: Request for sharing data

Sir
Thank you for sharing the drawings. After studying them it is requested to kindly provide the following:
1. The invert level of HRT at the present TBM face, at RD 10.5km from TBM entry point and at TBM entry point.
2. An Geological logs/ face logs of TBM excavated reach
3. A plan of HRT alignment on GT boundary indicating the horizontal distance of HRT from the urban center of Katra.
4. The seepage/discharge data from diffuser section of HRT TBU reach
With regards

(Dr. Harish Bahuguna)
Director Engineering Geology Division & Head of Office
Geological Survey of India
Ministry of Mines, Govt. of India
UT J&K, UTLadakh, Jammu

From: Bhumesh <BHUVNESH@MAHAGENTPC.CO.IN>
Sent: 14 January 2023 09:31:02
To: HOD NR
Cc: Dharmendra Singh; Anubhav; Manmeet Bedi ; NARESH CHANDRA PANT; HARISH BAHUGUNA; harishbahuguna@gmail.com; Chandra Dhar Tewari; RAJENDRA PRASAD
Subject: [External]Re: Request for sharing data

[illegible]

Please find attached the following as desired-
1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from intake, from Chorni adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face - Seepage is 3 Litres/Minute from TBM Face at present.

सादर/Regards,

भुवनेश कुमार /Bhuvnesh Kumar

अपर महाप्रबंधक (भू.विज्ञान) / AGM (Geology)
एनटीपीसी लिमिटेड/NTPC Limited
9650092472

"हिन्दी देश को एक सूत्र में पिरोने वाली भाषा है"

From: RAJENDRA PRASAD <RPRASAD@NTPC.CO.IN>
Sent: 24 January 2023 10:52
To: Chandra Dhar Tewari <CDTIWARI@NTPC.CO.IN>; Bhuvnesh <BHUVNESHKUMAR@NTPC.CO.IN>; Anubhav <ANUBHAV@NTPC.CO.IN>; NAVEEN CHANDRA PANT <NAVEENCHANDRAPANT@NTPC.CO.IN>
Subject: Fwd: Request for sharing data

Please see for n a

Manager

Get Outlook for iOS

From: ACSD MR <hsd.mr@gsi.gov.in>
Sent: Friday, January 13, 2023 4:26:57 PM
To: RAJENDRA PRASAD <RRAJENDRA@NTPC.CO.IN>
Subject: Fw: Request for sharing data

To,
Shri R P Ahirwar
Chief General Manager
TVNP
NTPC, Rudraprayag, Joshimath

Sir,

Director General GSI, Kolkata has deputed Dr. Harish Sahugunta, Director, GSI as the nodal officer for the geological assessment of the ensuing problem of ground subsidence at Joshimath. He shall be carrying out field assessment from 14th to 16th January 2023. In this context it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from intake, from chunni adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face, if any.
5) Any other relevant data/information as required by Dr Sahugunta

His contact number is 9566555307
This issue is being monitored by the highest level of officials of Government of India.
With regards.

शेष शुभ (Best)/ M V Srinivasulu

[illegible]
अपर महानिदेशक एवं विभागाध्यक्ष/ADG & HoD
भा.भू.स., उ.क्षे. / GSI, NR, Lucknow

शुभेच्छा / Regards

[illegible] Director, DSS
कृते अपर महानिदेशक एवं विभागाध्यक्ष/ for ADG & HoD
भा.भू.स., उ.क्षे. / GSI, NR, Lucknow

From: HOD NR
Sent: Wednesday, January 11, 2023 3:53 PM
To: rpshriwal@nhpc.co.in
Cc: NATIONAL MISSION HEAD 4; DDG SDN
Subject: Request for sharing data

To,
Shri R.P Ahirwar
Chief General Manager
TVHPP
NTPC, Ravigram, Joshimath

Sir,

Director General GSI, Kolkata has deputed Dr. Harish Sahuguna, Director, GSI as the nodal officer for the geological assessment of the ensuing problem of ground subsidence at Joshimath. He shall be carrying out field assessment from 14th to 16th January 2023. In this context it is requested to kindly provide him the following:

1) Final layout of the project clearly depicting the alignment of HRT
2) Updated position of the HRT face from intake, from channel adit and from TBM excavation.
3) Geological section along HRT
4) Data on the seepage in HRT at the present TBM face, if any.
5) Any other relevant data/information as required by Dr Sahuguna

His contact number is 9568555307.

This issue is being monitored by the highest level of officials of Government of India.

With regards,

नरेन्द्र वी. निनावे/ N V Ninawe
अप्पर महानिदेशक एवं विभागाध्यक्ष / ADG & HoD
भू.चु.भ., लखनऊ / GSI, NR, Lucknow