Landslide Mitigation and Management using Different Techniques and Methods : An Indian Scenario

by

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AT

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THE DISASTER MANAGEMENT ACT, 2005.

"Disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area;

DISASTER MANAGEMENT

- "Disaster management" means a continuous and integrated process of planning,
- organising, coordinating and implementing measures which are necessary or expedient for-
- (i) Prevention of danger or threat of any disaster;
- (ii) Mitigation or reduction of risk of any disaster or its severity or consequences;
- (iii) Capacity-building;
- (iv) Preparedness to deal with any disaster;
- (v) Prompt response to any threatening disaster situation or disaster;
- (vi) Assessing the severity or magnitude of effects of any disaster;
- (vii) Evacuation, rescue and relief;
- (viii) Rehabilitation and recconstruction.
- "Mitigation" means measures aimed at reducing the risk, impact

INDIAN INTEREST IN LANDSLIDE STUDIES

- Initially Landslide was not considered as Disaster in India
- Malpa Landslide Tragedy (11 and 17 August 1998 in Pithoragarh district of Uttarkhand about 380 people were killed when massive landslides washed away the entire village. Dead included 60 pilgrims on their way to Kailash Mansarovar Lake in Tibet.
- Indian Ocean Tsunami of 26 December 2004 led to development of EW for Tsunami.
- Formation of NDMA, Govt of India is trying its level best to spread awareness about disasters and for preparing country to face disasters to reduce loss of life and property.
- Since Disastar in Uttrakhand 2013 there has been a surge of interest in developing early warning systems for Landslides in India.

DTRL'S WORK ON LANDSLIDES

- DTRL started working in the Himalays after Malpa Tragedy (1998)in Pithoragarh district of Uttarkhand
- DTRL studied some Landslides of Uttrakhand and Himachal Pradesh in 1998.
- During 1999 till date DTRL is actively working on landslides of the Himalayan region right from Tawang to Srinagar
- DTRL has completed two Technology Demonstration (TD) Projects for Border Road Organisation (BRO)
- DTRL is currently working jointly with Geological Survey of India (GSI) for Development of Instrumentation and Monitoring of landslides for Early Warning System in India.
- DTRL has recently successfully conducted a National Seminar on Landslides LAMAMIS-2015 during Feb 15

LANDSLIDE ACTIVITIES OF DTRL TILL DATE…..

- Landslide Inventory for Sikkim Himalayas & North Eastern States, Jammu & Kashmir, Himachal Pradesh and Uttrakhand has been prepared.

- Landslide Hazard Zonation maps for Sikkim Himalayas & North Eastern States Jammu & Kashmir, Himachal Pradesh and Uttrakhand has been prepared.

- Two Landslides Atlases for Sikkim Himalayas & North Eastern States published & handed over to BRO.

- Detailed Investigation & Monitoring done at *9th Mile, B2 & Lanta Khola* Landslides in Sikkim Himalayas.

- A Real Time Early Warning System has been established at Tangni Landslide Site in Uttrakhand for the first time in Country in the Himalayan region.

- Eight Landslide Atlases are being published.

- Handbook on Control Measures is also being published

LANDSLIDE : MOST COMMON DISASTER IN INDIA

- Landslide, a frequently occurring natural hazard in the hilly terrains of India
- Mostly activie during the monsoon period from July to September and after the snow fall from January to March.
- Earthquakes also cause triggering of landslide,
- Nearly 15% of India's landmass or 0.49 million sq km area is prone to landslide hazard. This includes the Arakan Yoma ranges, the Himalaya, Nilgiri, Ranchi Plateau and Eastern & Western Ghats. 20 States of India are affected by different degrees of landslide hazard.
- Sikkim and Mizoram Extreme
- Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Nagaland and Manipur high to very high landslide hazard classes.
- Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Goa, Madhya Pradesh and Kerala constitute low to moderate hazard prone

LAMAMIS-2015 6-7 FEB 2015

- NATIONAL SEMINAR ON LANDSLIDES: MANAGEMENT & MITIGATION STRATEGIES (LAMAMIS-2015)
- DTRL ,Delhi, India
- 05-06 February 2015
- 200 DELEGATES PARTICIPATED

  EWS for landslides must be developed using Wireless sensors in cunjucation with conventional Sensors
- Every Institute /Organisation should adopt a landslide
- Bio-engineering Methods using aborginal specises must be used to stabalise landslides
-

LANDSLIDES OF NORTH EAST AND SIKKIM HIMALAYAS

B2 on North Sikkim highway

9th Mile Landslide on NH - 39

Landslides of Rishikesh-Badrinath Road, Uttrakhand

Several landslides were inspected and one landslide located at Tangni Village was selected for the present study





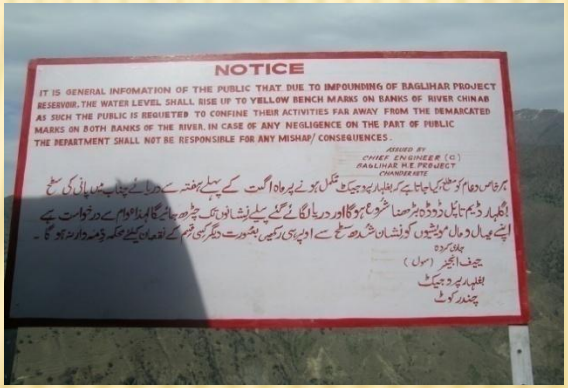

Landslide on NH-44 & 1B, Kashmir Himalayas

Route Map Location

Nashri Landslide At NH-1A

Landslide At NH-1B (Batota – Kishtwar) near Thatri

A View of Baglihar Dam



Baglihar Dam

Vehicles & persons stranded at Landslide site – Feb 2009

Landslides of Himachal Pradesh and Uttrakhand

Wangtu – Pooh – Kaurik Route

Tanakpur-Pithoragarh-Malpa Route

Dharasu – Yamunotri Route Landslide

Kaliasaur landslide on Rishikesh – Badreenath Route

Malin Landslide in Pune,Western Ghat

Chandrakant Zhanjare, who lost 13 members of his family, breaks down as he sits on an uprooted tree at landslide-hit Malin village in Pune on Friday


Rescuers search for survivors among the debris of houses at landslide-hit Malin village in Pune Maharashtra on Friday | PTI Photo

Some 40 of the 70 homes in Malin have been buried in the landslide


NDRF personnel stands at the site of a landslide at Malin village. Photo: Reuters

Malin Landslide in Pune,Western Ghat

DIFFERENT TECHNIQUES AND METHODS

- Creation of Landslide Hazard Zonation Maps
- Creation of Landslide Management Maps
- Regional Studies of Landslides
- Site Specific Studies of Landslides
- Control Measures for landslides
- Development of Early Warning System for different Landslides of India

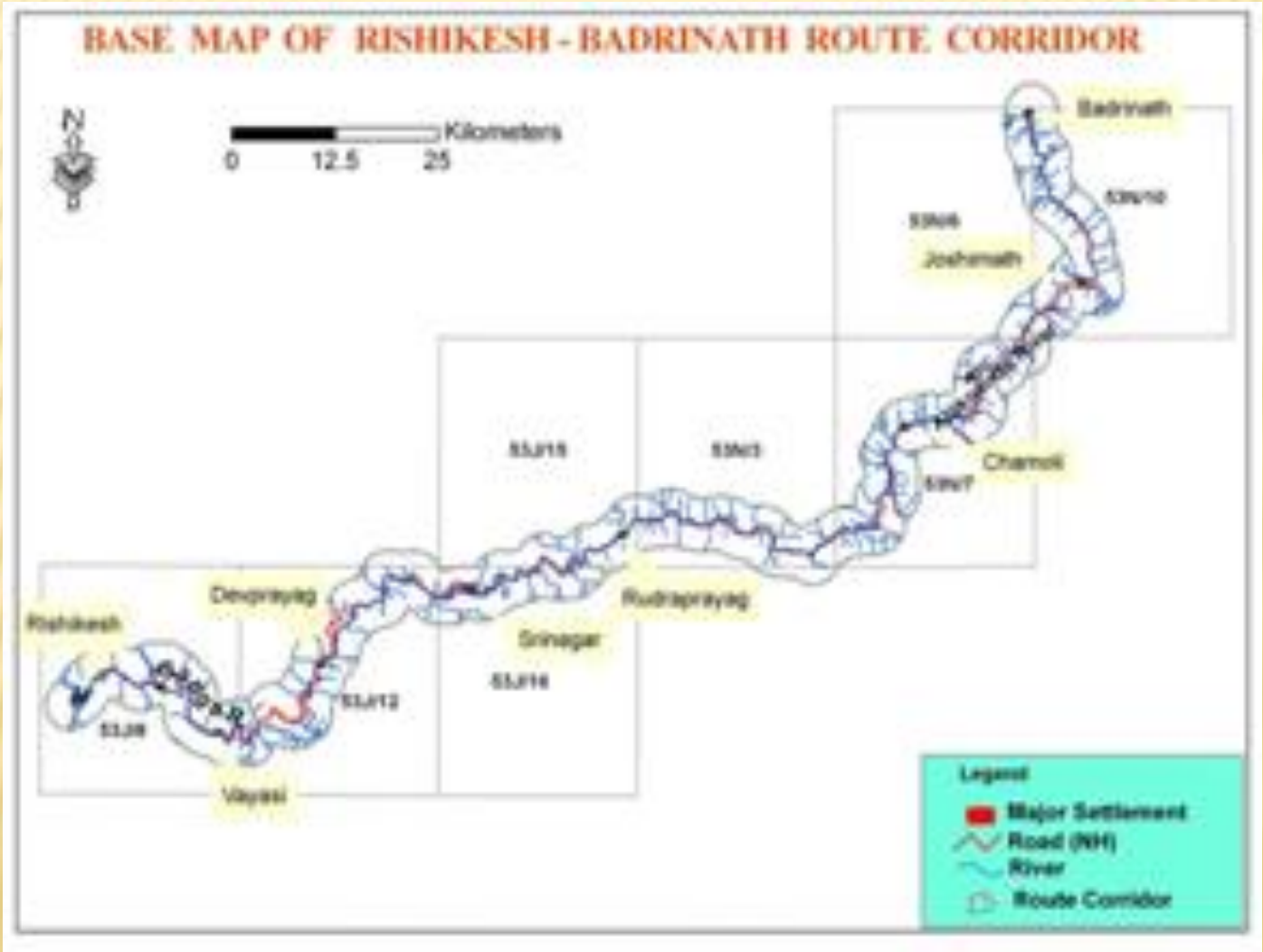
DTRL has created LHZ and LHM

Route ID	Route Name	State
R1	Rishikesh-Joshimath-Badrinath-Mana	Uttarakhand
R2	Rishikesh-Dharasu-Uttarkashi-Gangotri	Uttarakhand
R3	Dharasu-Yamunotri	Uttarakhand
R4	Tanakpur-Lohghat-Pithoragarh-Malpa	Uttarakhand
R5	Wangtu-Pooh-Kaurik	Himachal Pradesh
R6	Kulu-Manali-Leh-Pangyong-Chusul (including South Portal of Rohtang Pass)	Himachal Pradesh & J&K
R7	Jammu-Srinagar National Highway 1A	J & K
R8	Batote-Doda National Highway 1B	J & K

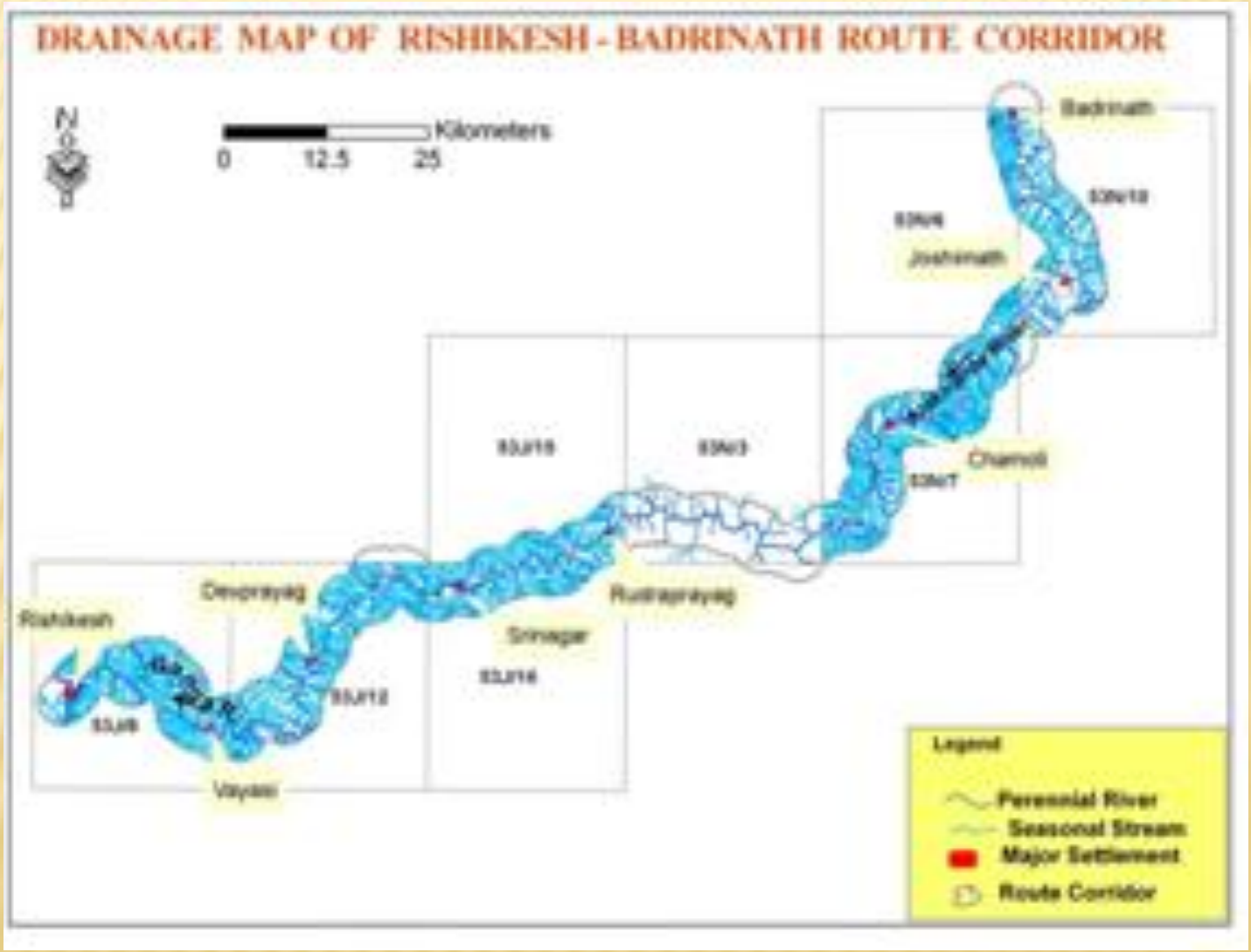
TASKS INVOLVED IN LANDSLIDE HAZARD ZONATION

- ❖ Field reconnaissance to study area.
- ❖ Inventory and mapping of landslides.
- ❖ Preparation of thematic maps at 1:50,000 scale, namely, **Base Map**, **Fault**, **Lithology**, **Slope**, **and Anthropogenic Activity.**
- ❖ Study of factor of importance of different thematic parameters and categories.
- ❖ Preparation of LHZ and LHM maps.
- ❖ Classification, selection and characterization of one representative landslide along each route.
- ❖ Detailed mapping of selected landslide at 1:1000 scales.

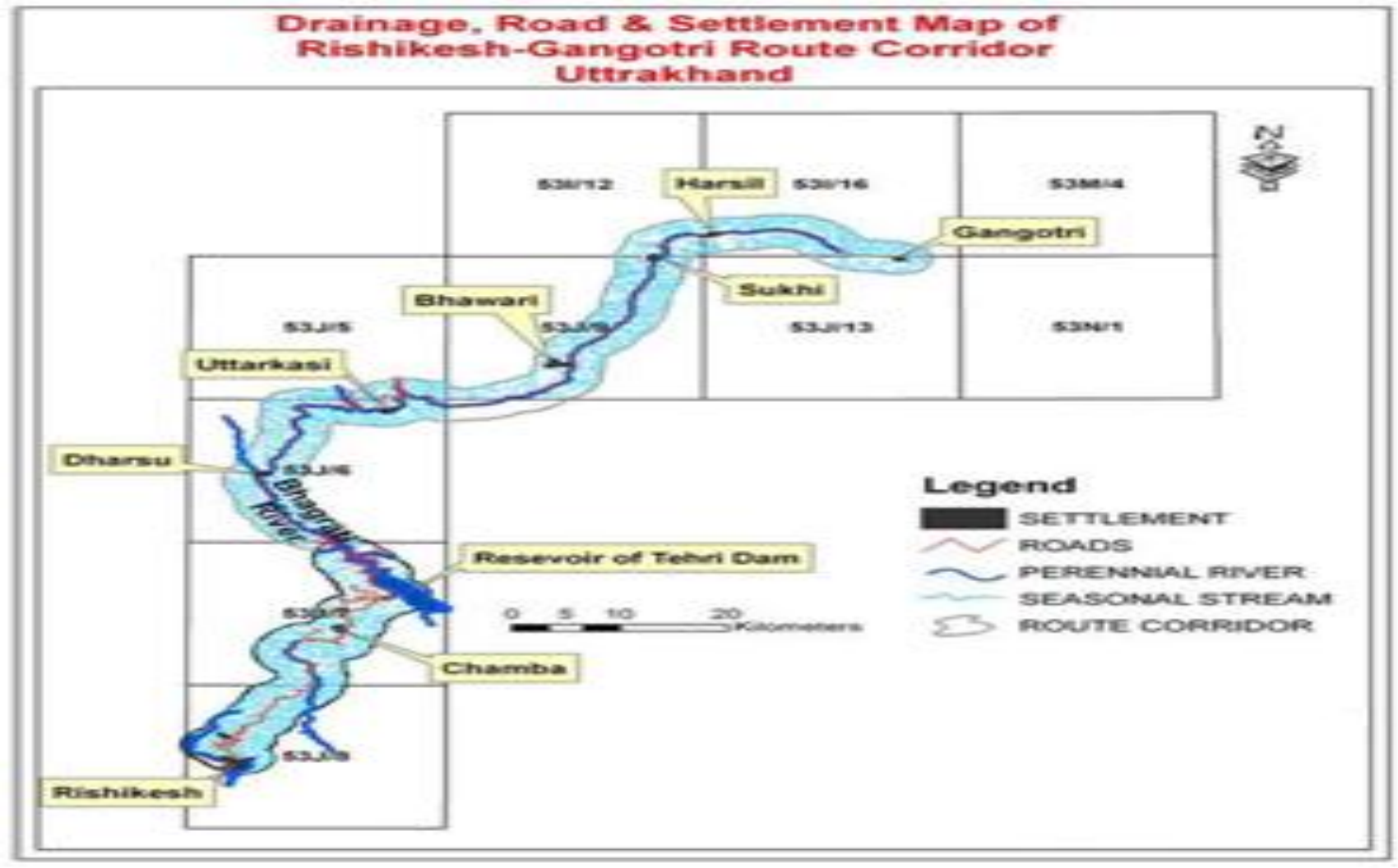
BASE MAP


BASE MAP OF RISHIKESH - BADRINATH ROUTE CORRIDOR
N
Kilometers
0
12.5
25
Badrinath
Joshimath
Chamoli
Rudraprayag
Srinagar
Devprayag
Rishikesh
Vayasi
Legend
Major Settlement
Road (NH)
River
Route Corridor

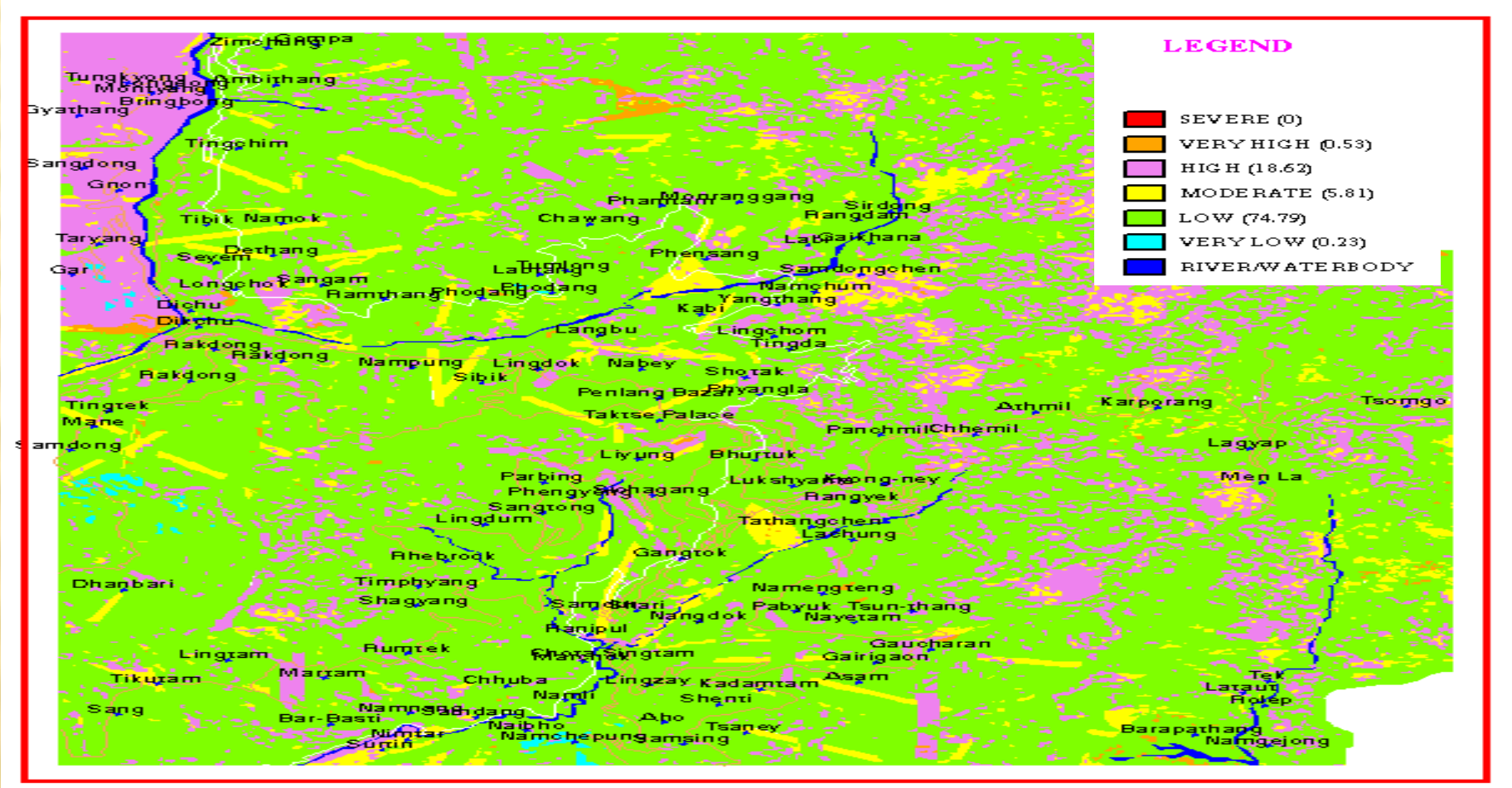
DRAINAGE MAP



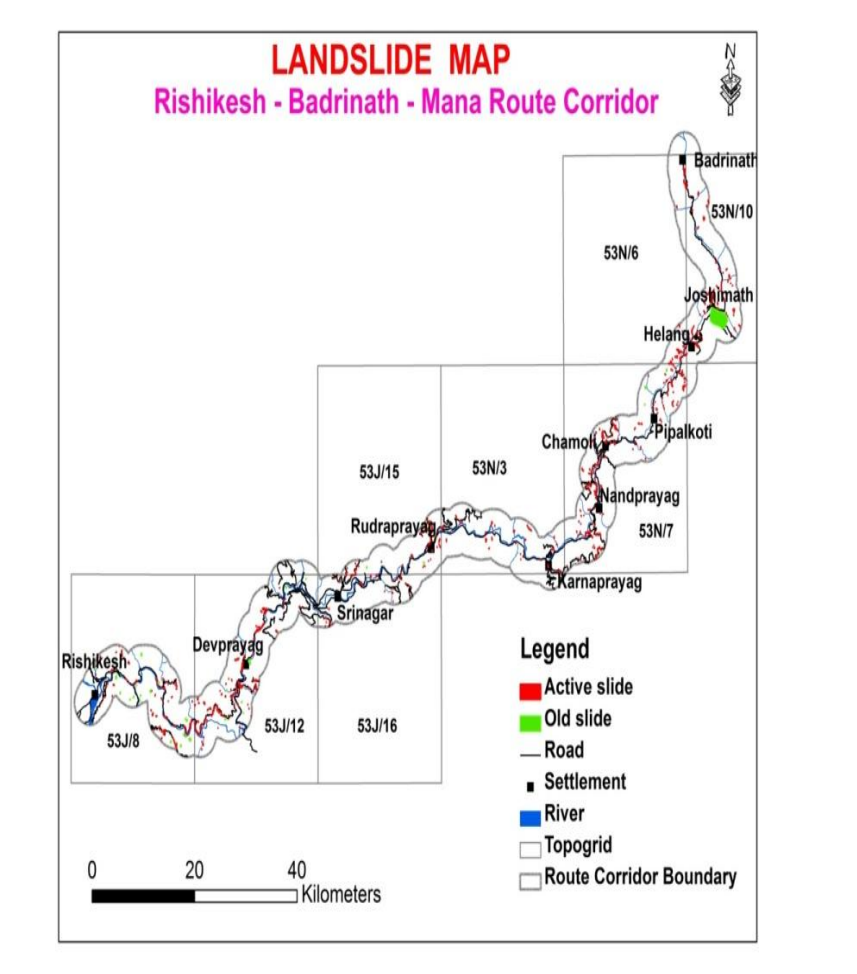
Merging of Drainage , Road and Settlement Maps to create LHZ Map

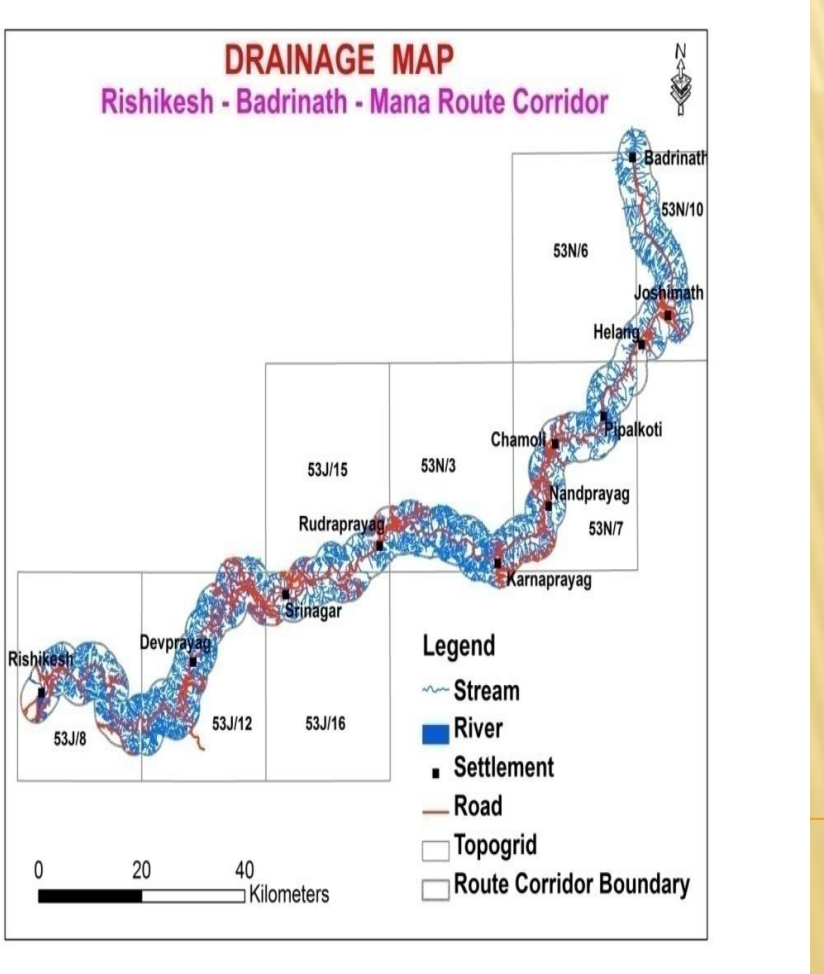


LANDSLIDE HAZARD ZONATION

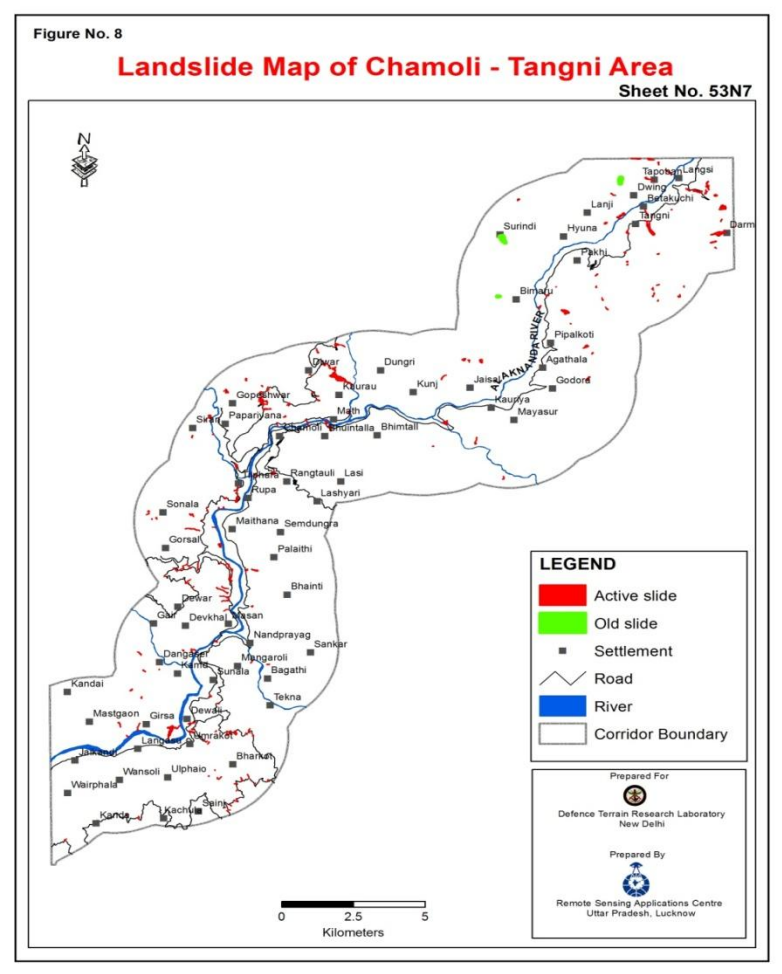


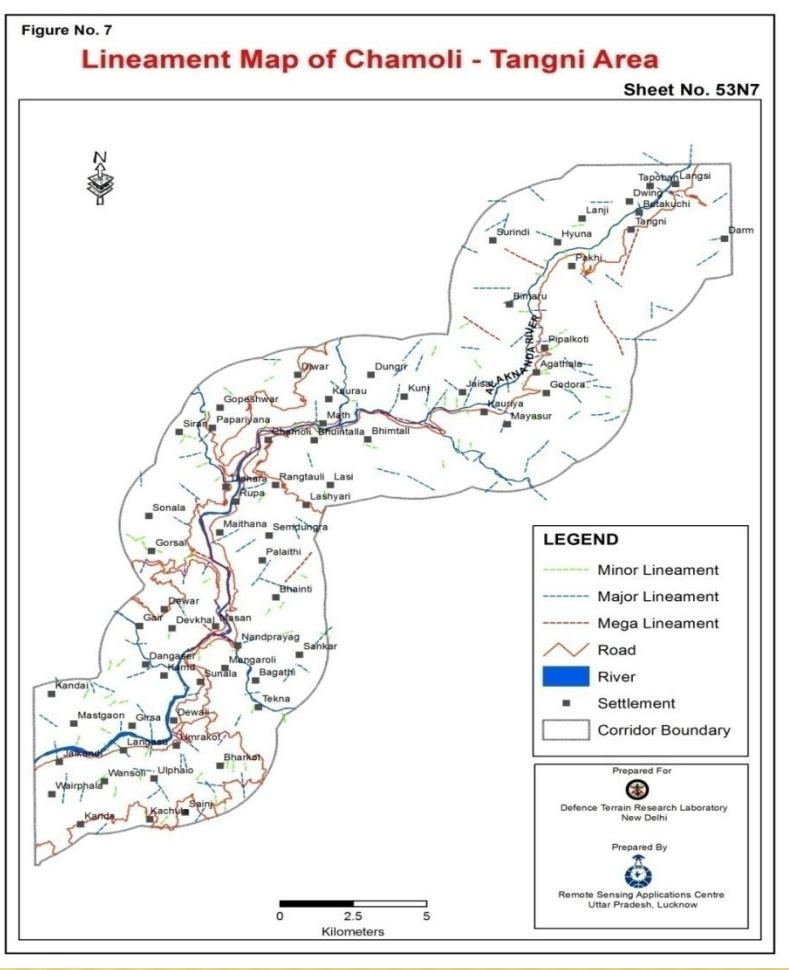
LANDSLIDE AND DRAINAGE MAP



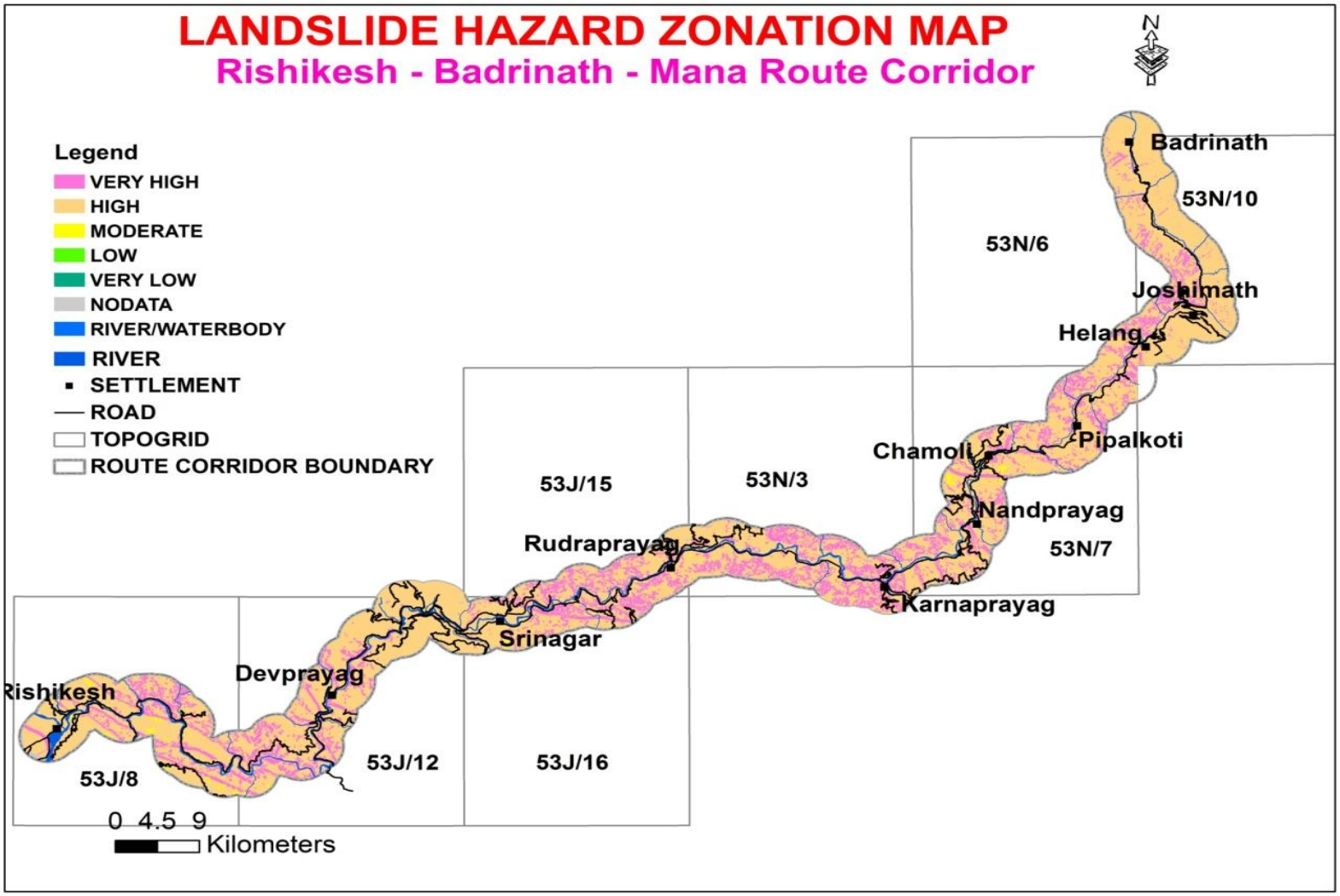


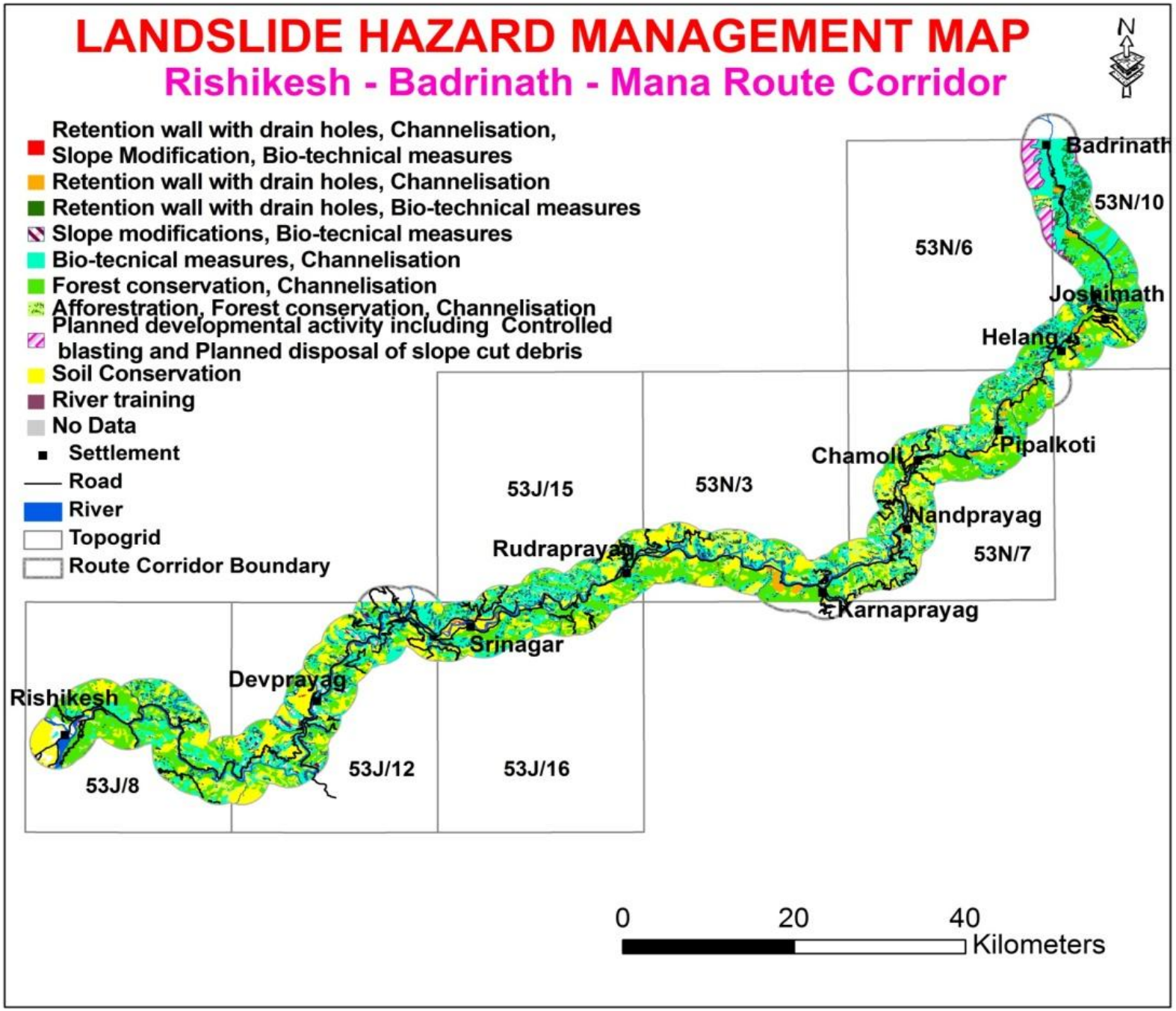
LANDSLIDE & LINEAMENT MAP OF CHAMOLI



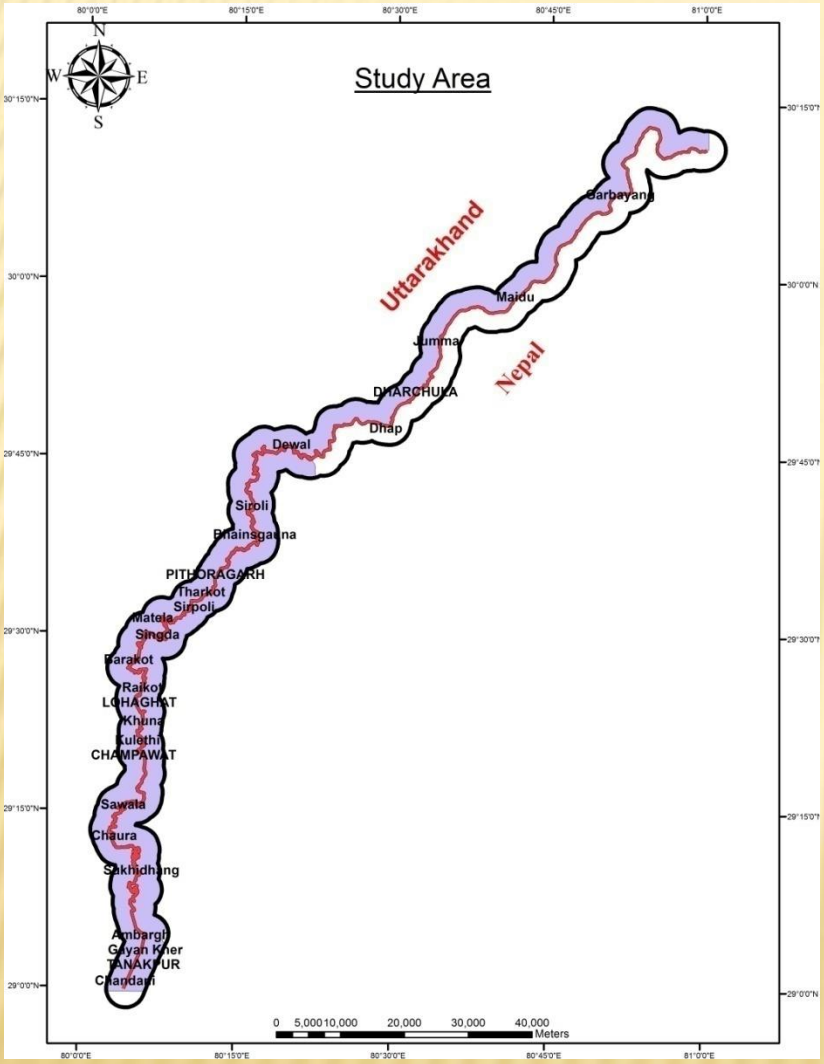


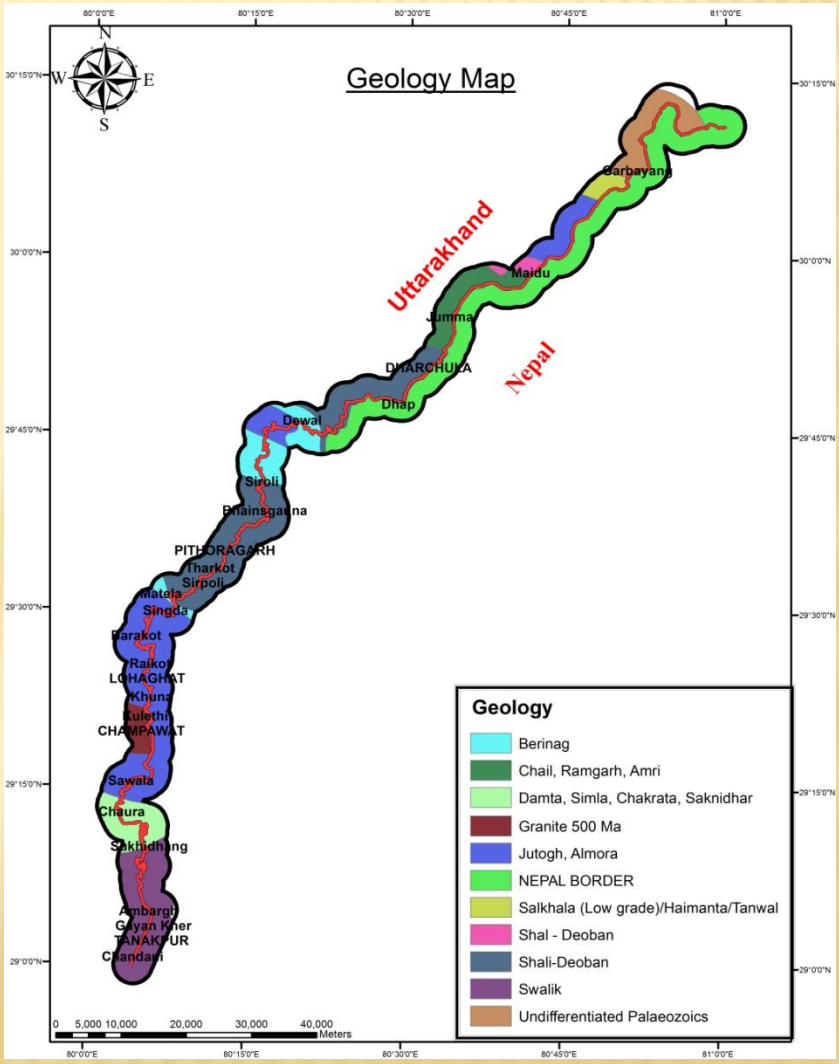
LANDSLIDE HAZARD ZONATION MAP



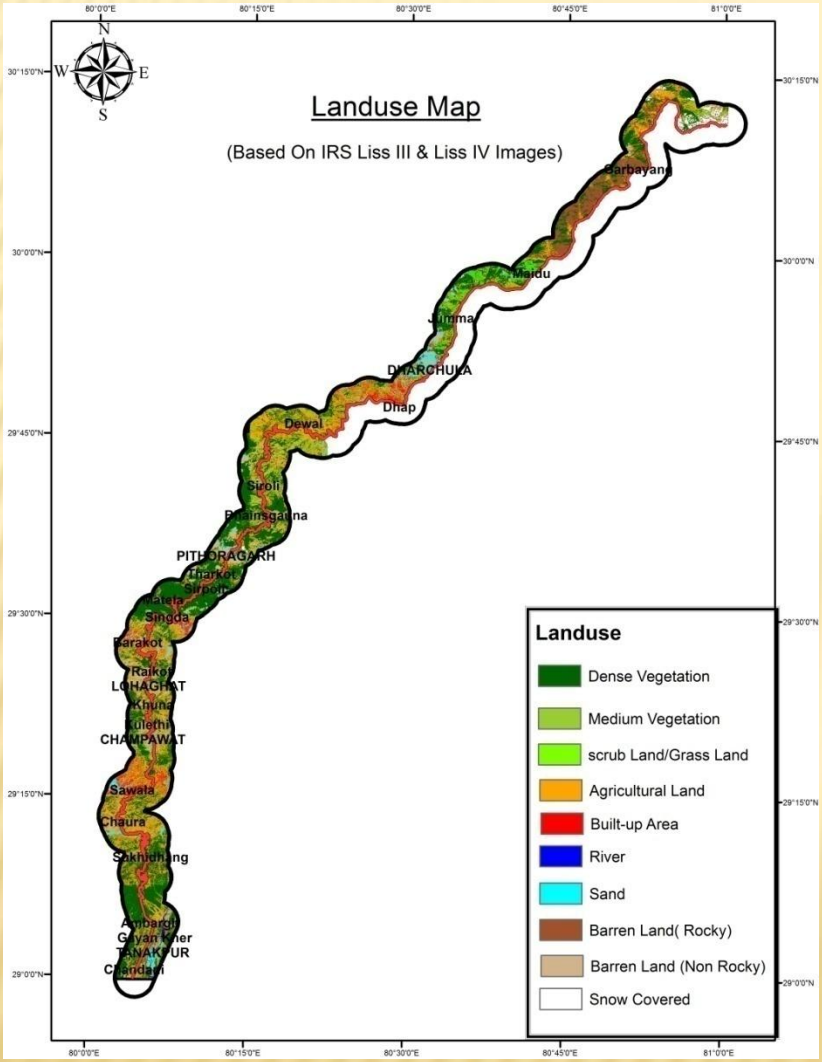

LANDSLIDE HAZARD MANAGEMENT MAP
Rishikesh - Badrinath - Mana Route Corridor
N
Retention wall with drain holes, Channelisation, Slope Modification, Bio-technical measures
Retention wall with drain holes, Channelisation
Retention wall with drain holes, Bio-technical measures
Slope modifications, Bio-tecnical measures
Bio-tecnical measures, Channelisation
Forest conservation, Channelisation
Afforestration, Forest conservation, Channelisation
Planned developmental activity including Controlled blasting and Planned disposal of slope cut debris
Soil Conservation
River training
No Data
Settlement
Road
River
Topogrid
Route Corridor Boundary
Badrinath
53N/10
53N/6
Joshimath
Helang
Pipalkoti
Chamoli
53J/15
53N/3
Nandprayag
Rudraprayag
53N/7
Karnaprayag
Srinagar
Devprayag
Rishikesh
53J/8
53J/12
53J/16
0
20
40
Kilometers

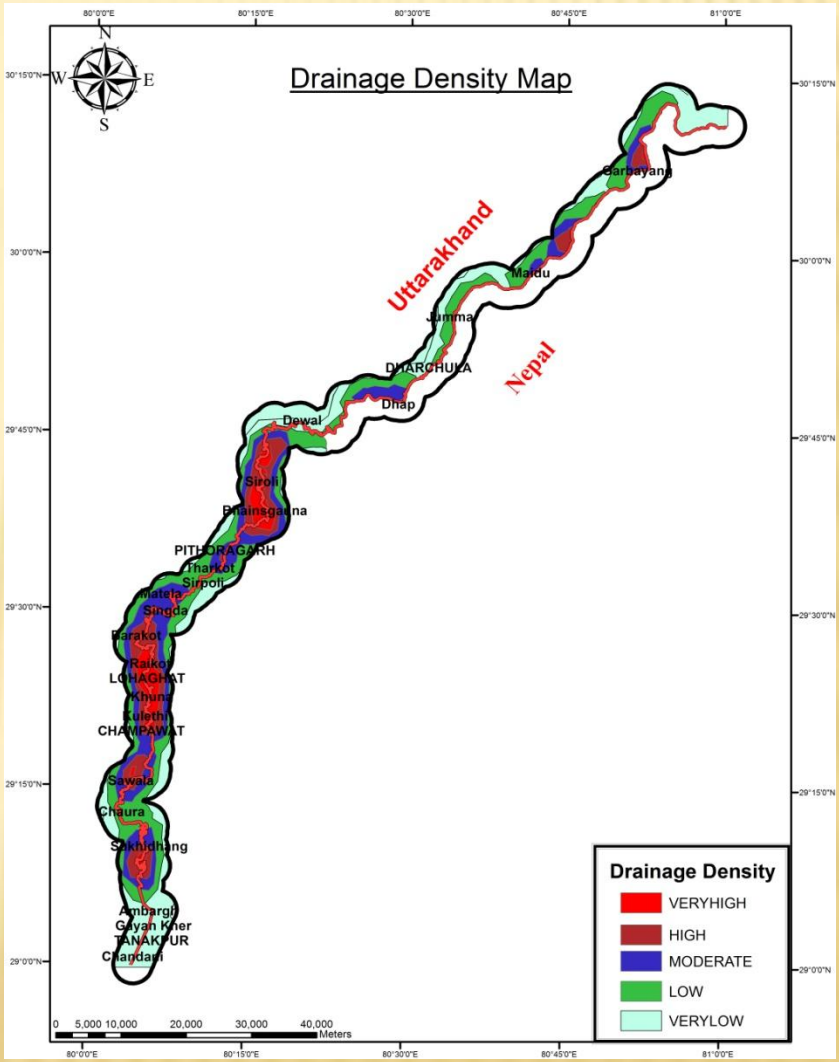
Generation of Thematic Maps and LHZ Maps
(Tanakpur-Lohghat-Pithoragarh-Malpa)



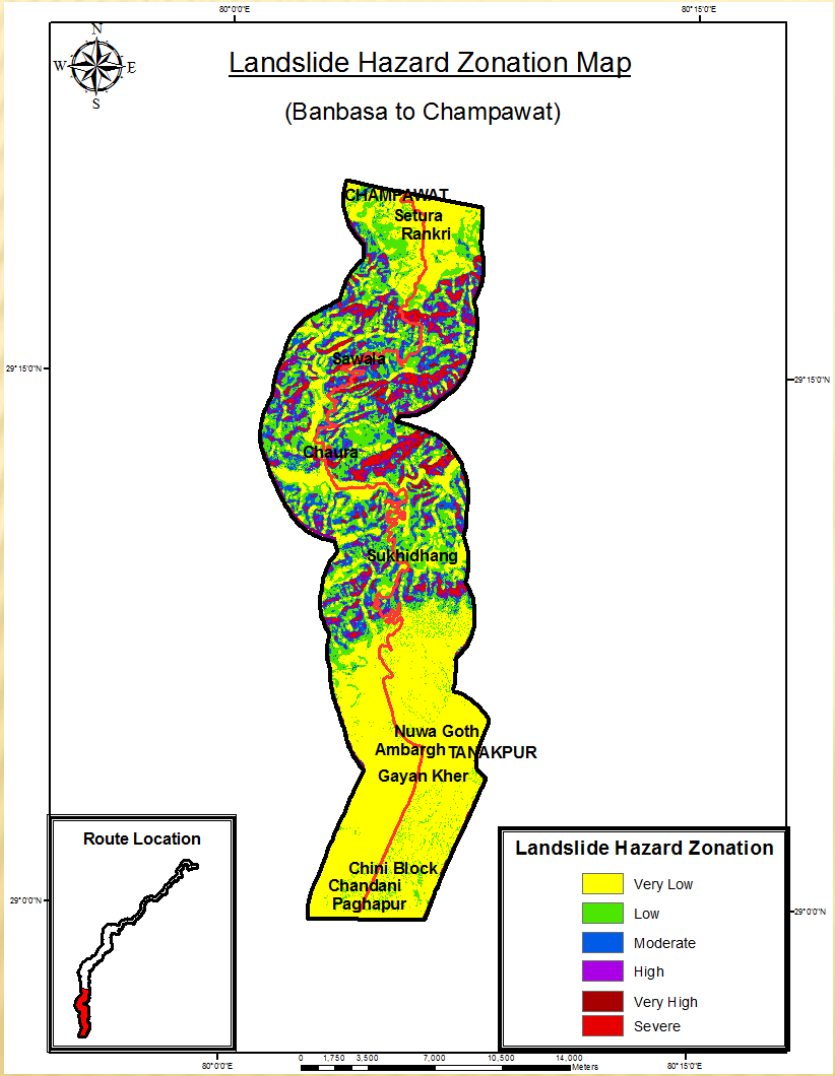


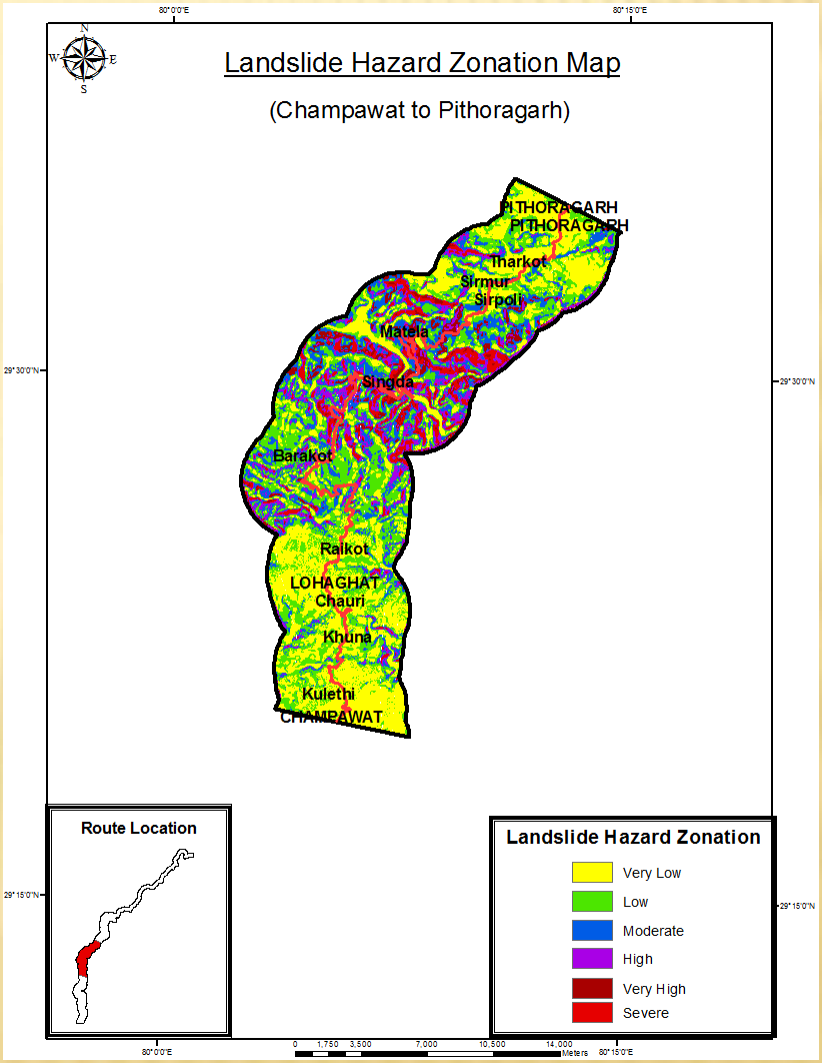
LANDSLIDE AND DRAINAGE MAP



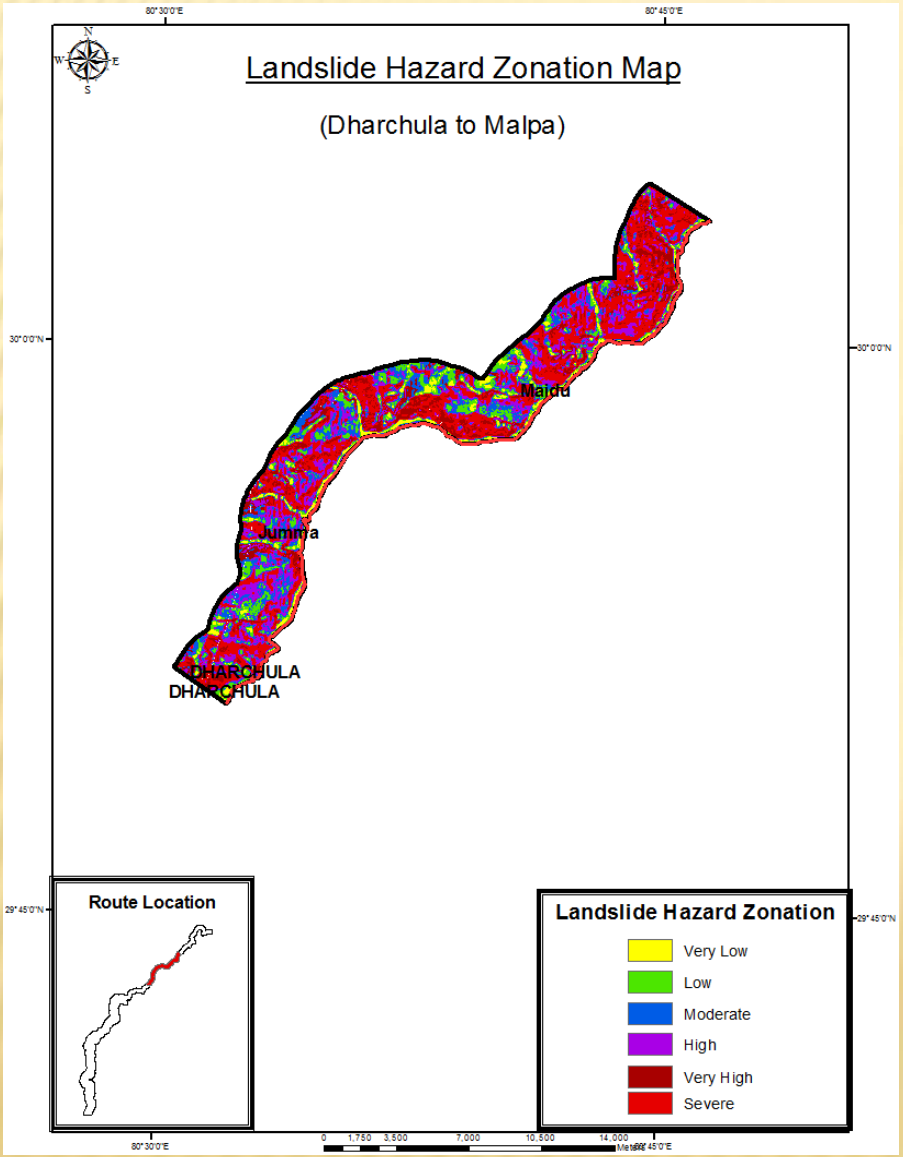


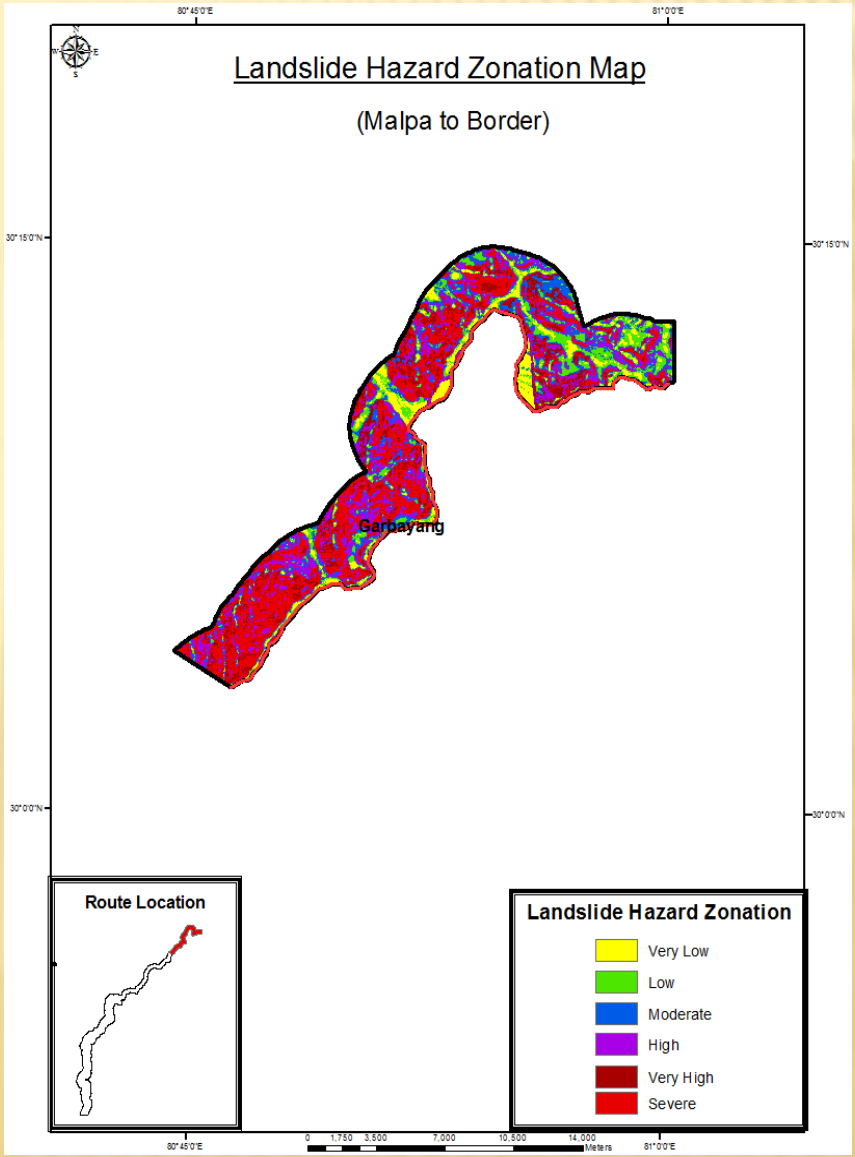
LANDSLIDE HAZARD ZONATION MAP



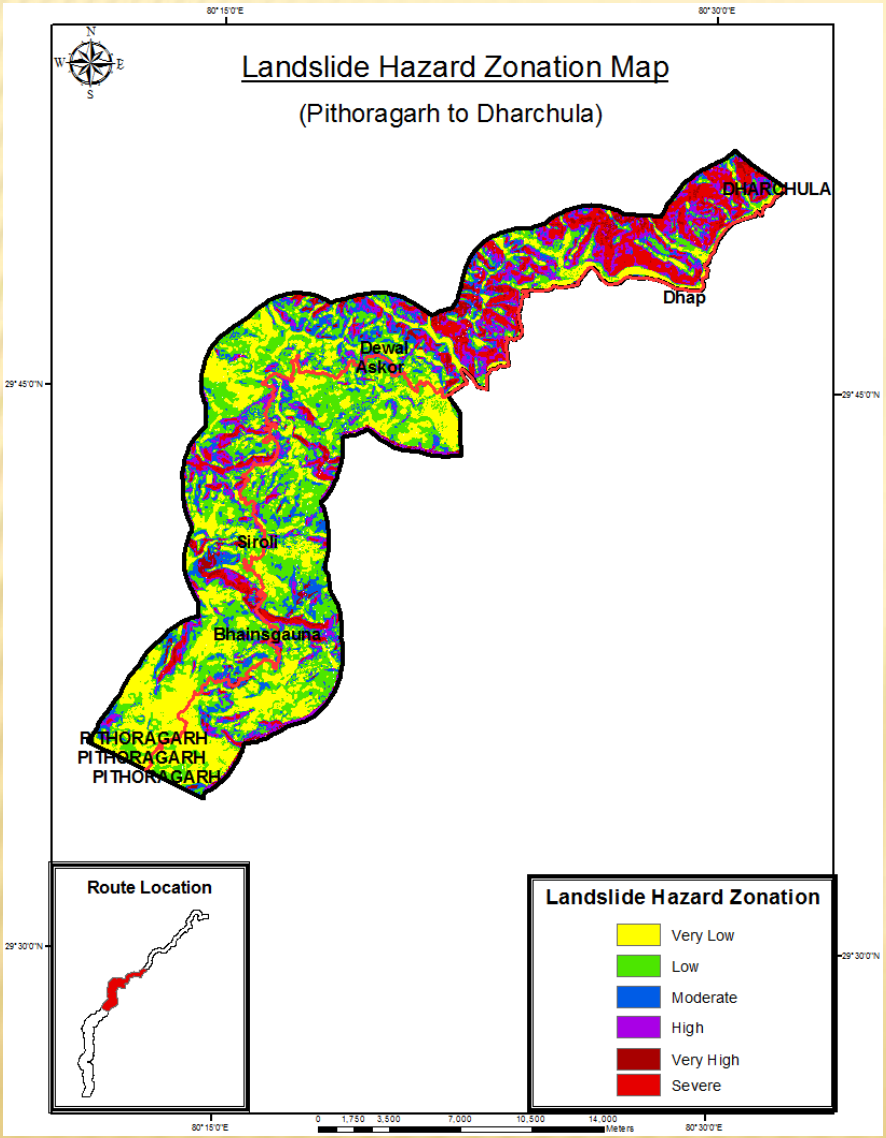


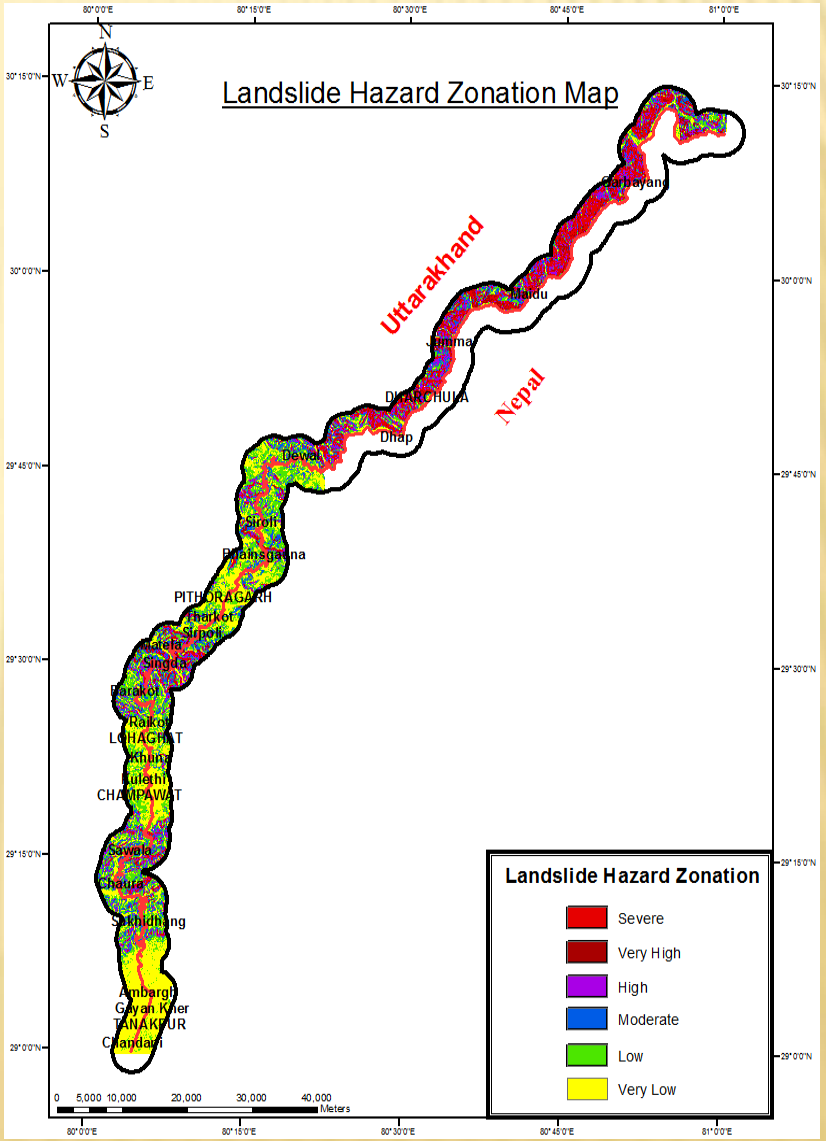
LANDSLIDE HAZARD ZONATION MAP





LANDSLIDE HAZARD ZONATION MAP





WHAT IS EARLY WARNING

- Early Warning can be defined as the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. The definition does not include a reference to the time scale on which a warning is given.

- International Strategy for Disaster Reduction (ISDR), United Nations (UN), 2006 says EW is the integration of four main elements:
- **Risk Knowledge**:
- **Monitoring and Predicting**:
- **Disseminating Information**
- **Response**:

EWS WORLD SCENARIO

- In US, USGS is the nodal agency for all landslides studies. Real-Time Monitoring of an active Landslide Cleveland Corral landslide at Highway 50, California is being done by USGS.

- In Japan, Japan Landslide Society is involved in EWS and Prediction all activities are carried out by it.

- UK, China, Peru, Malaysia, Egypt are also facing lot of problems related to landslides and at many places Early Warning Systems based on conventional as well as Wireless Sensors are being installed.

- The alpEWAS (early warning system for Alpine slopes) jointly developed by Germany, Switzerland and Austria uses a combination of underground cables and a surface-based video camera and laser scanner to detect and measure movement

EWS WORLD SCENARIO

- The alpEWAS also includes low-cost GPS antennas to measure surface movement and a piezometer for measuring the pressure of water. Computer software then compares this information with data on previous ground movements to estimate how much activity is likely to take place in a certain time and to raise alerts if certain triggering factors occur.

- Ministry of Disaster Management and National Building Research Organisation is managing the landslides activities in Sri Lanka.

- SAARC Disaster Management Centre, Delhi is nodal centre for all landslide related studies and issues of SAARC Countries.

- In Pakistan. JICA is developing an EWS at Muzaffarabad Landslide Site

- In Afghanistan “Amu River Early Warning System” is funded by European Commission DG Humanitarian Aid and Civil Protection under its DIPECHO Seventh Action Plan for South Asia to risk reduction mechanism in Afghanistan by piloting a community based river basin early warning system in Khamab and Qarquin districts in Jawzjan province and Kaldar and Shortepa districts in Balkh province.

EWS INDIAN SCENARIO

- DTRL along with CBRI installed & monitored 9th mile & B2 landslide sites in Sikkim by using EDM, piezometer, extensometer , inclinometer in year 2005. Data for two season was collected monitored and analyzed. It was stand alone monitoring system with no real time data acquisition capability
- CSIO, Chandigarh, CBRI,Roorkee and CRRI, New Delhi jointly installed Sensors at Mansa Devi near Haridwar in June 2006. No real time data acquisition and transmission was established.
- CSIO is also currently developing a Fibre Based EWS in Napta Jhakri, HP.
- DTRL has created an EWS at Tangni Landslide Site
- CBRI, Roorkee has also developed an EWS near Tangni
- GSI and DTRL have signed MoU on 5 Sep 2014 at Kolkata on Development of Instrumentation and Monitoring of landslides for Early Warning System in India Narender Nagar, Uttrakhand has been selected for development of EWS.

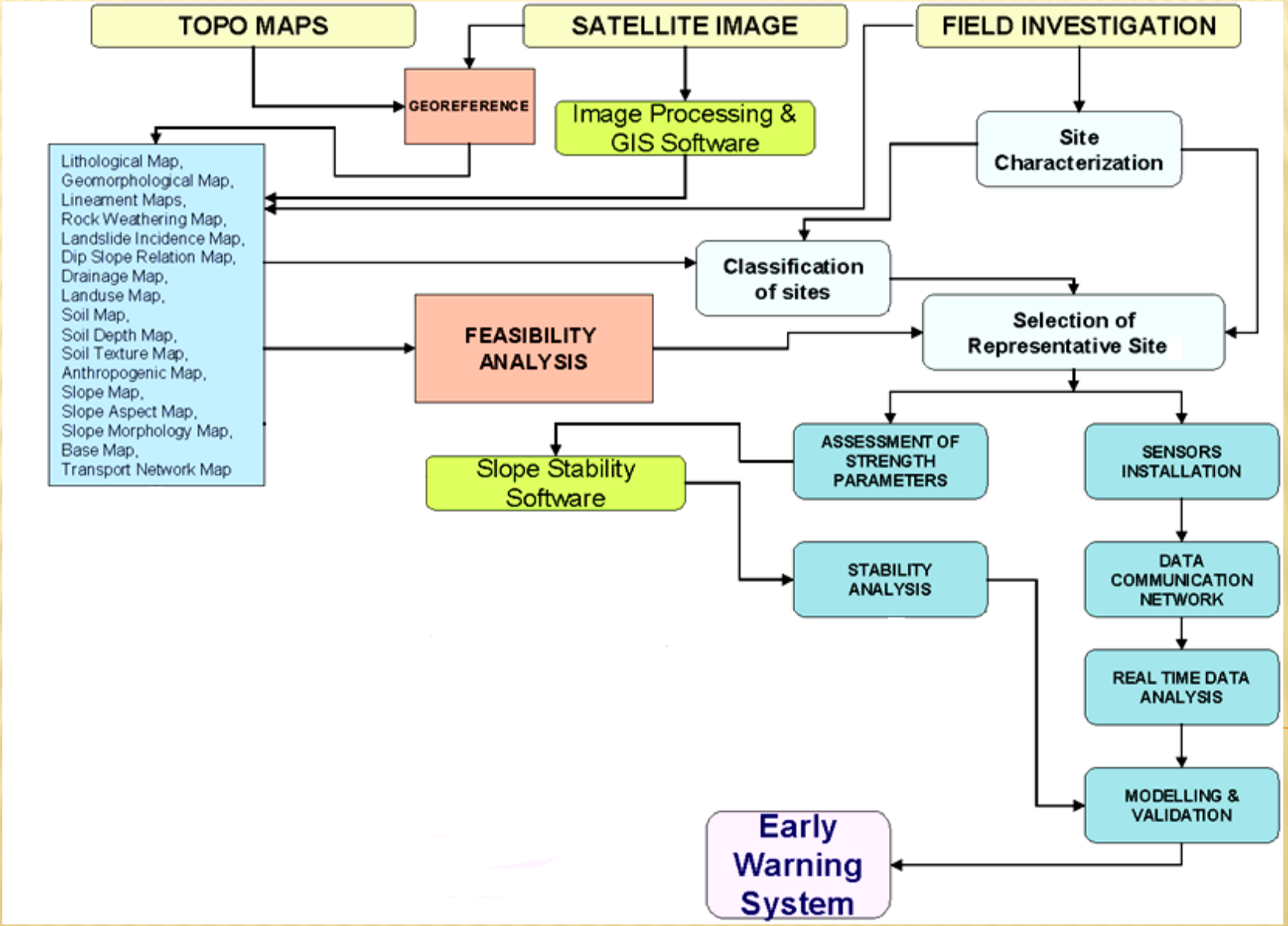
MoU Signing Cermony with GSI at Kolkatta

BACKGROUND OF INDIAN EWS EFFORTS

- First EWS was attempted by AMRITA University in technical collaboration with WINSOC (Wireless Sensor Networks with Self-Organization Capabilities for Critical and Emergency Applications which is co-funded by INFSO DG of European Commission) at Munnar, Idukki, Kerala by using wireless sensor network. Real time data acquisition and transmission was established through EDUCOM Satellite.

- DTRL has established a real time EWS at Tangni landslide site in year 2012. This is the country's first and only indigenous EWS which has used conventional sensors for data acquisition and a full-fledged real time communication system .

Flow Diagram For EWS



Site Selection Criteria for EWS

- Active but not very large in dimension.
- Safety and security of the Intrumentation Setup
- Landslide with history of slope movement in recent times.
- Proximity to a near by town or Village
- Accessible for Instrumentation and data collection
- Visibility of complete landslide from a stable reference point at road level so that EDM studies are carried out
- Ideal for using other sensing technologies like Acoustic Emission technique etc in future

Investigation of Landslide for EWS

(In Collaboration with CBRI, Roorkee)

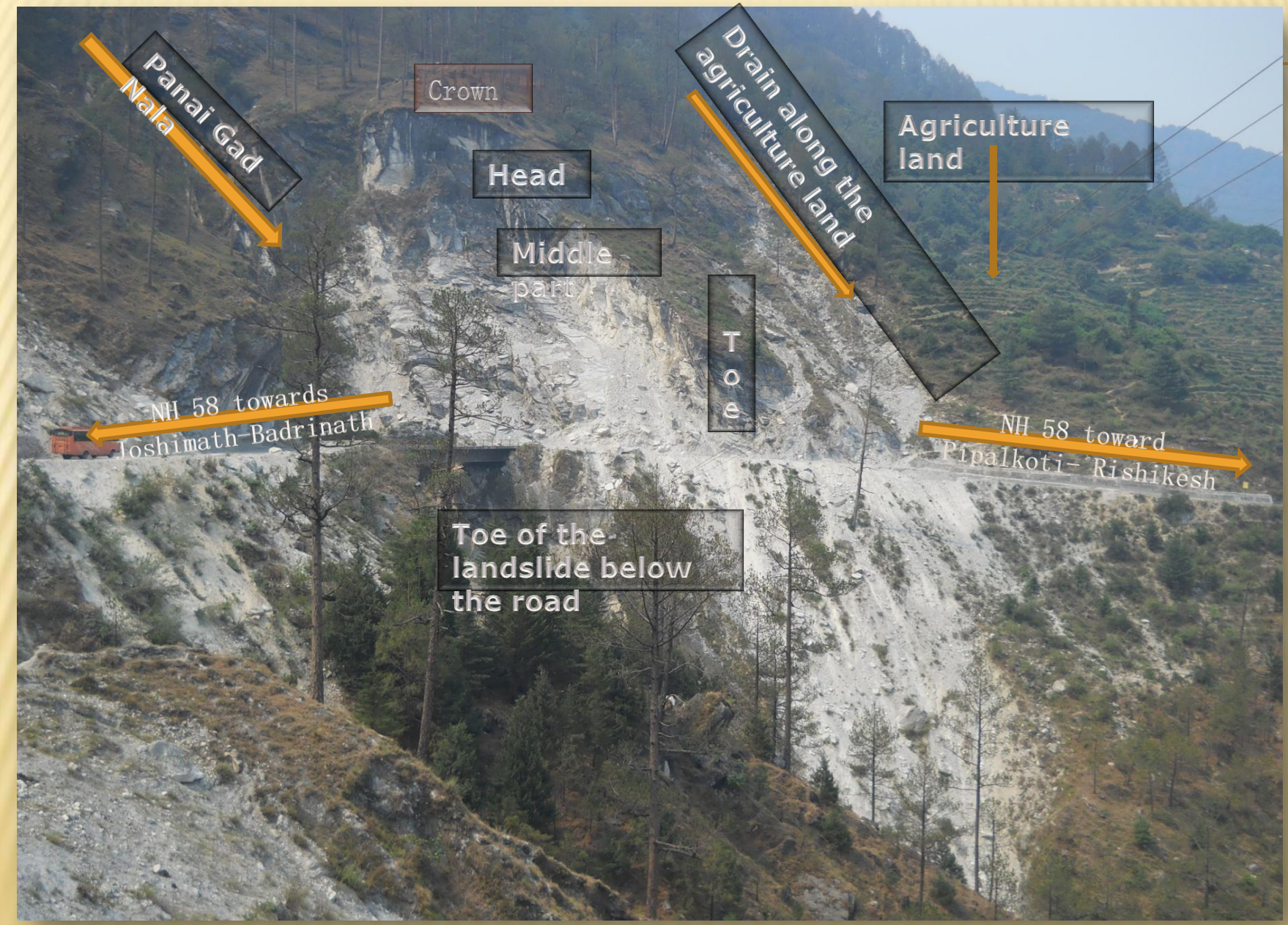
- Tangni landslide on Rishikesh-Joshimath-Badrinath road was studied for development of EWS to know :
- **Surfacial deformations**
- **Position of failure plane**
- **Evaluation of critical parameters**
- Collection of historical data and reconnaissance
- To identify locations for placement of instruments/sensors for detailed monitoring of and installation of EWS.
- Topographic survey and contouring of selected landslide at 1:500 scale with 0.5 m contour interval.
- Geological, structural, geo-morphological and hydrological mapping of selected landslide.
- Identification of causative factors for the selected landslide.

Investigation of Landslide for EWS

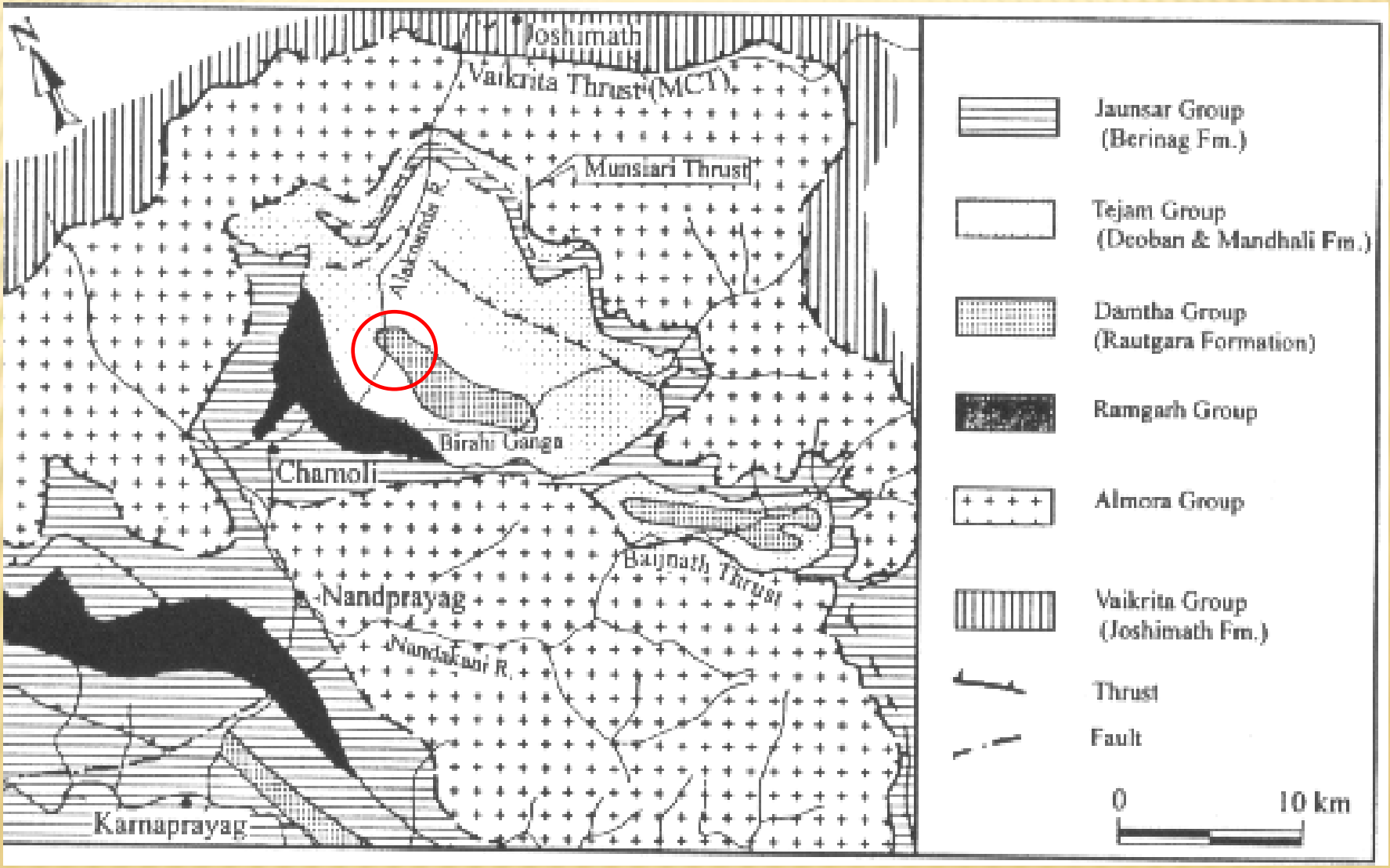
(In collaboration with CBRI, Roorkee)

- Geophysical survey for sub-surface mapping was done
- Geo-technical investigation and material characterization for slope stability analysis done
- Periodic landslide movement monitoring through Total Station measurements by hundred Iron Markers
- Study of rainfall pattern (duration and intensity) vis-à-vis movement pattern (nature and extent) was done
- Generation of detailed photographic record with periodic intervals
- Change detection in landslide geometry over time
- Data analysis of extent and nature of movement of selected landslide
- Identification of critical parameters to be studied in detail
- Identification of locations for instruments/sensors for further EWS study

PANORAMIC VIEW OF TANGNI LANDSLIDE

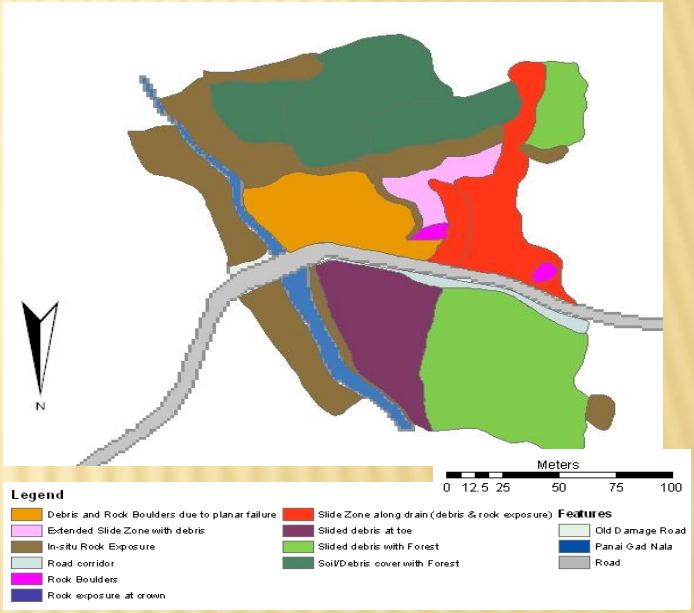


Regional Geological Map



GEOLOGY OF TANGNI LANDSLIDE

- Tangni Landslide area is complex, consisting of Precambrian lithological units of Garhwal region of NW Lesser Himalaya.
- The study area lies in the vicinity of Main Central Thrust (MCT).
- The area is tectonically active and experiences moderate to high magnitude earthquake.
- The area is drained by the river Alaknanda and its tributaries.
- The rocks in the landslide area belong to the Tejam and Damtha group.

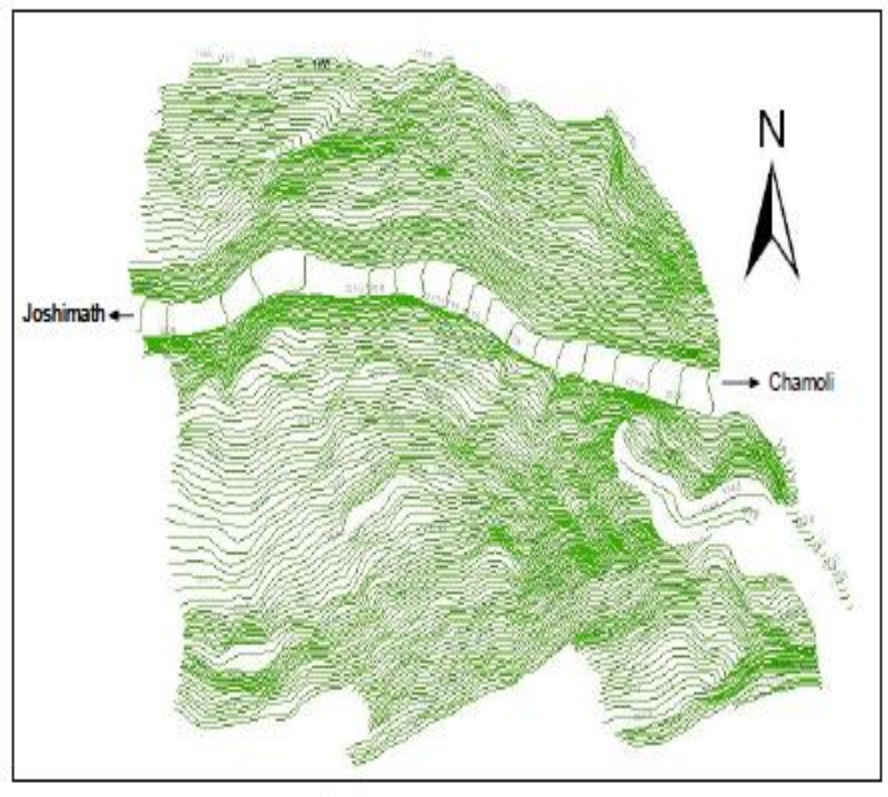


Lithology, Type and Causes Of Tangni Landslide

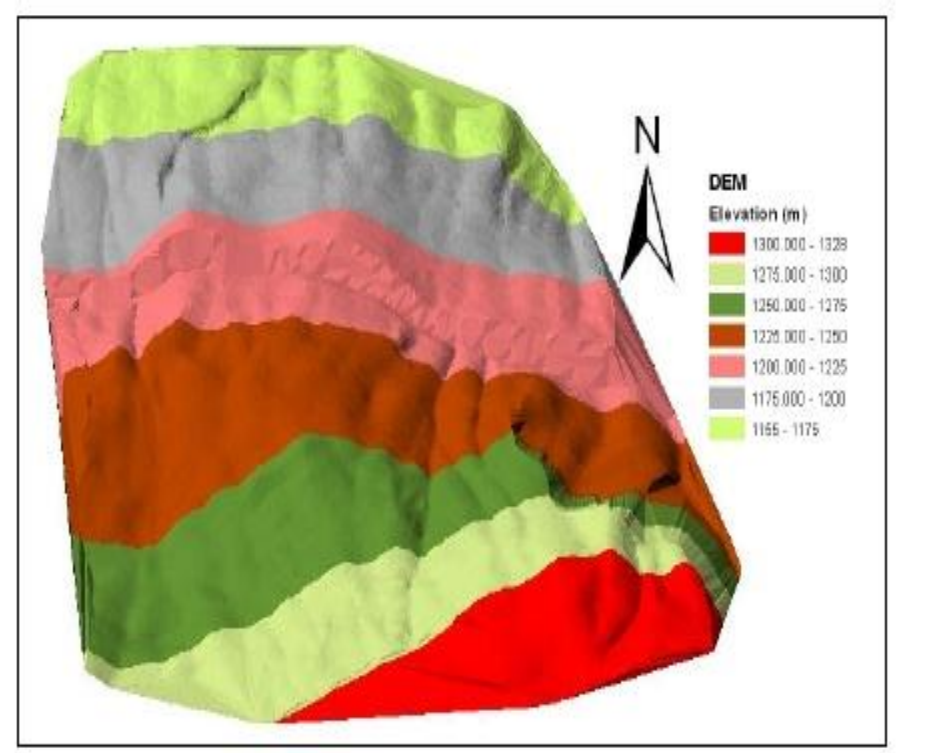
- Type - It is a Rock & Debris slide
- Failure Plane - Planar Failure along discontinuity plane
- Rock types are mainly Phyllites /Slate & Dolomite
- Mass Structure
  - Jointed Rock Mass
  - Bedding - 35°/N5°
- Rock strength – UCS – 72 Mpa – Moderately Strong rock
- Causes
  - Highly jointed & fractured rocks
  - Unfavorable discontinuity plane
  - Surface water flow
  - Tectonically active zone

Investigation of landslide for EWS

(In Collaboration with CBRI, Roorkee)



Contour Map of the Landslide Area



Digital Elevation Model of The Slide Area

Resistivity Survey

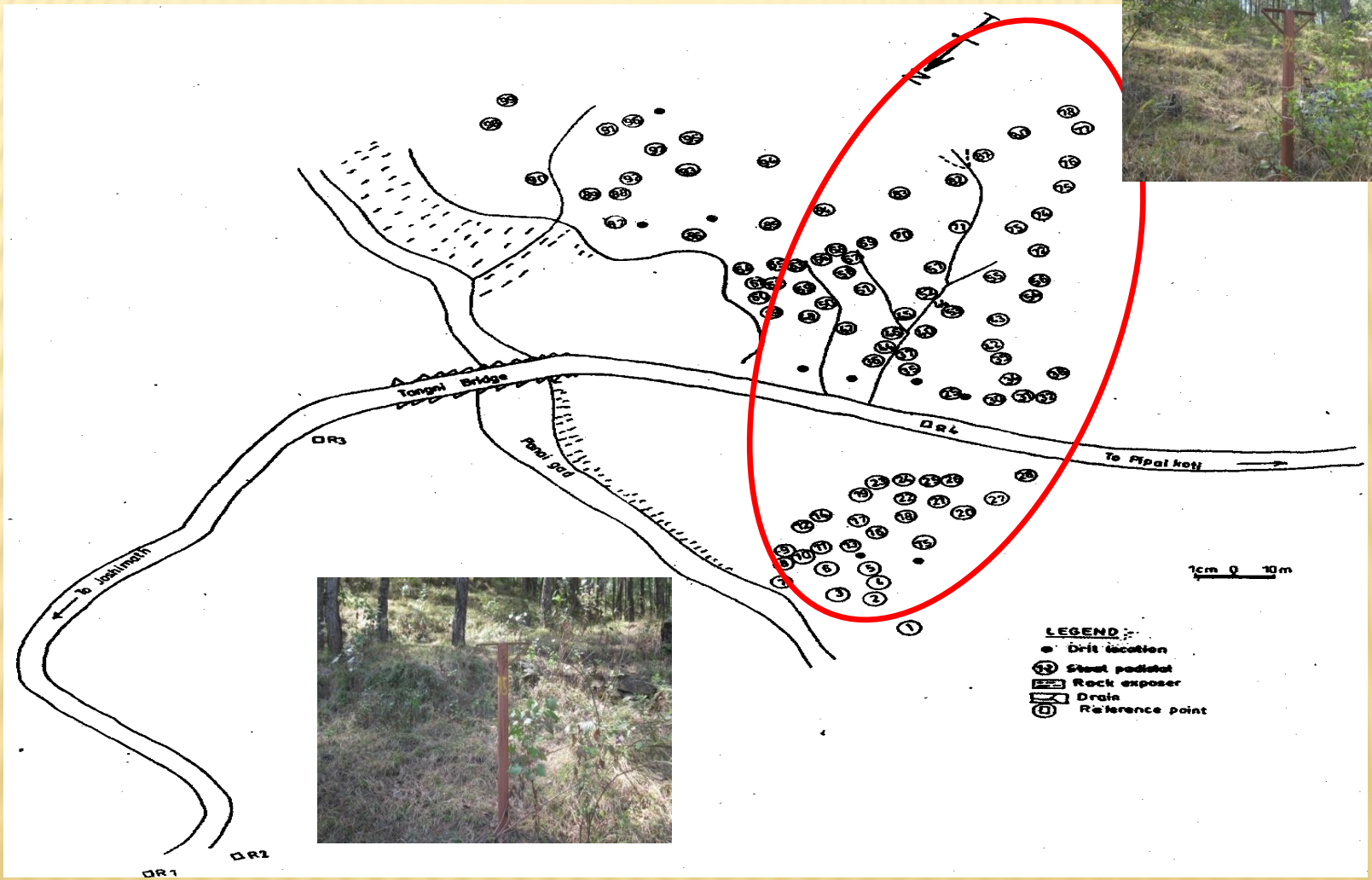
- Resistivity data near crown level shows a dip in the resistivity values at 6 m to 9 m depth. This indicates some fractured rock mass at this depth.

- The previous data shows the lower resistivity values at 5.5 m to 8.1 m depth.

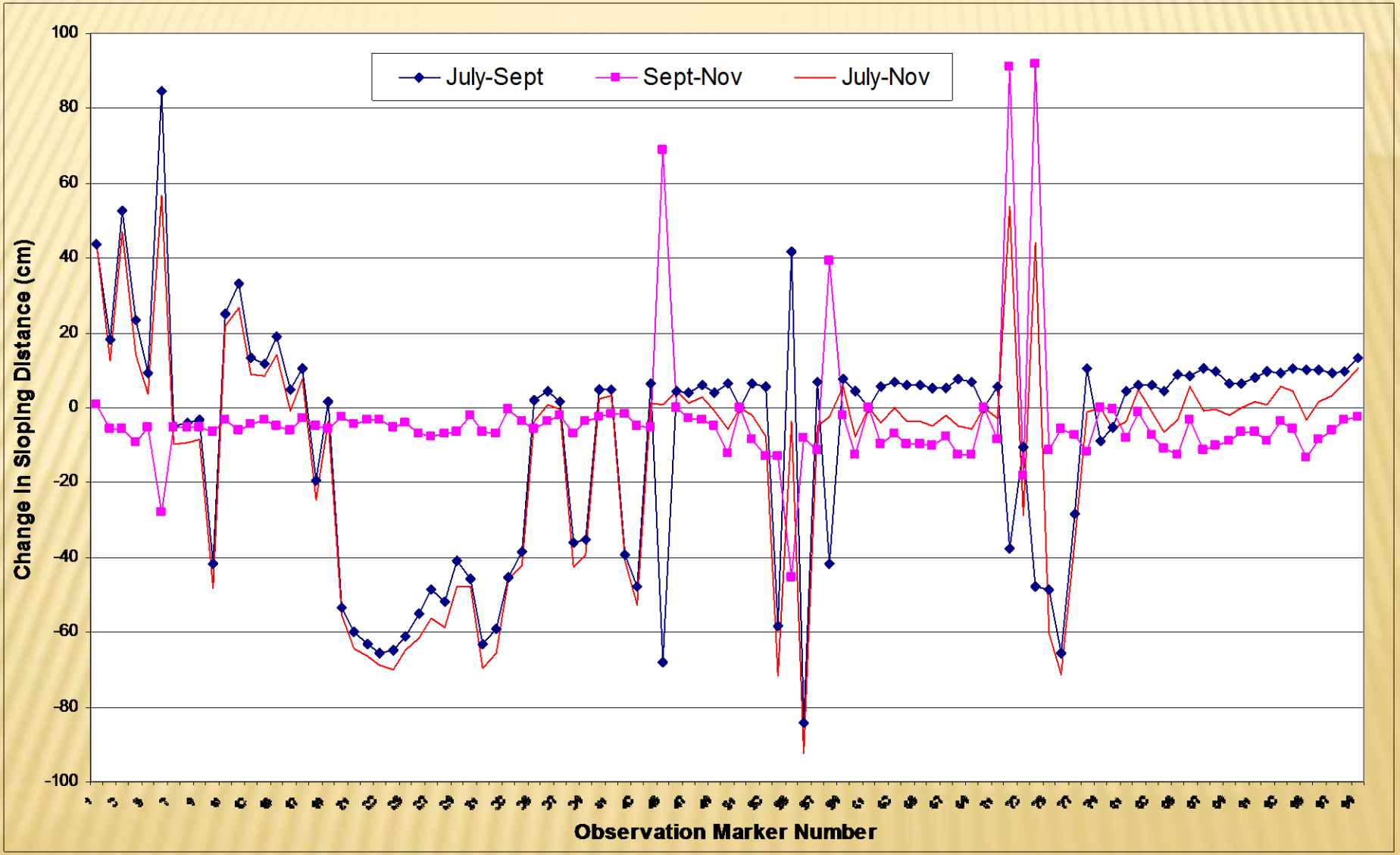
- Resistivity data at Road level shows lower resistivity values as compared to crown level, indicating the presence of debris below the road. These values further lowered at 5.7m to 12.3m suggesting weak zone or fractured strata.

- It may be inferred from resistivity data that the depth of failure plane may lies below 9m.

Use of Total Station for Observation of Iron Rod Markers



Observation showing movement of Markers



Observations and Inferences

- Clear Indication of Surface Displacements after the Monsoon
- Main causative factor for landslide movement in the area is precipitation.
- This calls for real-time monitoring of surface and sub-surface movements.
- To establish the thresholds for displacement and rainfall thresholds more surface & sub- surface movement data are required

Early Warning System by DTRL

Automated and Remote Monitoring of Landslide (ARMOL)

Objectives- Automated and remote monitoring of Tagani landslide and generation of Alert/Warning of slope failure

Selection of Instrumentation for ARMOL

Selection of type of sensors and locations

- System design including the architecture, specification of sensors, interface requirements, data logger and software
- Digging of boreholes
- Installation of sensors, interfacing, calibration and installation of monitoring software.
- Automated recording of measurements to enterprise database

SELECTION OF INSTRUMENTATION

- Water levels : **Vibrating Wire Piezometer**
- Displacement : **In Place Inclinometers** / Tiltmeters
- Surface Deformation : **Extensometers/** Time Domain Reflectometry (TDR)
- Ground Vibration : Geophones
- Rainfall : **Rain Gauge**
- Data Acquisition, Monitoring and Warning : Data logger
- Dissemination & Communication : GSM modems
- Power Supply: Solar panel and batteries

- In this case, Rainfall is considered as primary triggering factor. So Geophone sensors were avoided.

Drilling Process and Installation of MS Casing

Process of Drilling

Installation of MS Casing

ABS Casing Connection

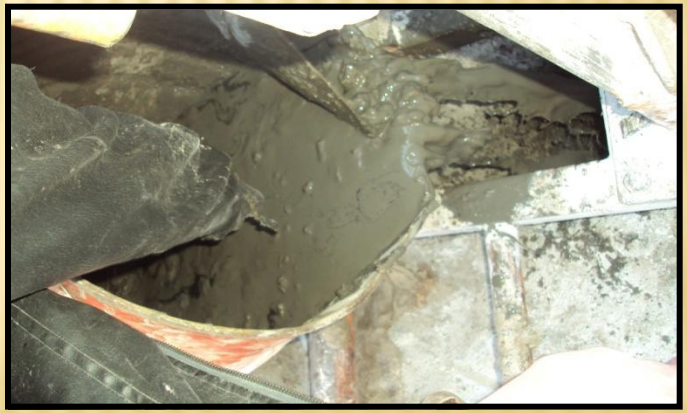
Platform created around Casing

Installation of Piezometers

Piezometer secured in Sand Bag

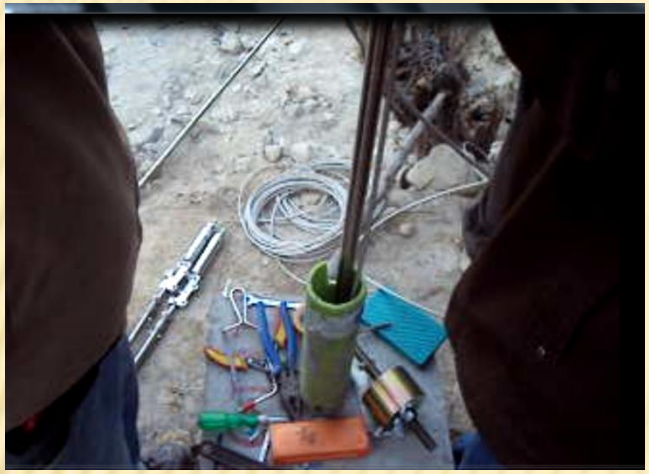
Lowering of Piezometer

Bentonite Pellets



Filling of Borehole with cement Slurry

Lowering of Inclinometer Sensor inside Casing



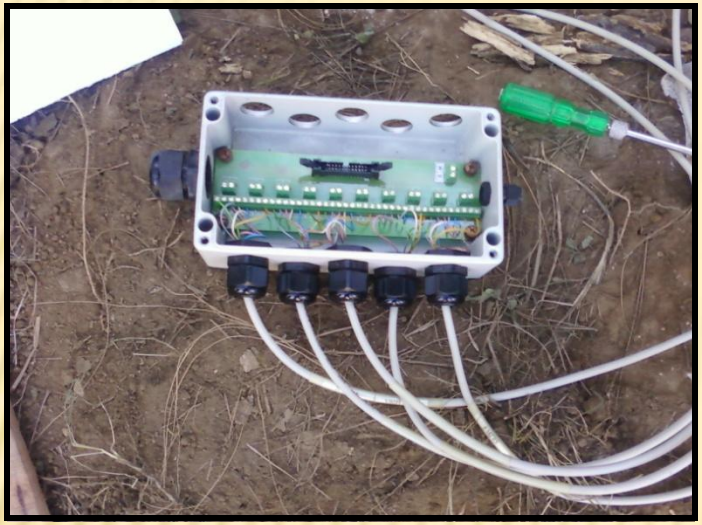
Lowering of Sensor

Bottom Wheel Assy-Sensor-Gauge Tube

Wires held together with Gauge Tube

Top Cap Assy. with wires through Groove

Junction cum Switch Box



IPI Sensors connected to JCB

Piezometer connection to JCB

Knob for Switching Channels while noting IPI sensors reading

Steel Box Housing for IPI & Piezometers

Piezometer inside Box

IPI wires inside GI Pipe

IPI wires to JCB within GI Pipe

Piezometer wires to JCB within GI Pipe

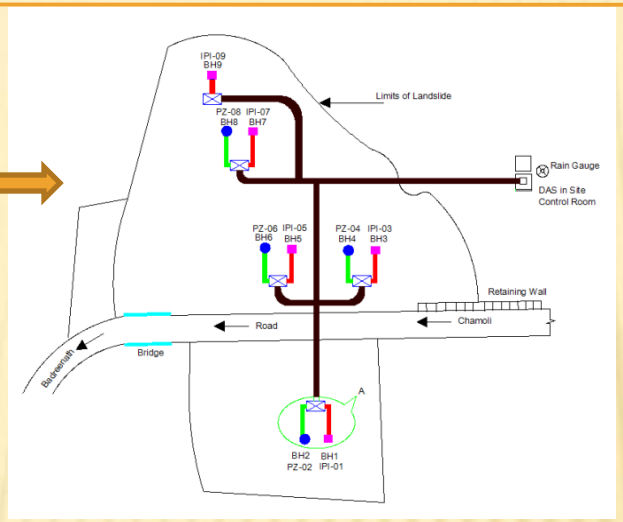
Pipes buried inside soil

INSTALLATION OF WIRE EXTENSOMETERS

INSTALLATION OF WIRE EXTENSOMETERS

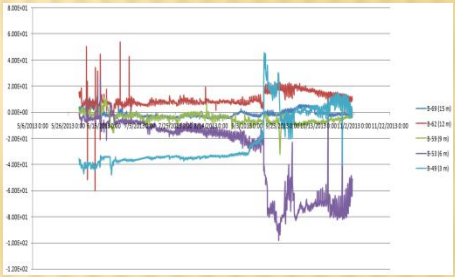
Automated Remote Monitoring of Landslide (ARMOL)

Tangni Landslide



Sensors Location

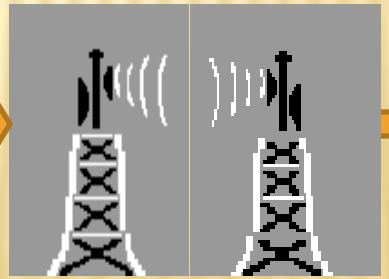
Landslide Warning/ Alert



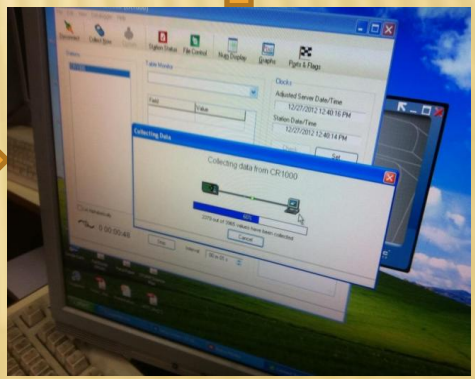
Data Presentation

Data Logger

Control Station



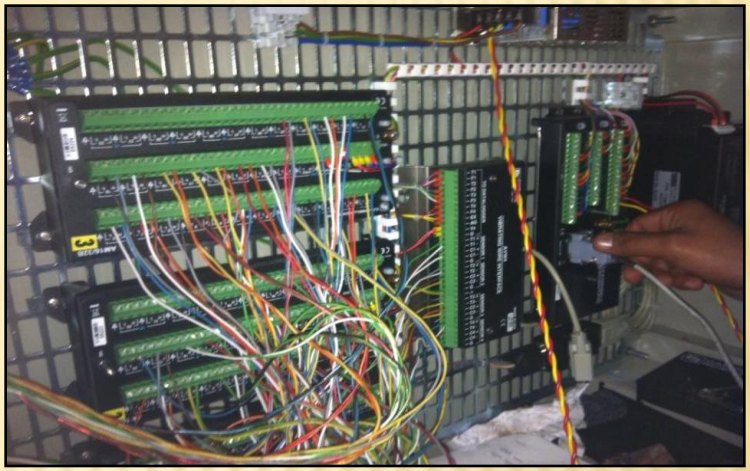
GSM Link



Data Download at DTRL

Control Station for Early Warning System

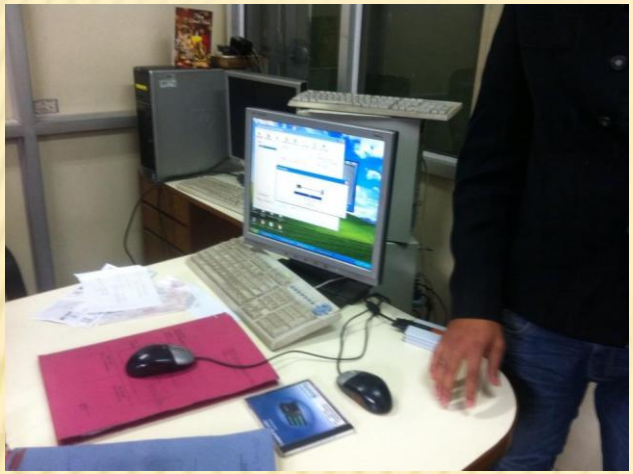
CONTROL STATION (HUT) TO HOUSE INSTRUMENTS

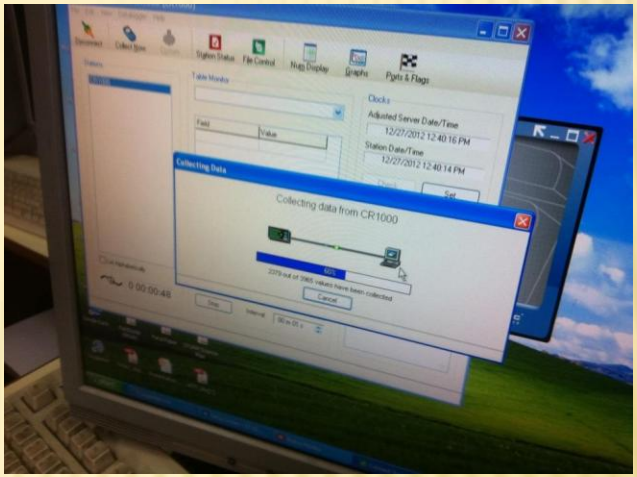


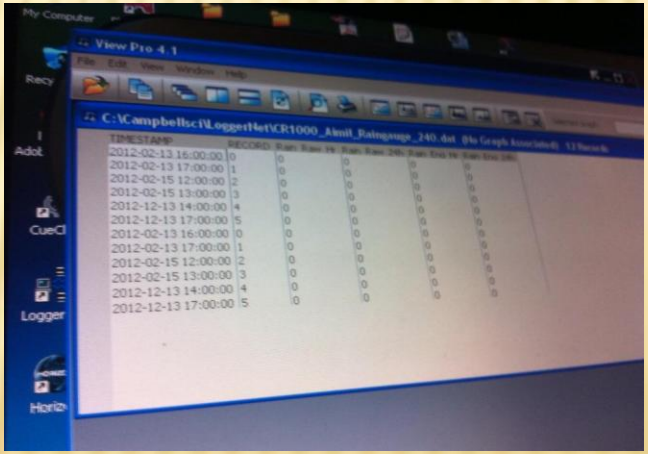
WIRE EXTENSOMETER

Early Warning System

DATA DOWNLOAD FROM DATALOGGER AT TANGNI SITE TO SERVER AT DTRL

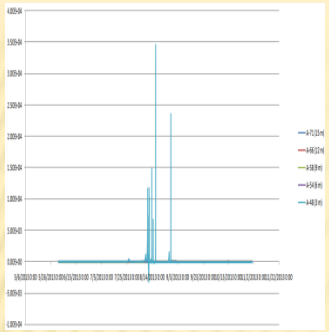
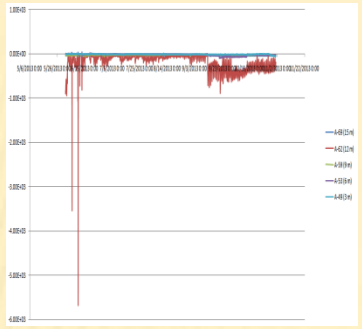
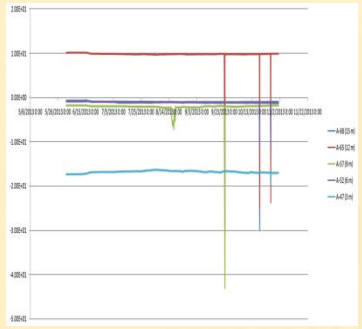
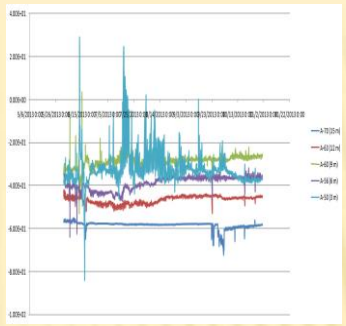
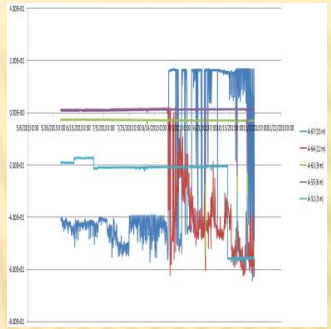




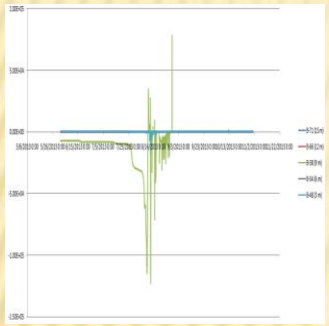
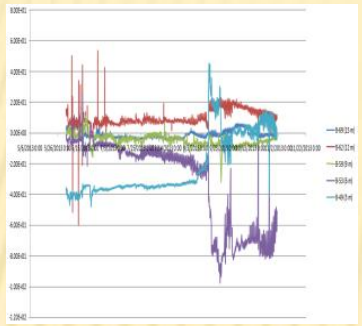
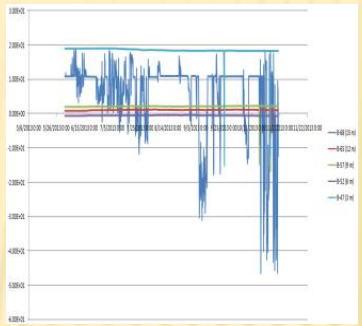
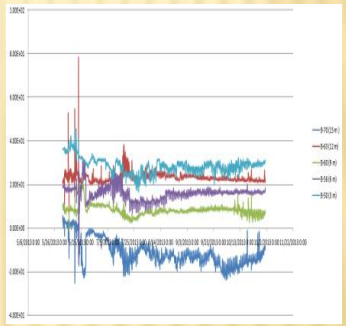
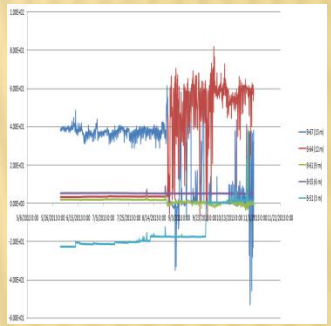


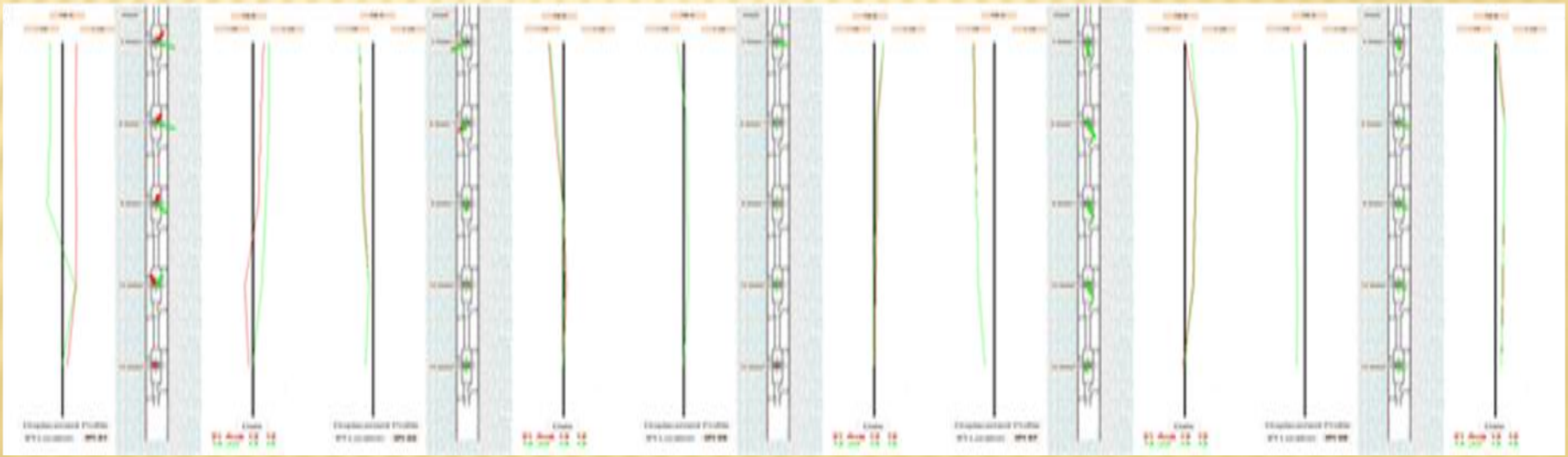
Analysis of Data

A-axis

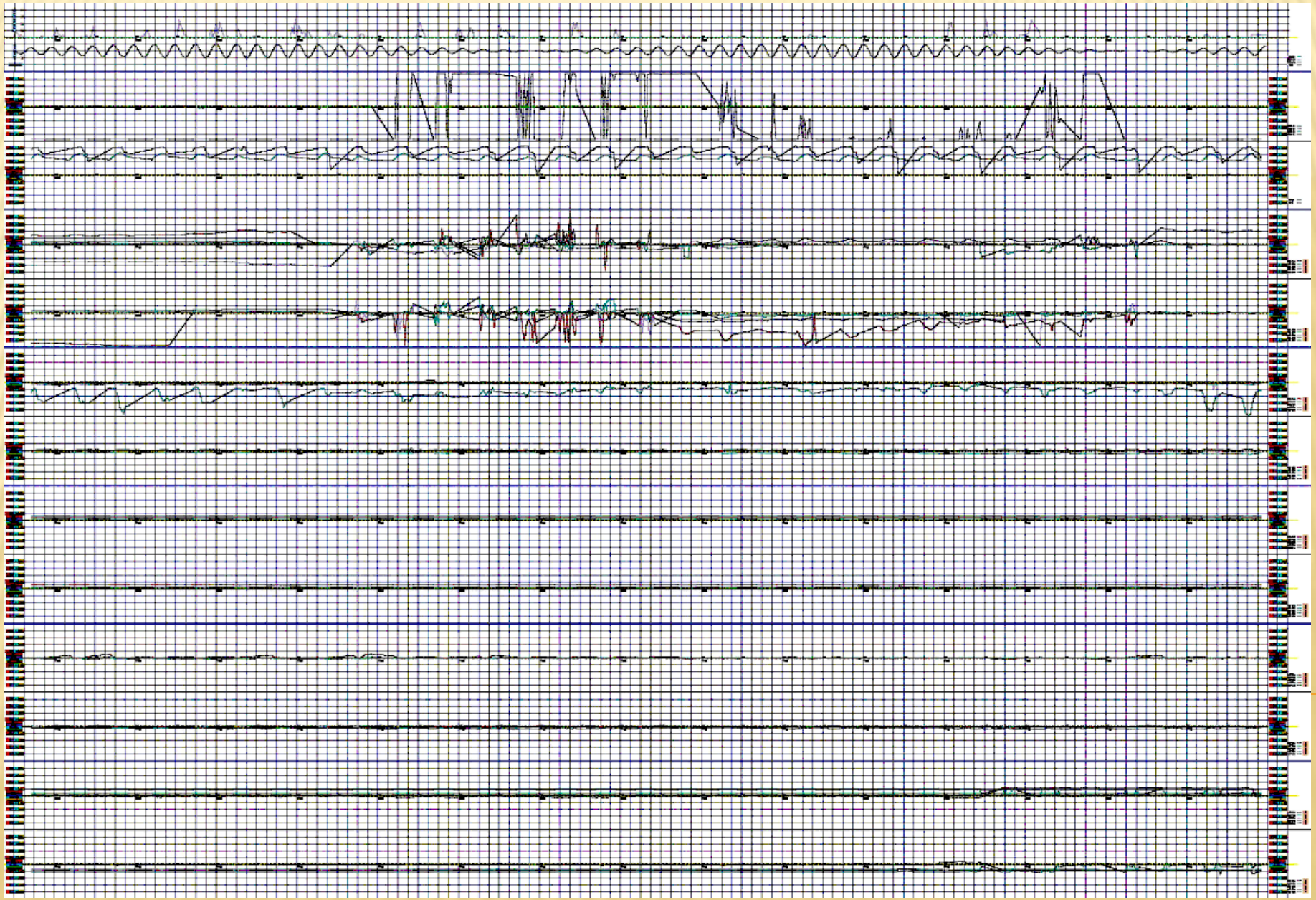






B-axis

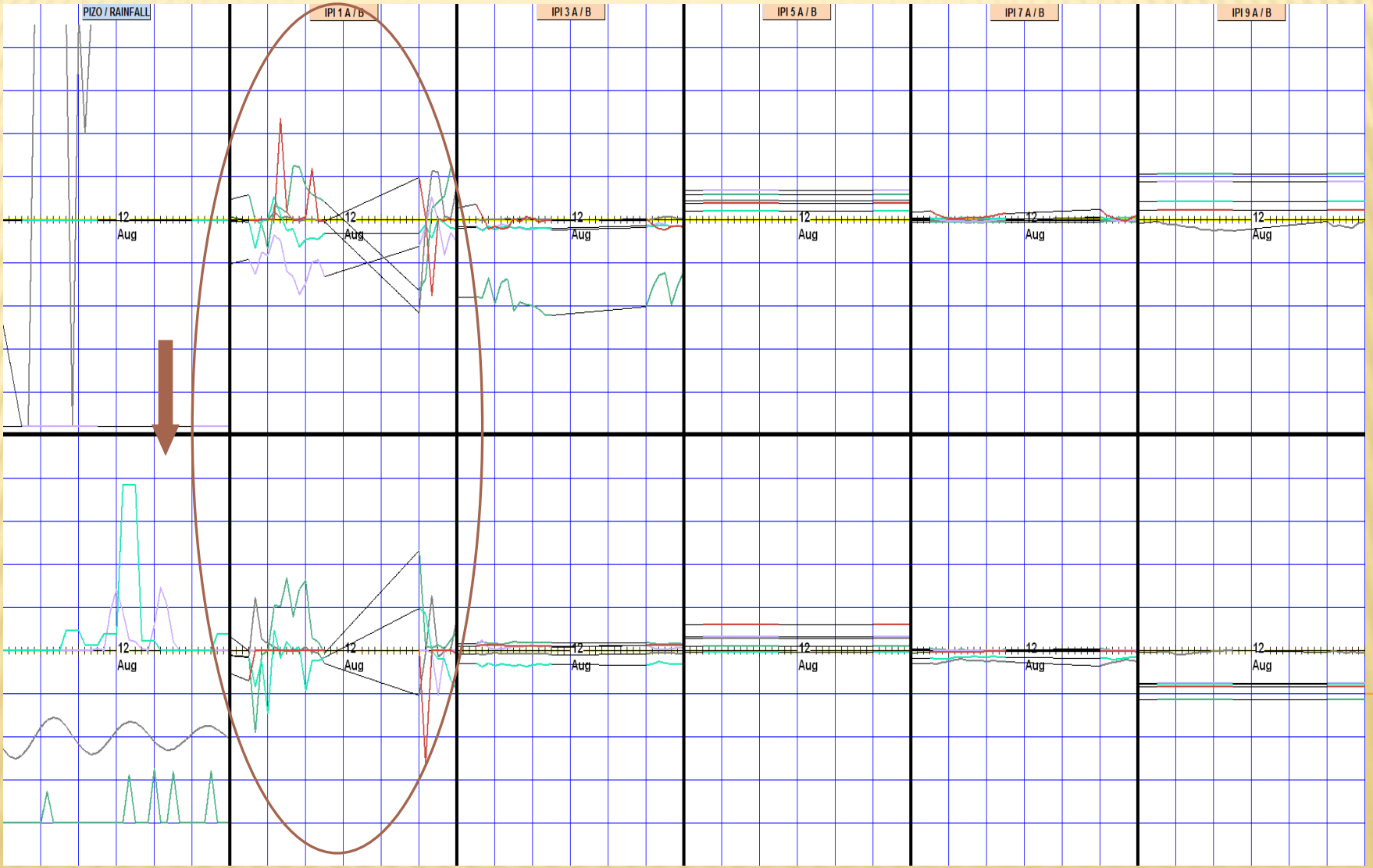








ARMOL : AUGUST 2013

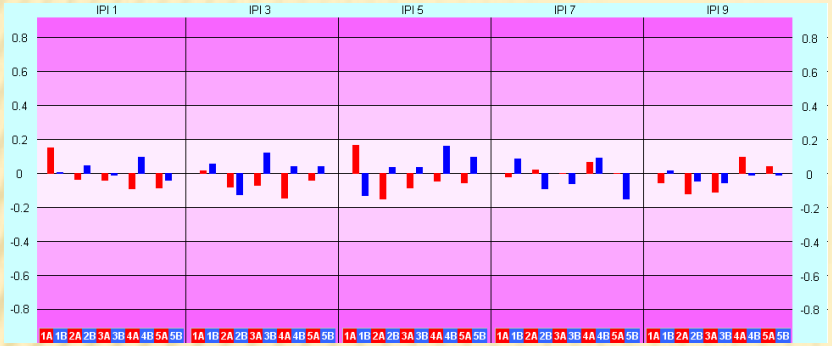


INCLINOMETER RESPONSE : 12 August 2013



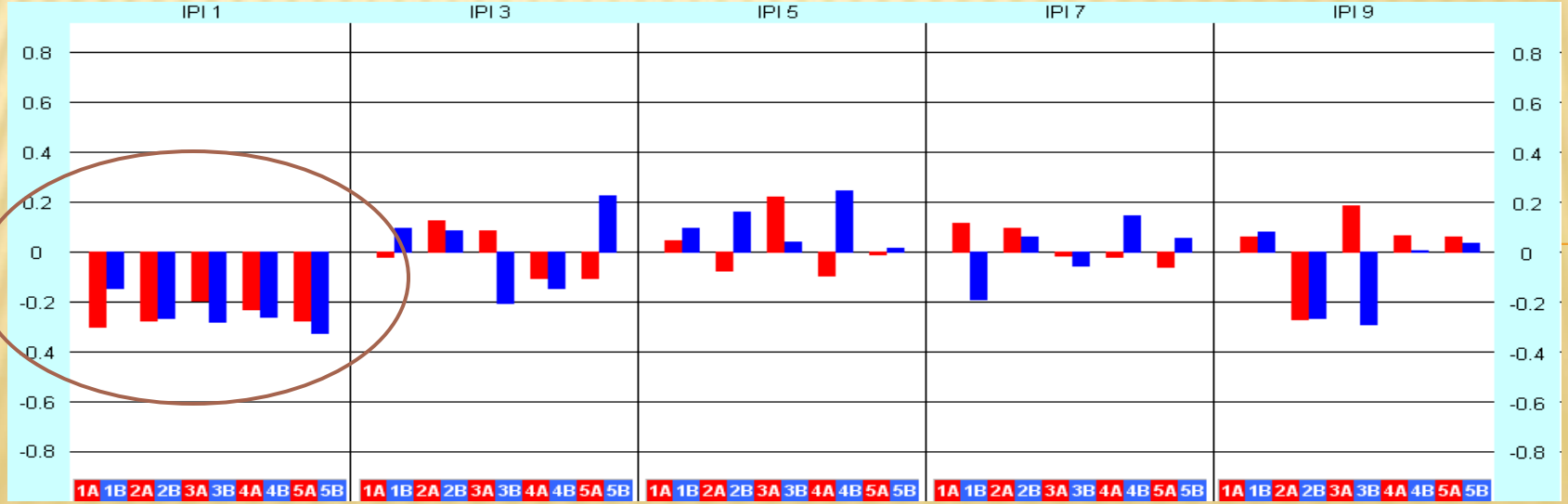
INCLINOMETER CORRELATION ANALYSYS AUGUST 2013

TRMM



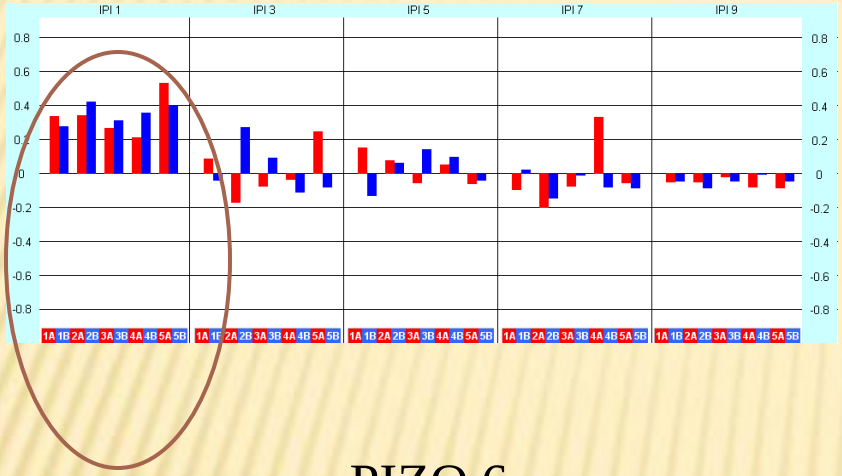
Rain Gauge - Pipalkoti

Tidal Force

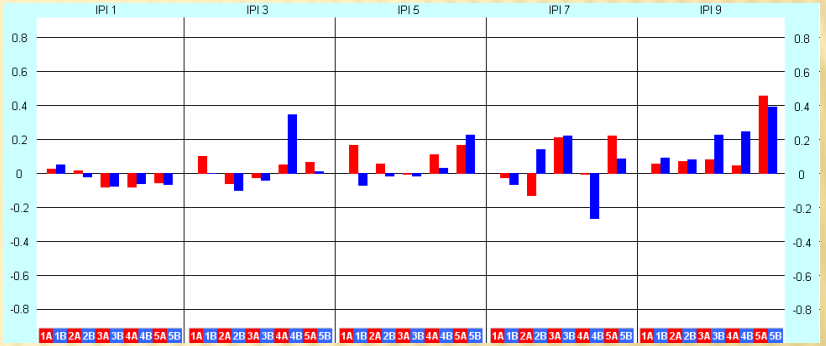


INCLINOMEYER CORRELATION ANALYSIS AUGUST 2013

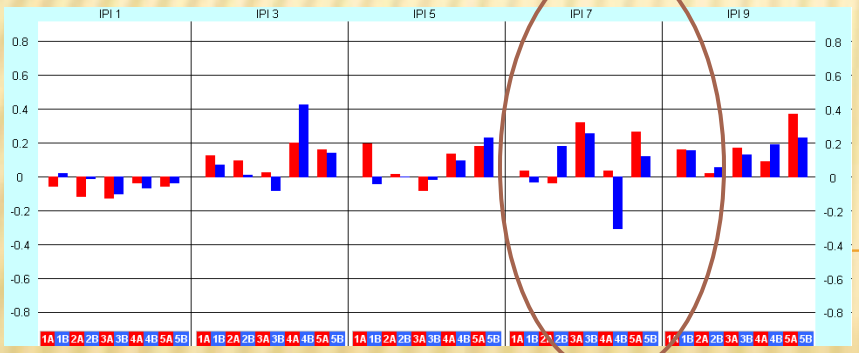
PIZO 2



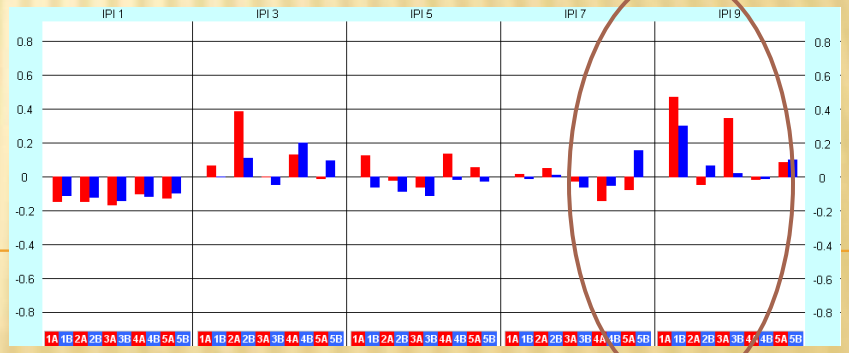
PIZO 4



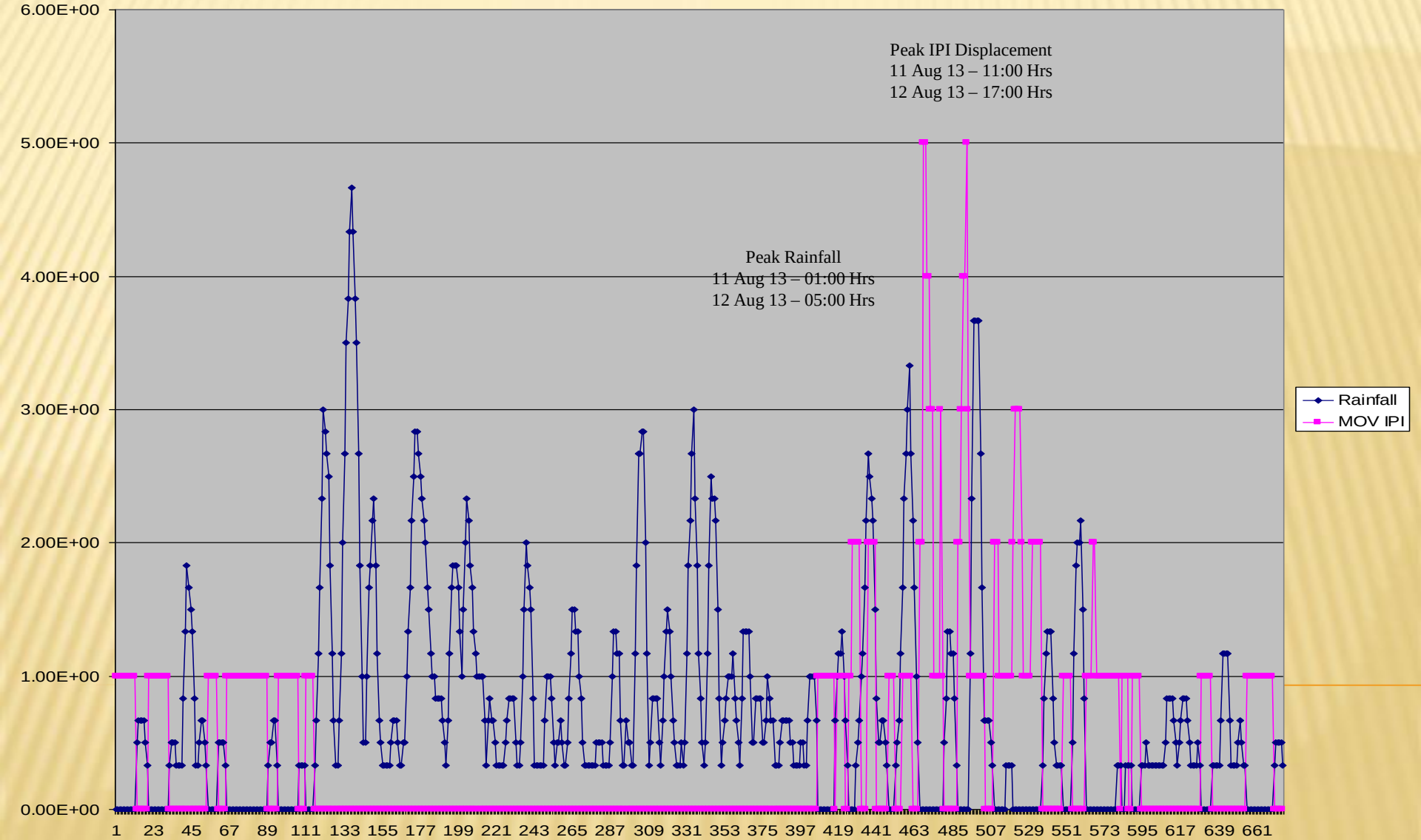
PIZO 6



PIZO 8



Rainfall VS IPI Movement

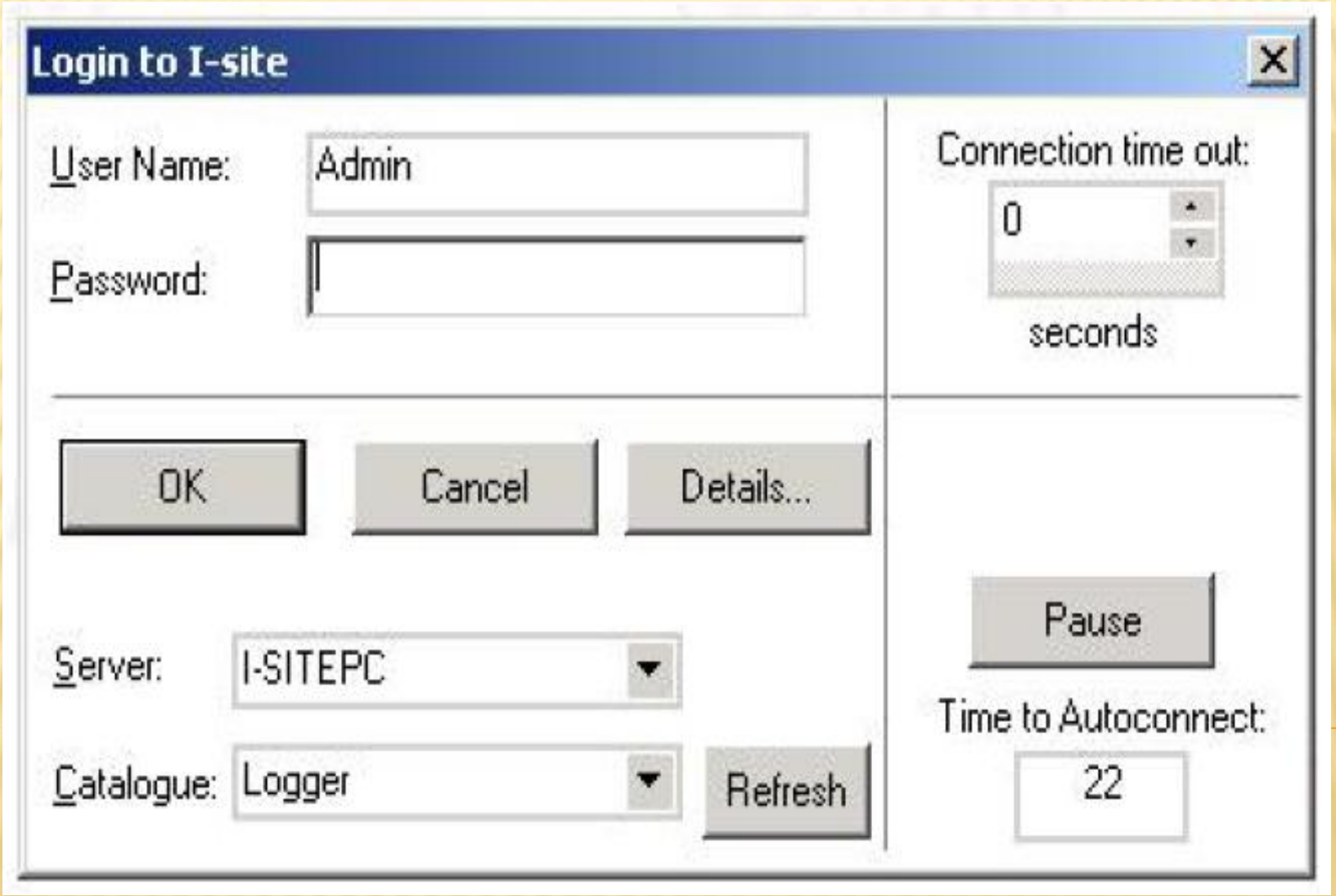


Remote Monitoring and Generation of Alerts

- Graphical representation of site and sensors.
- Automated retrieval of sensor measurements.
- Storage of data to a RDBMS.
- Display sensor data as a graph.
- Setting up of thresholds.
- Generation of alerts/alarm to specified individuals on Mobile .

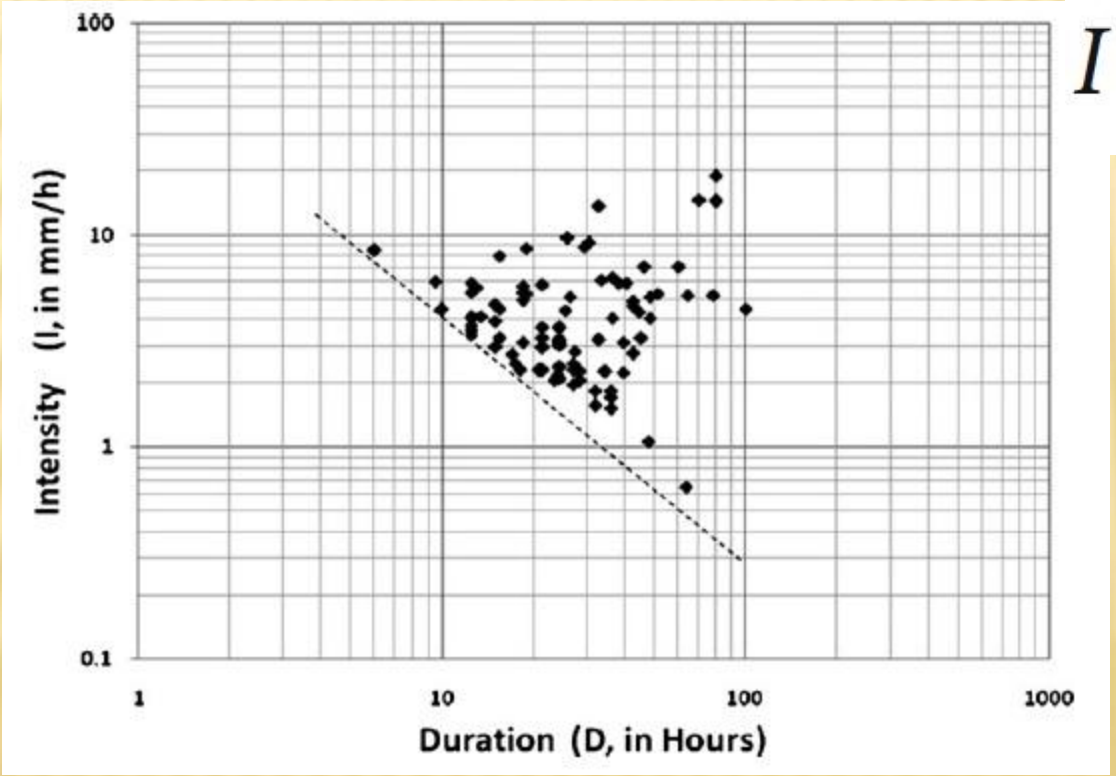
I-Site/ Argus from Soil Instruments

Argus Login Setup



I-D BASED RAINFALL THRESHOLD ALONG ROUTE RISHIKESH-MANA

136 records have been used for I-D threshold modeling and validation from Rishikesh to Mana.



$$I = 58.7D^{-1.12}$$

-MPI 4.8 mm/h, MD 31.4h
- PI 2.4 mm/h , 18h
- PI 8.2 mm/h, 6h
- PI 4.5 mm/h, 100h
- PI 19.1 mm/h, 80h

Landslide Prediction Modeling

- **Input Parameters-**
  - Intensity and duration of threshold
  - Pore water pressure
  - Lateral movement of soil layers
- **Output**
  - Probability of Landslide
- **Approaches-**
  - Finding the governing equations of the physical phenomena
  - Function regression using higher order polynomial
  - Modeling with multivariate distribution
  - ANN

Landslide Mitigation

Landslide Mitigation attempts to lessening the effect of landslides by constructing various man made projects on slopes which are vulnerable to landslides Slope stabilisation methods in rock or in earth, can be collocated into three types of measure:

Geometric : In which the geometry of the hillside is changed

Hydrogeological : in which attempt is made to lower the groundwater level or to reduce the water content of the material

Chemical and Mechanical : in which attempts are made to increase the shear strength of the unstable mass or to introduce active external forces (e.g. anchors, rock or ground nailing) or passive (e.g. structural wells, piles or reinforced ground) to contrast the destabilising forces.

CONTROL MEASURES

Objective: To provide the Site Specific Solution to minimize the hazard from Landslide.

Various type of measures:

- Retaining structures/Engineering structures
- Drainage structures
- Synthetic fibers
- Vegetation practices
- Slope modification, etc.

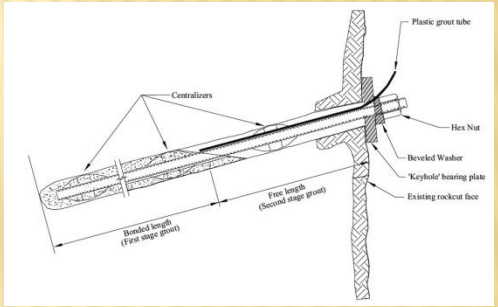
Based on site conditions, the above measures can be used as single or in combinations.

STATUS:

A Document is being prepared based on **IS-14680:1999 Guidelines for Control and IS-144458 Part I, II, III** of Bureau of Indian Standard suggesting various control measures which can be useful in different landslides sites for which inventory has been prepared in the project URUSWATI.

R1	Rishikesh-Joshimath-Badrinath-Mana

1. Latitude/ Longitude : 30^0 31' 17.568" N, 79^0 31' 21.947" E
2. Landslide Type : Active slide
3. Lithology : Biotite schist with grey granite gneiss
4. Geomorphic Unit : Mass wasting deposit
5. Slope Morphology : Convex
6. Slope(in degrees) : 45-60
7. Soil Depth : 0-25cm(shallow)
8. Soil Texture : Sandy skeletal soil
9. Land use/Land Cover : Barren land(rocky)
10. Rock Weathering : Very High
11. Anthropogenic Factor : NIL
12. Landslide Area (in sq. km.) : 3653.58
13. Landslide Hazard Zone : **Severe Hazard**



Control Measures:

Stabilizing Rock Slopes: Drilled-in rock bolts, and Wire mesh blankets, usually only effective for containing small blocks of a rock on a slope.

R2	Rishikesh-Dharasu-Uttarkashi-Gangotri

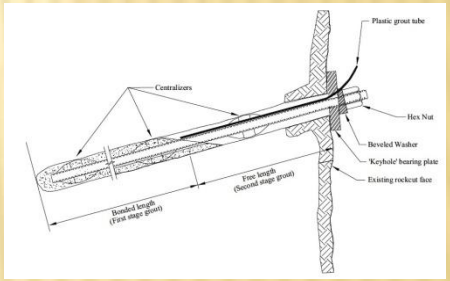
1. Latitude/ Longitude : 30^0 6‘14.310" N, 78^0 19‘ 4.058" E
2. Landslide Type : Active Slide
3. Lithology : Dolomite/Marble
4. Geomorphic Unit : Mass wasting deposit
5. Slope Morphology : Convex
6. Slope(in degrees) : 0-15
7. Soil Depth : 25-50cm(Moderate)
8. Soil Texture : Silty soil
9. Land use/Land Cover : Dense Vegetation
10. Rock Weathering : Very High
11. Anthropogenic Factor : Road/Slope Cutting
12. Landslide Area (in sq. km.) : 0.48
13. Landslide Hazard Zone : **Very High Hazard**

Control Measures:

Scaling along with Gabion Walls – Rectangular Containers fabricated of thick galvanized wires.

R5	Wangtu-Pooh-Kaurik

1. Latitude/ Longitude : 31^0 35' 2.426" N, 78^0 23' 39.080" E
2. Landslide Type : Active slide
3. Lithology : Granite
4. Geomorphic Unit : Mass wasting deposit
5. Slope Morphology : Straight
6. Slope(in degrees) : 25-30
7. Soil Depth : 0-25cm (shallow)
8. Soil Texture : Rock outcrop
9. Land use/Land Cover : Barren land(rocky)
10. Rock Weathering : High
11. Anthropogenic Factor : No activity
12. Landslide Area (in sq. km.) : 95875.00
13. Landslide Hazard Zone : **Very High Hazard**



Control Measures:

Stabilizing Rock Slopes: Drilled-in rock bolts, and Wire mesh blankets, usually only effective for containing small blocks of a rock on a slope.

DTRL CONTRIBUTIONS

- Based on the studies and recommendations of DTRL, BRO and State Govts have stabilized many landslides and slopes in Sikkim, NE and Uttrakhand. Soil Erosion has been arrested in many places in the Himalays thereby making strong impact ecology and environment of the area.

- DTRL is now planning to start the use of Bio-Shields on experimental basis on certain identified landslides and would reccommand the BRO and other agencies to increase the use of aborginal species as Bio-Shields to stabalise the landslides

Selected Landslide is Narendranagar Town


2003


2010


2011


2013

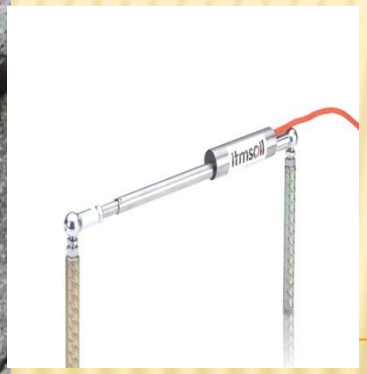
Recent View of Barkoat Landslide

SENSORS TO BE USED FOR EWS AT NARENDER NAGAR

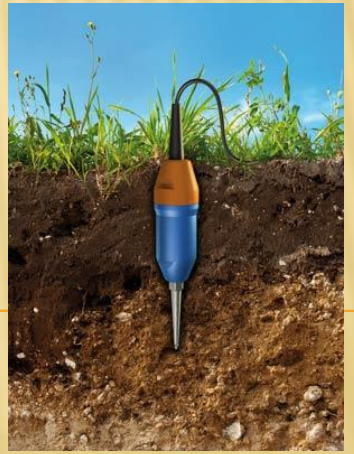
- Vibrating Wire Piezometer
- In Place Inclinometers / Tiltmeters
- Extensometers
- Geophones
- Tensiometers
- Crackmeters
- AWS (Automatic Weather Station)
- Acoustic Sensors
- Data Acquisition, Monitoring and Warning : Data logger
- Dissemination & Communication : FTP
- Power Supply: Solar panel and batteries
- Wireless sensors network (WSN) will also be integrated with above mention conventional sensors.

Additional sensors

Tensiometers



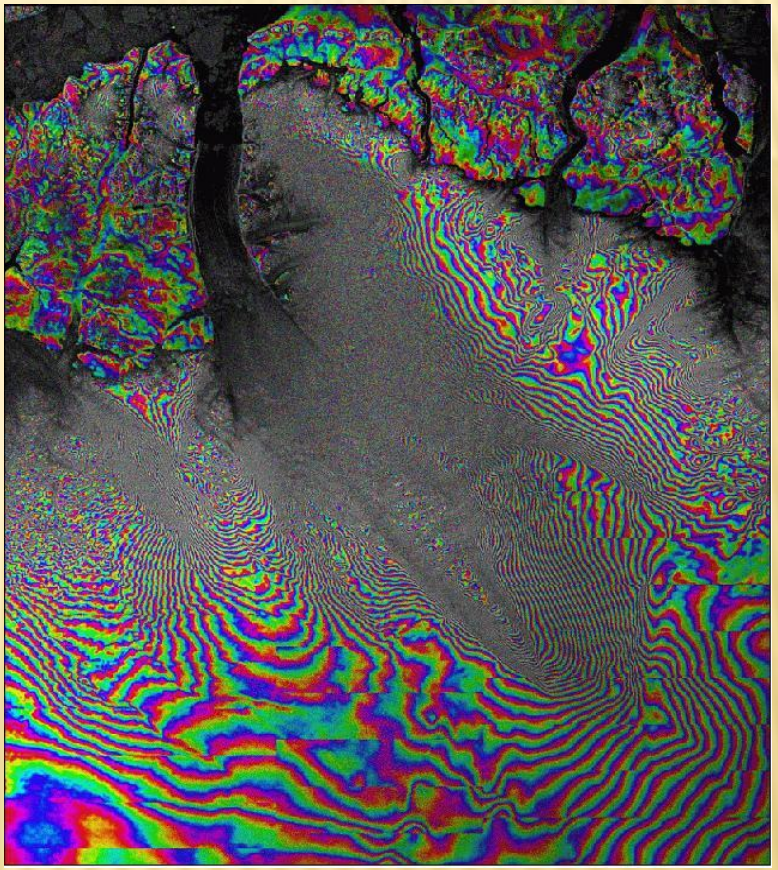
Crackmeters



Geophone

Event Monitoring

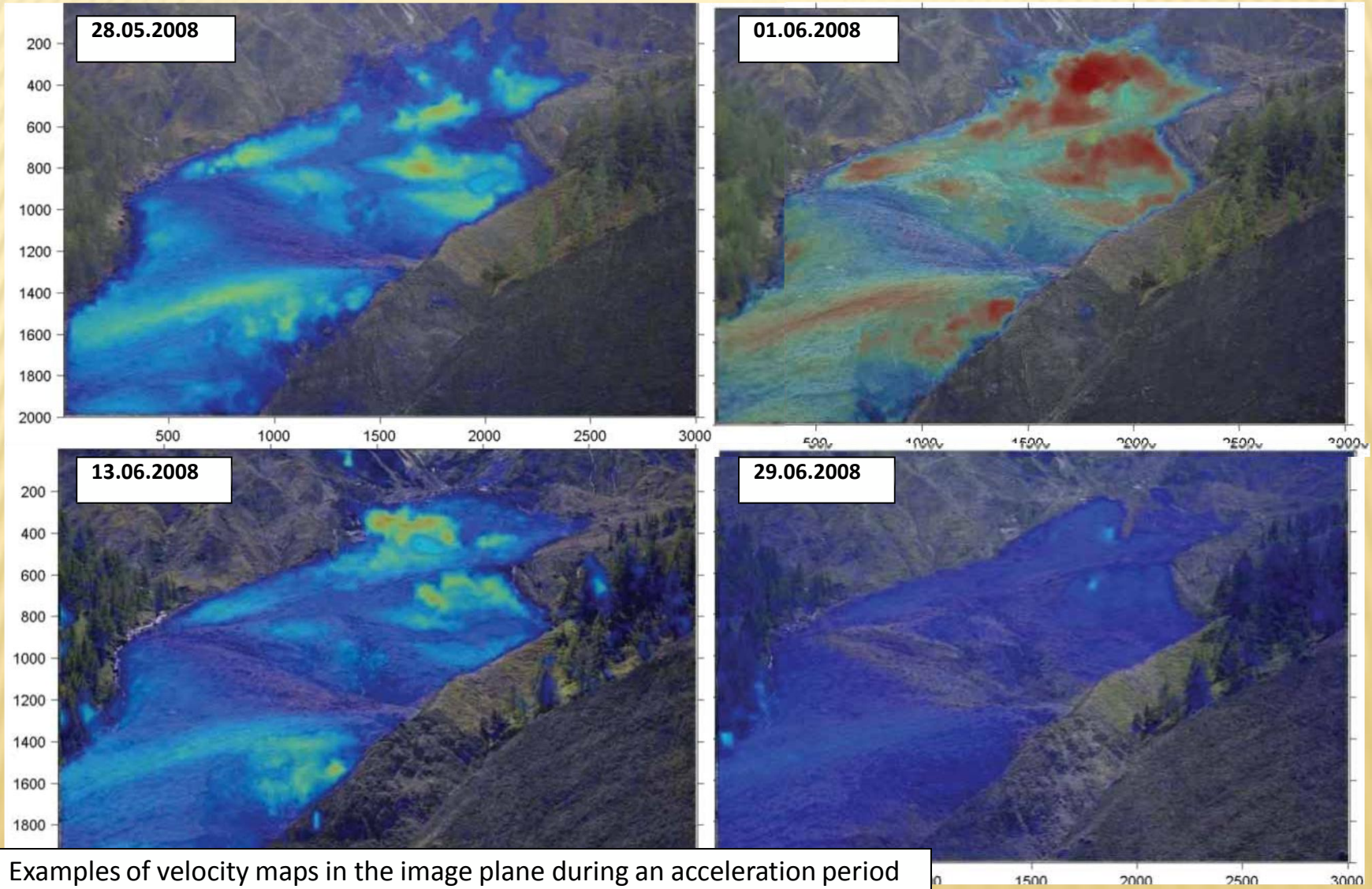
Video Monitoring System



Din-SAR Monitoring

Monitoring Landslide Kinematics

Correlation of High resolution optical images



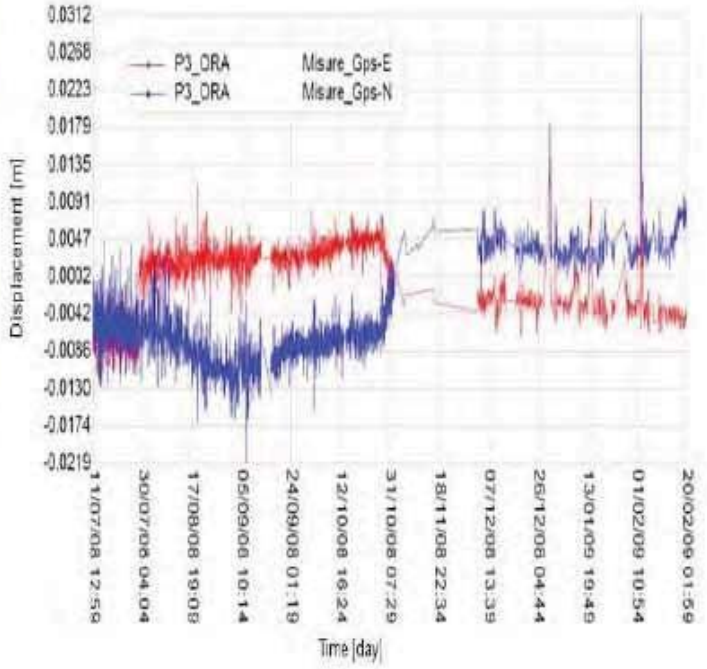
Examples of velocity maps in the image plane during an acceleration period

Monitoring Landslide Kinematics

dGPS measurements

Leica L1/L2 GRX1200 receiver

Examples:
Valoria landslide
Ancona landslide, Italy



Bertacchini et al. (2010)

Monitoring landslide kinematics

Terrestrial Laser Scanning - TLS

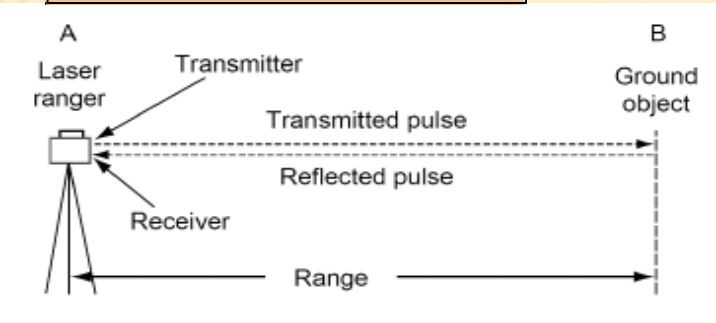
TLS LMS-Z620

TLS ILRIS 3D (Picture extracted from: www.Optech.ca)

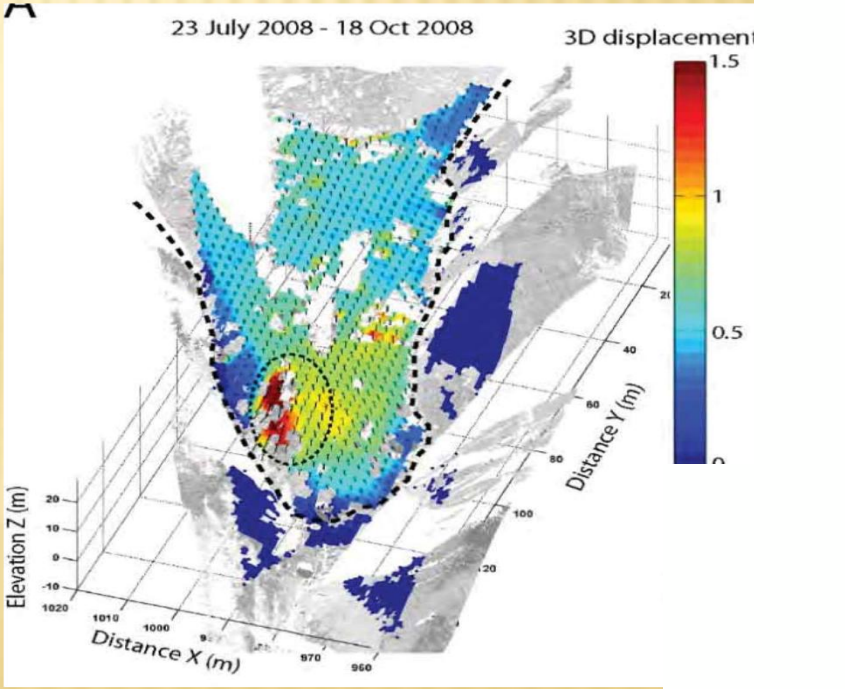
Trimble GX 3D

Monitoring Landslide Kinematics

Terrestrial Laser Scanning - TLS

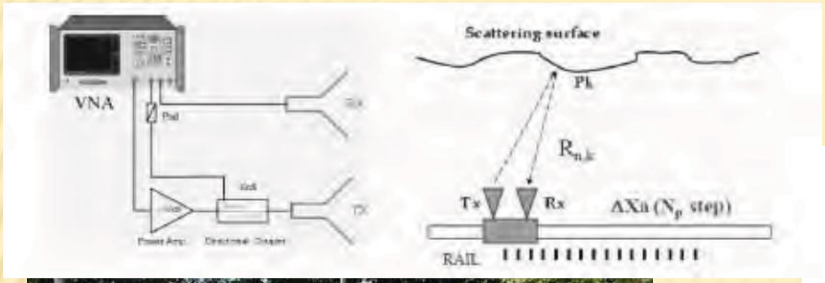


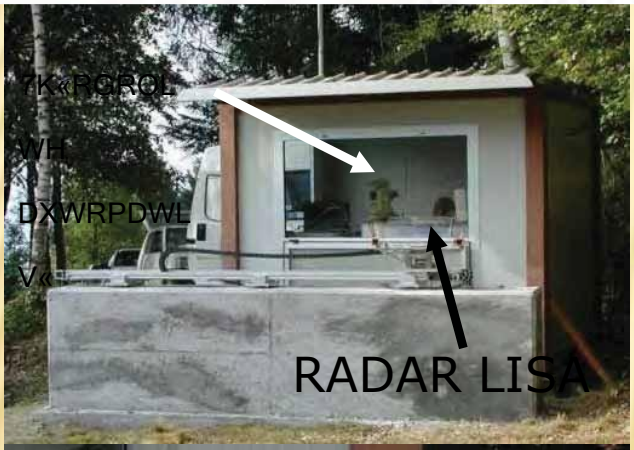
Super-Sauze landslide

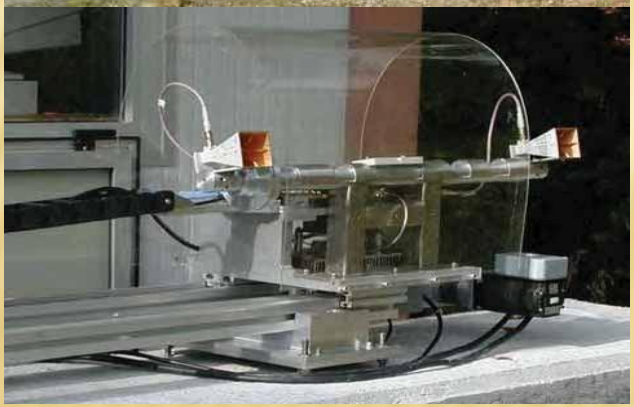


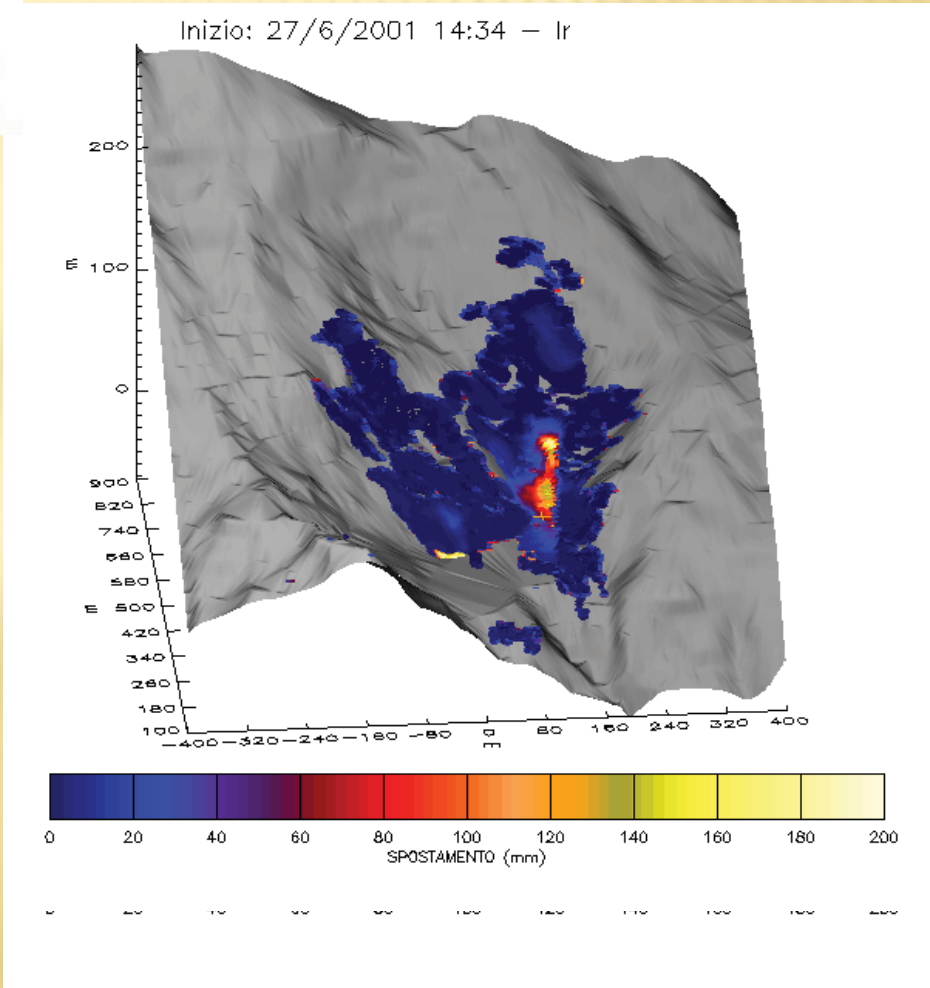
Monitoring Landslide Kinematics

Ground-based SAR (GB-InSAR, GB-PSInSAR)









CONTROL MEASURES BY BIOLOGICAL METHODS

- Landslides have been tradionally controled by engineering methods but now world over Biological Methods have become very popular to arrest the landslides as these methods are very good for maintaining ecological balance and conservation of soil etc

- DTRL is now planning to use Bio-Shields and Soil Bioengineering Methods for Landslide Control in the Himalayas

BIO-SHIELDS FOR LANDSLIDE MITIGATION

- Bio-shields are strips of trees and shrubs grown along the coasts to protect coastal areas from high velocity winds and waves.
- Mangrove is a natural bio shield while Malay apple, *ramphal*, *sapota*, guava, sweet lime, gooseberry and pomegranate and Cashew and bamboo can also act as bio shields. Salicornia, a salt-tolerant local plant, has also been planted.
- They serve as sand binders and also reduce wind speed during cyclones. Bio-shields also prevent the entry of seawater into the mainland during cyclones and tsunami, according to researchers.
- Bio-shields can also be used for carbon sequestration – the process of capturing and storing atmospheric carbon dioxide while releasing oxygen back to the atmosphere. The process is considered a crucial step in mitigating impacts of climate change, as carbon dioxide emission is one of the key contributing factors to global warming.

BIO-SHIELDS

- Dense mangrove forests served as a "speed breaker, reducing the damage done" during the 2004 tsunami which affected Tamil Nadu and other southern states.
- Bio-shields have been successfully used in Indonesia, Maldives and Sri Lanka. In Project SILAMAT India, Indonesia, Maldives and Sri Lanka under the aegis of Asian Disaster Reduction and Response Network (ADRRN) are using Bio-Shields are coastal protection.
- Environment Ministry is considering the idea of developing bio-shields comprising mangrove and non-mangrove species in coastal areas adjoining critical infrastructure projects such as power plants and oil storage depots. (On the Suggestion of Dr MS Swaminathan)
- In Thrissur project,Kerala Forest Research Institute will create bio-shields of 10 and 20 Kms on the Ganeshamangalam and Manakkakadavu beaches respectively in Kadannappally panchayat

BIO-SHIELDS FOR LANDSLIDES

- **Grasses** like *Bouteloua curtipendula* (sideoats grama) *Chasmanthium latifolium* (Inland sea oats)and *Elymus virginicus* (Virginia wildrye) and Agave cantula)have acted as Bio-shields for Landslides

- Bamboo also hold the earth in place with its dense and wide-spreading system of roots and act as natural Bio-shields. The roots of a bamboo plant can expand by 25 percent to hold six cubic meters of soil. Bamboo have been planted in TACLOBAN CITY, LEYTE, in Philippines.

- **Sedges** are grass like but don't grow as tall as grasses—both of these grow to around 1 foot. They have the advantage of being evergreen and also having fibrous roots. *Carex blanda* (eastern woodland sedge) *Carex cherokeensis* (Cherokee sedge)

BIO-SHIELDS FOR LANDSLIDES

- **Ferns** have also acted as Bio-Shields whwn there is enough moisture available. *Asplenium platyneuron* (ebony spleenwort) *Polystichum acrostichoides* (Christmas fern) also act as Bio-Shields as they anchors soil admirably.
- ***Ziziphus jujuba*** and many other species is also a natural bio-shields
- Prickly Pear (Thor - ***Cactus decumanus*** *and* **Opuntia dillenii**) a wild plant of Cactaceae Family also acts as Natural Bio-Shields in the Himalayan Regions.
- Pine Species like Pinus Longifolia (Chir) and ***Pinus gerardiana*** *(Chilgoza Pine)* also act as Bio-Shields.

HESCO HAS USED BIO-SHIELDS

- TREE SPP.
- a) Wendlendia excelsa(Takuli)
  b) Erythrina suberosa (Mandara)
- B. SHRUBS:
  - a) Vitex negundo(Simali)
    b) Agave cantula used by HESCO in Yemkeshwar, Chamoli Dugadda and Pauri.
    c) Adhatoda vasica(Vasinga)
- C. GRASS:
- a) Vetevaria zizaniodes(Khas-Khas)
  b) Saccharum spontaneum(Kans)
  c) Cymbopogon flurosence(Saing-grass)
  d) Eulaliopsis binata(Babad)
  e) Pogonanthrum spp.(Khekla)
  f) Eriophorum comosum(Murraya)

FORESTS, ENV. WILDLIFE MANAGEMENT DEPARTMENT GOVERNMENT OF SIKKIM HAS STABILIZED

(TURUNG, DONOK SETI KHOLA LANDSLIDE BY USING FOLLOWING)

- **Anthrocephalus cadamba ,**
- **Erythrina indica,**
- **Pischofia javanica ,**
- **Terminalia myriocarpa,**
- **Agave americana,**
- **Schima wallichii,**
- **Alnus nepalensis**
- **Bambusa nutants**
- **Dendrocalamus hemlintonii**
- **Cephalostachym capitatum**
- **Populus Sp.**

SOIL BIOENGINEERING FOR LANDSLIDES

- Soil bioengineering (SB) uses live plant materials to provide erosion control, slope and stream bank stabilization, landscape restoration, and wildlife habitat. These techniques are used alone or in conjunction with conventional engineering techniques.

- Soil bioengineering employs a partnership of the professions of soil science, landscape architecture, civil, hydrological, and geotechnical engineering, and horticulture.

- Soil bioengineering is an excellent tool for stabilizing soil surface erosion. These methods should not, however, be viewed as the only solution to erosion problems.

BENEFITS OF SB

- Projects usually require less heavy equipment excavation. As a result, there is less cost and less impact. In addition, limiting crews to one entrance and exit route will cause less soil disturbance to the site and adjoining areas.

- Erosion areas often begin small and eventually expand to a size requiring costly traditional engineering solutions. Installing soil bioengineered systems while the site problem is small will provide economic savings and minimize potential impacts to the road and adjoining resources.

- Use of native plant materials and seed may provide additional savings. Costs are limited to labor for harvesting, handling, and transport to the project site. Indigenous plant species are usually readily available and well adapted to local climate and soil conditions.

BENEFITS OF SB

- Soil bioengineering projects may be installed during the dormant season of late fall, winter, and early spring. This is often when other construction work is slow.
- Soil bioengineering is often useful on sensitive or steep sites where use of heavy machinery is not feasible.
- Soil bioengineering systems are strong initially and grow stronger as vegetation becomes established. Even if plants die, roots and surface organic litter continues to play an important role during reestablishment of other plants.
- Once plants are established, root systems reinforce the soil mantel and remove excess moisture from the soil profile. This is often the key to long-term soil stability.
- Soil bioengineering provides improved landscape and habitat values.

BIOENGINEERING MEASURES IN MIDDLE PORTION OF VARUNAVAT PARVAT

To ease the process of stabilization, benches were formed and these were then covered by geo-jute to check soil erosion and conserve soil moisture.

Species were used for bioengin

- ***Cymbopogon citratus***
- ***Cymbopogon martinii***
- ***Cymbopogon nardus***
- ***Pennisetum purpureum***
- ***Panicum maximum***
- ***Crotalaria sp.***
- ***Mimosa himalayana***
- ***Debregeasia hypoleuca***
- ***Vitex negundo***
- ***Rumex hasatus***
- ***Alnus nepalensis***
- ***Bauhinia variegata***
- ***Trema politoria***

BIOENGINEERING MEASURES IN DUMPING SITES

Species used for bioengineering application..

- ***Cymbopogon citratus,***
- ***Cymbopogon martinii***
- ***Cymbopogon nardus***
- ***Pennisetum purpureum***
- ***Stylosanthes hamata***
- ***Dodonaea viscosa***
- ***Rumex hasatus***
- ***Vitex negundo***
- ***Crotalaria* sp.**
- ***Alnus nepalensis***
- ***Trema politoria***
- ***Bauhinia variegata***

CONCLUSIONS

- Institutions and organisations must coordinate with each other to stop duplication of Landslide work.
- A Nodal Agency should act as Watchdog to avoid duplication of work. NDMA and GSI can work as Watchdog.
- Each Institution/organisation must adopt a landslide to do research in each and every method so that understanding of its problem is fully exploited.
- Minimum instrumentation required for Early Warning System (EWS) must be arrived at so


SHIVALIK
सावधान
CAUTION
LANDSLIDE
&
ROCKFALL
ZONE
KEEP MOVING
CAUTIOUSLY
75 RCC
21 BRTF

Thanks