Case studies: Baliyanala and Kedarnath

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Close up view of the main scarp of the Baliyanala landslide




View of target slope

Failed slopes

Scarp of failed slope – Loosely held

Loose debris covers the bed rock




Various measures undertaken by the Government for stabilization of Baliyanala

The hills around Nainital are fragile and vulnerable to landslide. It has been reported that habitation in Nainital started only after 1841, and Nainital town has been repeatedly devastated landslide. The slip of 1867 from the Sherkadanda Hill necessitated examination of the hill sides by committees of Engineers in 1867 and 1873 who recognized the action of water as the chief cause in bringing about slips in the peculiar formation of the hills around Nainital in which the natural conditions were favourable to slips. They recommended measures for dealing with drainage and for supporting the hill slopes at bad places by walls, etc. The big slips in 18th September 1880 killed 151 persons of whom 43 were Europeans. (fig.1 The Naini Tal Catastrophe of 18th September 1880) After the landslide, further erection of buildings, quarrying and digging of terraces or platforms were absolutely prohibited on the hill slopes. Steep slopes were turfed and planted with trees and grass. Cutting and grazing were absolutely banned. The catastrophe resulted in construction of drains, to safely drain off the water from the vulnerable slopes. The Nainital drainage system, aiming at the speedy and affective drainage of the hillsides, has been designed and constructed with the greatest care. As on its efficiency depends the stability of the hill slopes, it is very important that the efficiency should be maintained at the highest point, by the proper maintenance. In this connexion, it is necessary also to consider the upkeep of the municipal and provincial roads and roadside drains in the settlement as the former, with a total length of over 30 miles, contribute no mean share to the drainage and the latter (about 20 miles in length) carry, in addition to the drainage from the roads a portion of the hillside drainage as well, so the roads have a fairly important bearing on the question of stability. Rule regarding observation for the slope movement pillar were constructed. If between June 1 and October 15 a movement of 6 inches or more occurs in any pillar within 24 hours the matter must be immediately reported to the District Engineer or, in his absence from the station at the time, to the Divisional Engineer. In 1898 Nainital had to face the wrath of nature again in the form of the Kailakhan landslide that caused the death of 27 Indians and one European. Nainital was devastated again by landslides in 1893, 1898, 1924, 1989 and 1998. In the year of 2017 as an Executive Engineer I, informed the authorities that area is vulnerable and sensitive for landslides as Irrigation department is not specialist in landslide treatment this area must be treated by the specialist those who are treating the landslide in other parts of the state.

Accordingly, a High Power Committee, comprising of the following members, is constituted to treat the fragile site at Balianala from further damage.

- The Director, Wadia Institute of Himalayan Geology, Dehradun.
- The Director/Additional Director, Forest Research Institute, Dehradun.
- Senior-most Professor (Civil Engineering) of Indian Institute of Technology, Roorkee.
- The Chief Engineer, Irrigation Department, State of Uttarakhand.
- The Chief Engineer, Public Works Department, State of Uttarakhand.

The Registrar, Forest Research institute shall be the Secretary of the committee. The Committee shall meet on or before 12-10-2018 to find out permanent solution to prevent further damage. The Committee shall make its recommendation on an urgent basis within a period of one month from today. It shall be open to the High Power Committee to take assistance of any expert throughout the world.

Amar Ujala 14 November 2018

बलियानाला देखने फिर पहुंचे वैज्ञानिक

एफआरआई को बनाया गया नोडल एजेंसी, 15 नवंबर को हाईकोर्ट में पेश करनी है रिपोर्ट

अमर उजाला ब्यूरो

नैनीताल। बलियानाले में हो रहे भूस्खलन की रोकथाम को लेकर हाईकोर्ट के आदेश के बाद प्रभावित क्षेत्र के पुनः निरीक्षण को लेकर गठित समिति नैनीताल पहुंच गई है। एफआरआई को नोडल एजेंसी बनाया गया है जिसके निर्देशन में मंगलवार को टीम ने नैनीताल क्लब में एक घंटे तक मंथन कर भूस्खलन प्रभावित क्षेत्र का मुआयना किया।

बलियानाले में जारी भूस्खलन के चपेट में आकर नैनीताल का रंज़ होटल पहले ही जमींदोज हो चुका है वहीं अब हरिनगर क्षेत्र की आबादी भी खतरे की जद में आ गई है। खतरे की जद में आए परिवारों को जिला प्रशासन की ओर से विस्थापित कर दिया है। बलियानाले में बने खतरे को लेकर हाईकोर्ट में एक याचिका दाखिल की गई थी जिसके बाद कोर्ट ने एफआरआई को नोडल बनाते हुए पांच विभागों के निदेशकों की टीम का गठन कर बलियानाले में हो रहे भूस्खलन के कारणों का पता लगाने के साथ ही उपचार को लेकर रिपोर्ट तैयार करने को कहा था। कोर्ट ने कमेटी को बलियानाले के भूस्खलन प्रभावित क्षेत्र का पुनः निरीक्षण कर संशोधित रिपोर्ट पेश करने को कहा है। नैनीताल पहुंची टीम प्रभावित क्षेत्र का निरीक्षण कर 15 नवंबर को हाईकोर्ट में रिपोर्ट प्रस्तुत करेगी।

बलियानाले के पास टीम के सदस्य को सहारा देते अधिकारी। अमर उजाला

इन्होंने किया निरीक्षण

एफआरआई के वरिष्ठ वैज्ञानिक डॉ.विजेंद्र पनवार, आईआईटी रुड़की से प्रो.सतेंद्र मित्तल, डीएमएमसी से डॉ. केएस सजवान, वाडिया से डॉ. के सुयाल, लोनिवि के मुख्य अभियंता केपी जोशी, सिंचाई विभाग के एसई एमसी पांडे, ईई सीएस नेगी, ईई हरीश चंद्र सिंह, जिला आपदा अधिकारी शैलेश कुमार, प्रिया जोशी, एसई एनएस पतियाल, विजय जोशी, दीपक गुरुरानी।

Following the directive of the Hon'ble High Court of Uttarakhand, Nainital with the mandate to treat the fragile site at Balianala from further damage and an objective to find out permanent solution to prevent further damage. The high power committee constituted by the Hon'ble Court visited the affected site and after studying the possible causes of the landslide have suggested suitable measures to address the issue. The report on the Balianala comprises different sections dealing with; geological setup, geomorphology, rainfall characteristics, scientific research updates on landslides, technological updates on stabilization/mitigation of landslides, past efforts undertaken on Balianala, landslides by government and other Institutions, field observations, possible causative factors, remedial measures, and action plan.

High Power Committee recommended Short term & Long term measures to treat the fragile site at Balianala Nainital from Further Damage.

POSSIBLE CAUSATIVE FACTORS

- **Geologically, the area lies in the Krol Formation of the Lesser Himalayan sequence comprising of dolomitic limestones, shales/ slates and their weathered derivatives.**

- **The area also lies in close proximity to Main Boundary Thrust (MBT) and is closely traversed by a number of local tectonic discontinuities like Lake Fault and**

- **Baliyanala Fault. Thus, the rocks are highly sheared and shattered in the area.**

- **Stress Factors reducing the factor of safety (FoS):**

  - i. Loading of the slope: Dead loads of the buildings and other infrastructures
  - at the upslope of the crown.
  - ii. Development of pore water pressure: Water recharge of the perched aquifer from the catchment drainages and the wastewater discharge from the buildings in the catchment.
  - iii. Subsidence of the habitated upslope in a retrogressive manner and simultaneous erosion from crown portion of the Harinagar landslide.

- **Strength factors reducing the Factor of Safety (FoS):**

  - i. Weathering of dolomitic limestone and shale/slate substantially reduced the strength characteristics of the slope material.
  - ii. Water seepage into the slope contributed in reducing the cohesion of the soil.
  - iii. Change in gradient of slope (becoming steeper) due to subsidence and surface erosion influenced the angle of repose of the loose debris material.
  - iv. Removal of toe support due to toe erosion by Baliyanala.

REMEDIAL MEASURES

Drainage Measure in the Catchment: Planning and design of surface drainage network by strengthening the existing drainage network in the catchment area to channelize the surface water (rain water & household discharge) for its discharge in to the Baliyanala.

Toe Protection: Providing toe support to the Harinagar landslide with proper design and execution of RCC retaining wall with adequate provision of weep holes. A drainage filter layer of properly graded stones/gravel/sand to avoid chocking of weep holes should be provided at the backside of the retaining structure.

Treatment of initiation zone at crown:

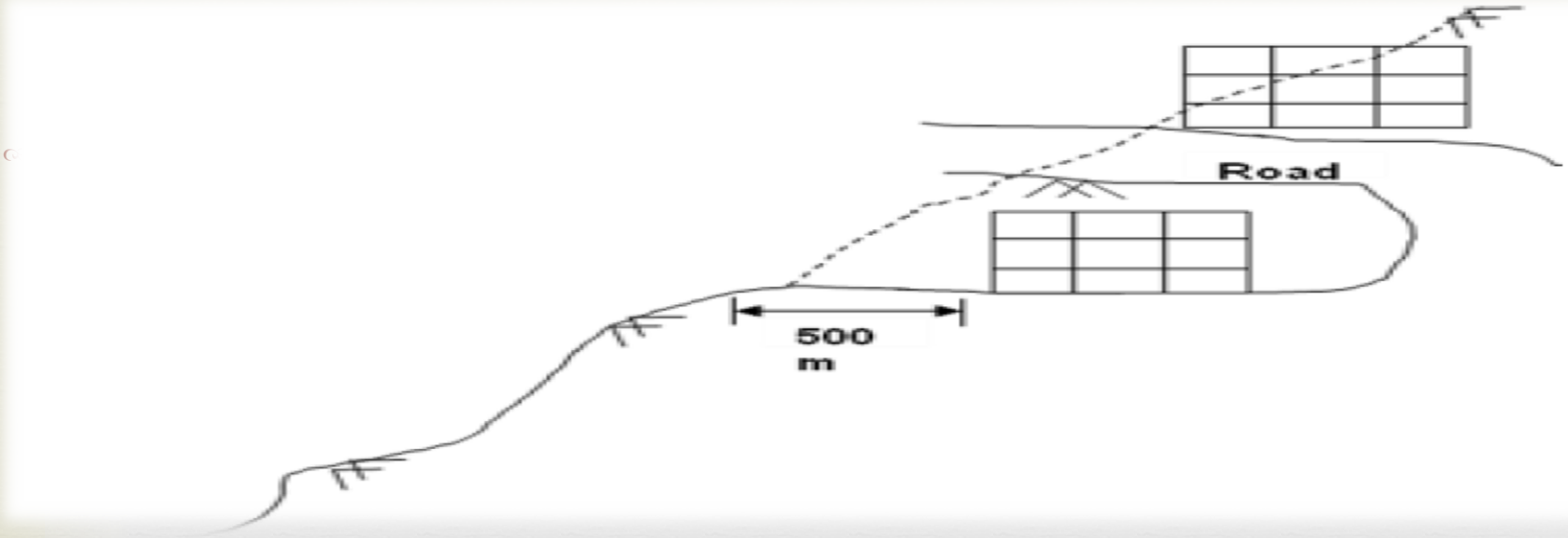
The zone of initiation (source zone) of the Harinagar slide can be treated with soil nailing technique, which may be a feasible and cost effective solution. However, the different parameters for soil nailing such as length and diameter of the nails, horizontal and vertical spacing's between nails etc. have to be properly designed with optimization to achieve the overall desired factor of safety of the treated slope as 1.5 under static and 1.2 under dynamic conditions.

Short term measures

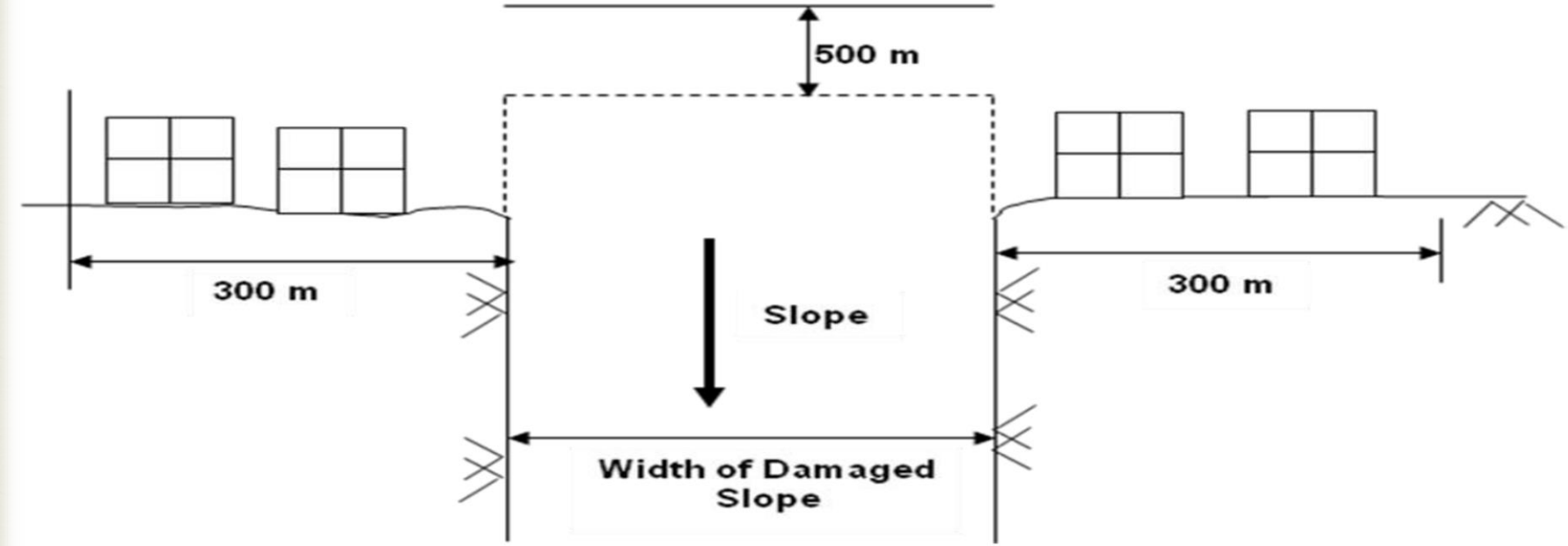
- Evacuation and relocation of people from unsafe area is being carried by District Administration & so many family has been Evacuated and relocated.
- Following work has been carried out by Irrigation Department.
- Restoration & Realignment of drain in landslide area of Balianala has been completed and report in this regard has been submitted by Executive Engineer, Irrigation Division Nainital to HPC vide no. 2888/ID Nainital/Balianala/ 24-07-2019.
- Gabion Structure (Wire create with boulder) to minimize the debris runoff on the stream has been completed. 150 no. Wooden Piling, 42 no. MS Perforated Pipe, 157 no. SDA has been installed on first slope as PILOT Project on first slope, Meeting held by HPC on 29-05-2020

Report submitted by IIT Roorkee on Geophysical investigation for study of delineation of path of flow of sub surface water in Upstream of Balianala indicate that there is 4 to 5 m thick layer which make corresponds to water saturated shall and clay or fracture zone in his report IIT Roorkee has mention that the data has been matched with drilling report of the JICA. He also indicated that water saturated zone is occurring as a sheet like body with an aerial extension of about 200 m from GIC School ground and Sepaidhara, where the water is being tapped. *Therefore, it is required to tap the water near GIC school ground as well which will also help in mitigating the landslides as well as will be helpful in supply of water to lower reaches and will also reduce the load from drawing water from the Naini lake.*

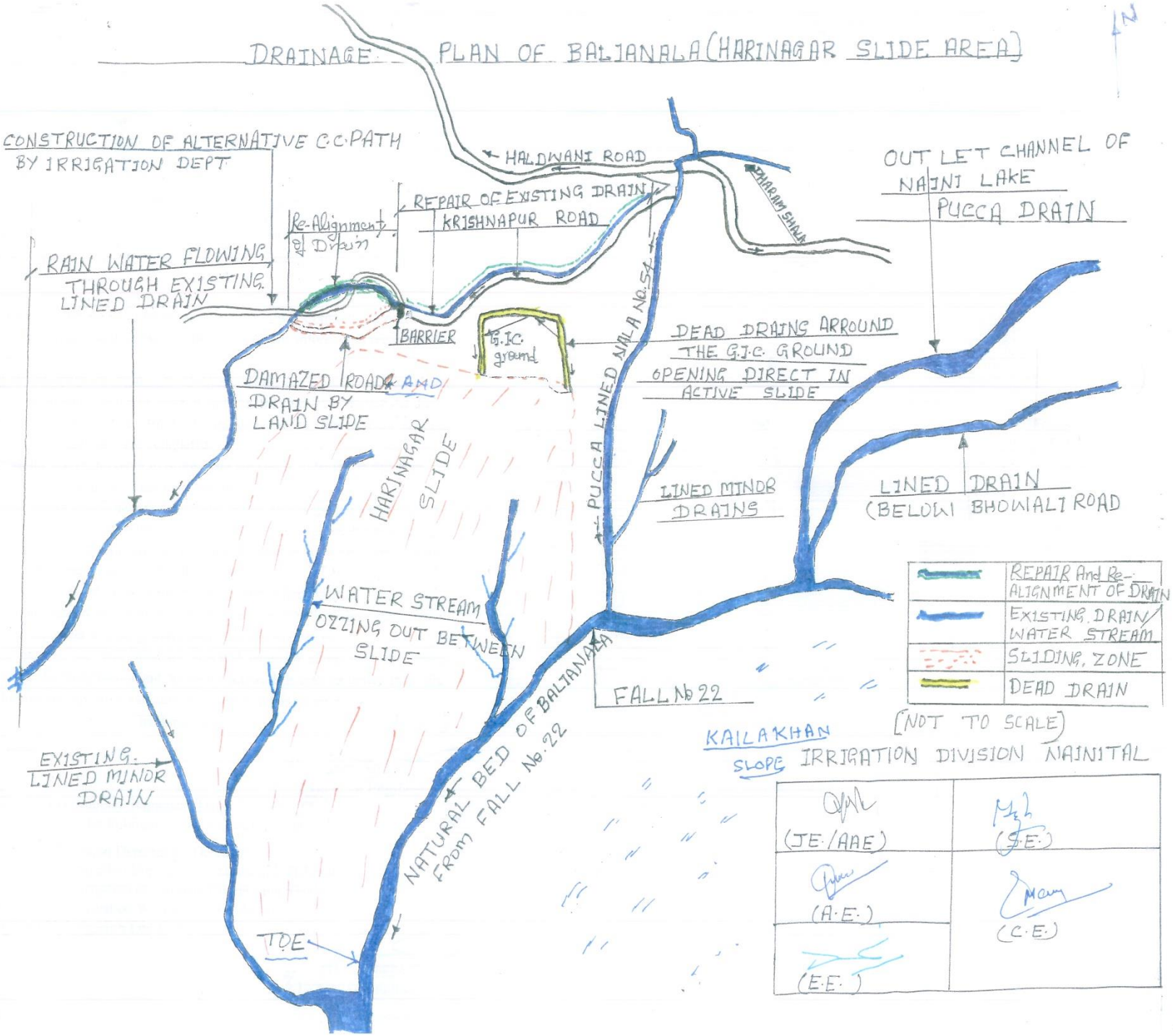
3 no. Landslide monitoring system has been installed by IIT Mandi and report received indicates that system no. 3 has displacement in Z- direction only.



Section (not to the scale)



Plan View From Valley Towards Up Slope (not to the scale)


DRAINAGE PLAN OF BALJANALA (HARINAGAR SLIDE AREA)
N
CONSTRUCTION OF ALTERNATIVE C.C. PATH BY IRRIGATION DEPT
HALDWANI ROAD
REPAIR OF EXISTING DRAIN
KRISHNAPUR ROAD
Re-Alignment of Drain
RAIN WATER FLOWING THROUGH EXISTING LINED DRAIN
BARRIER
G.I.C. ground
DAMAZED ROAD AND DRAIN BY LAND SLIDE
HARINAGAR SLIDE
PUCCA LINED NALA No. 5A
DEAD DRAING ARROUND THE G.I.C. GROUND OPENING DIRECT IN ACTIVE SLIDE
OUT LET CHANNEL OF NAINI LAKE
PUCCA DRAIN
LINED MINOR DRAINS
LINED DRAIN (BELOW BHOWALI ROAD
WATER STREAM OZZING OUT BETWEEN SLIDE
FALL No 22
EXISTING LINED MINOR DRAIN
NATURAL BED OF BALJANALA FROM FALL No. 22
TOE
KAILAKHAN SLOPE
REPAIR And Re-ALIGNMENT OF DRAIN
EXISTING DRAIN/ WATER STREAM
SLIDING ZONE
DEAD DRAIN
[NOT TO SCALE]
IRRIGATION DIVISION NAINITAL
(JE/AAE)
(S.E.)
(A.E.)
(C.E.)
(E.E.)

अमर उजाला my city हल्द्वानी-नैनीताल

भूस्खलन संभावित क्षेत्रों पर लगाए लाल निशान

विशेषज्ञों की मौजूदगी में निरीक्षण को बलियानाला क्षेत्र पहुंचे अफसर, बलियानाला के ट्रीटमेंट के लिए जायका ने तीन विकल्प दिए

माई सिटी रिपोर्टर

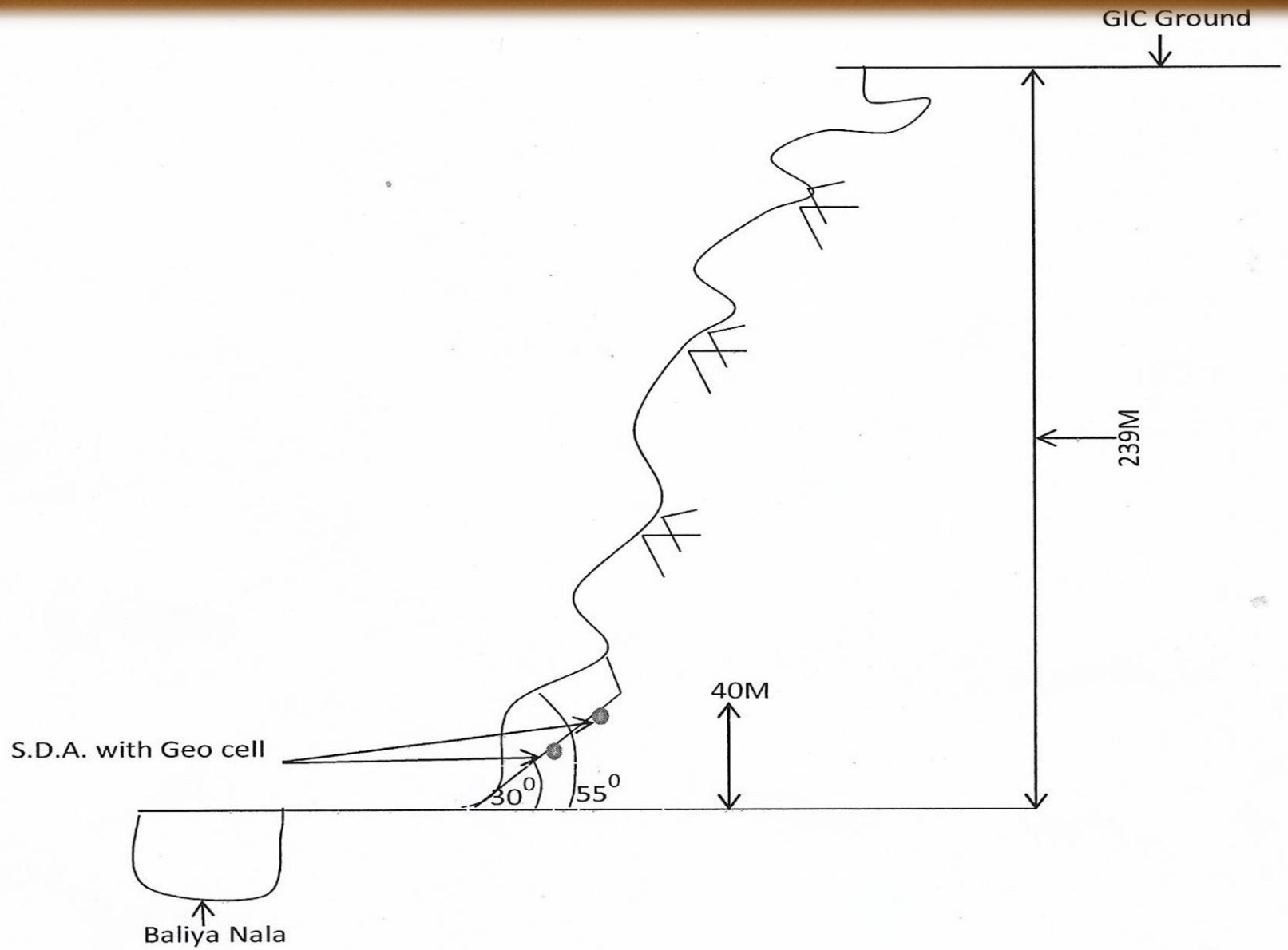
नैनीताल। आपदा प्रबंधन प्रकोष्ठ के अधिशासी निदेशक समेत भू वैज्ञानिकों और स्लोप स्टेबलाइजेशन एक्सपर्ट की टीम ने बुधवार को बलियानाला क्षेत्र में भू-स्खलन रोकने के लिए किए जा रहे कार्यों का स्थलीय निरीक्षण किया। इस दौरान सर्वे रिपोर्ट और डाटा प्रजेंटेशन के बाद टीम ने भू-स्खलन के प्रति संवेदनशील स्थानों पर लाल निशान लगाए।

पिछले दिनों इसरो की टीम ने बलियानाला क्षेत्र का सर्वे कर रिपोर्ट जिला प्रशासन को सौंपी थी। इसके बाद शासन ने हाई पावर कमेटी का गठन किया। बुधवार को कमेटी में शामिल आपदा प्रबंधन प्रकोष्ठ के अधिशासी निदेशक पीयूष रौतेला ने भू वैज्ञानिकों और अधिकारियों के साथ पहले प्रशासन अकादमी में सर्वे रिपोर्ट पर प्रेजेंटेशन डाटा प्रजेंटेशन देखा और फिर बाद में बलियानाला की टीम के सदस्यों ने एडीएम प्रशासन जगदीश और भू-वैज्ञानिक आचार्य लू. सुशील खंडूरी, जेकटेल, स्लोप स्टेबलाइजेशन एक्सपर्ट डॉ. मनीष सेमवाल आदि ने प्रभावित क्षेत्र का निरीक्षण किया। टीम ने प्रभावित क्षेत्रों के प्रस्तावित ट्रीटमेंट के लिए लाल पेंट से अस्थायी निशान भी लगाए। आपदा प्रबंधन प्रकोष्ठ के अधिशासी निदेशक पीयूष रौतेला ने बताया कि बलियानाला के ट्रीटमेंट के लिए जायका ने तीन विकल्प दिए हैं।

इनमें जीआईसी का आधा मैदान, जीआईसी का पूरा मैदान और जीआईसी स्कूल भवन शामिल है। इन तीन विकल्पों में से किस विकल्प पर भू-स्खलन रोकने संबंधी कार्य प्रभावी तरीके से कराया जा सकता है, इसे देखने के लिए यह निरीक्षण किया है। एसडीएम विनोद कुमार ने बताया कि तीन विकल्पों का स्थलीय निरीक्षण कर लिया है। अब हाई पावर कमेटी इस संबंध में शासन को रिपोर्ट भेजेगी। उसके बाद काम शुरू कराया जाएगा। निरीक्षण के दौरान जायका प्रतिनिधि दीपक भट्ट, अमन रायजादा, सिंचाई विभाग के अधीक्षण अभियंता एनएस चतियाल, ईई हरीश चंद्र सिंह आदि रहे।

बलियानाला क्षेत्र का निरीक्षण करती अधिकारियों की टीम।

बलियानाले की जद में आ रहे मकानों पर लाल निशान लगाकर चिन्हित करती टीम।

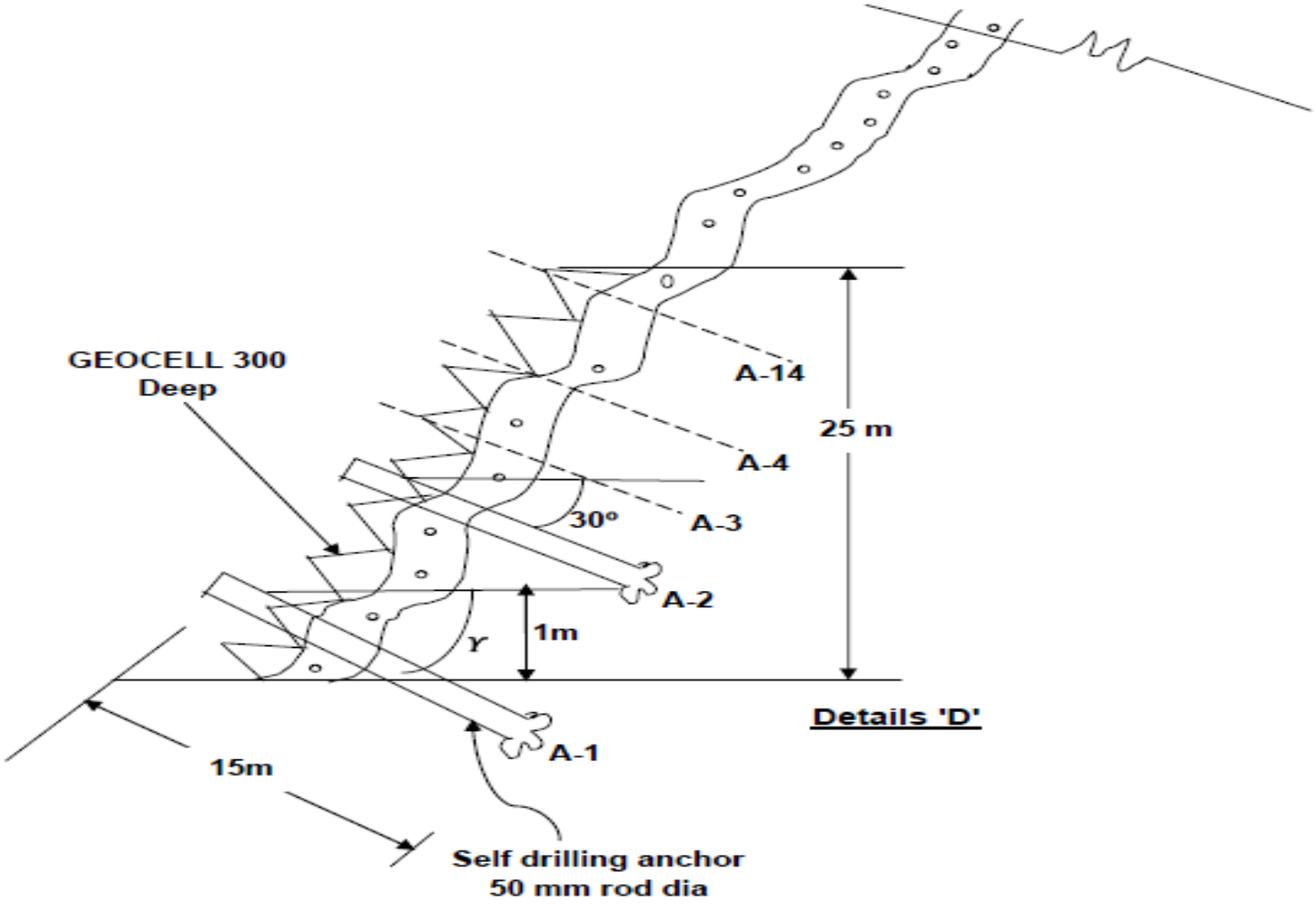


Short Term Measure Work At Baliya Nala Nainital for Stablization of Slope

Notes :-

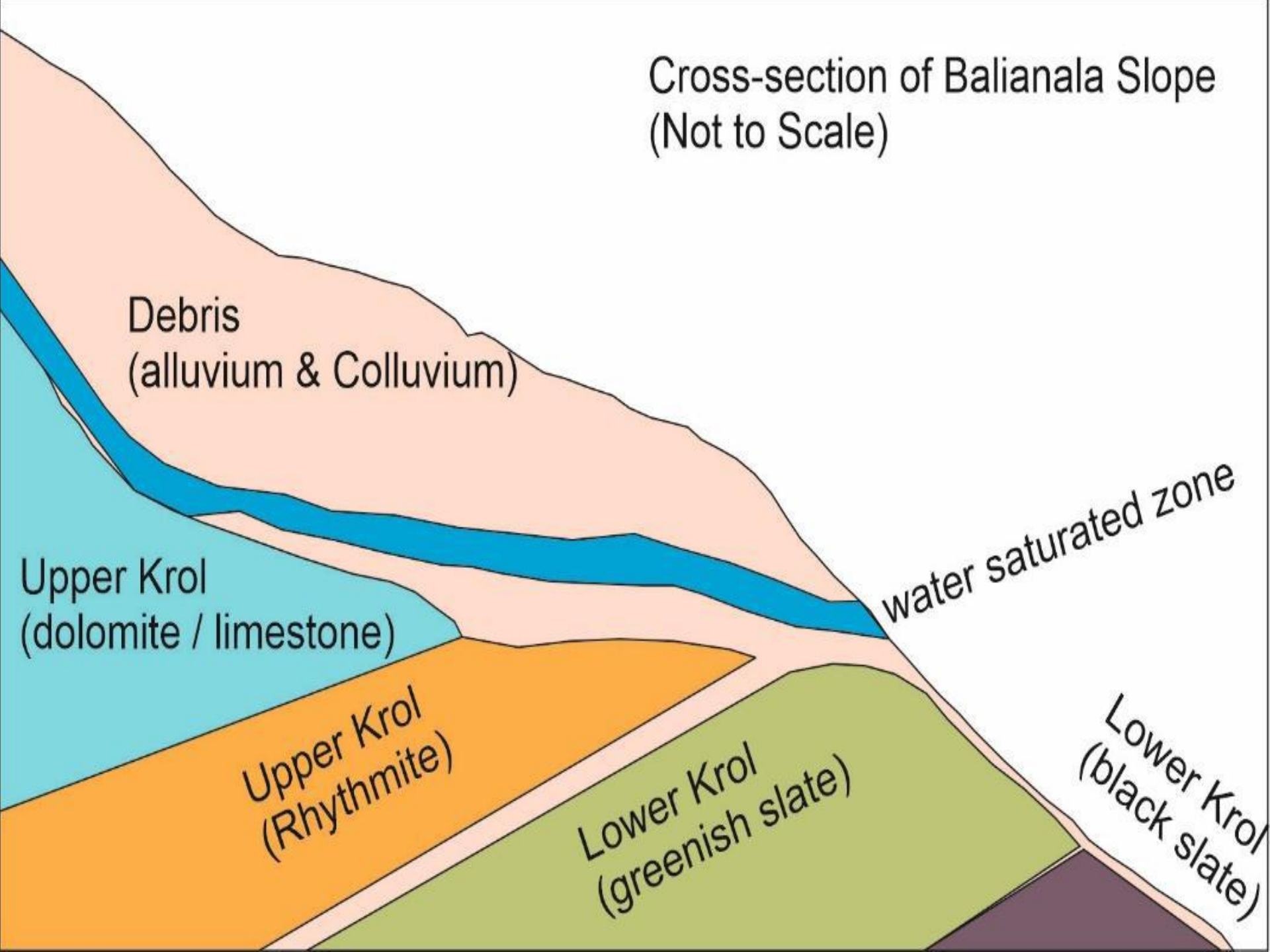
1) Geocell (STRATA make) 300 mm deep shall be provided from NGL (River bed level) to 25 m height only. It shall not be filled with any material.
2) Self drilling anchors shall be provided as follows :

Anchor	Length (m)	γ	Vert. spacing (m)	Horiz. spacing (m)
A-1	15	As per site penetrating into bed	1m from bed level	2
A-2 to A-13	15	30°	2	2



Details 'D'


JCB
JCB
UltraTech
Ambuja Cement
SHREE CEMENT


Cross-section of Balianala Slope
(Not to Scale)
Debris
(alluvium & Colluvium)
Upper Krol
(dolomite / limestone)
water saturated zone
Upper Krol
(Rhythmite)
Lower Krol
(greenish slate)
Lower Krol
(black slate)

Conclusion of Geophysical Investigation

The water saturated zone is occurring as a sheet like body with an aerial extension of about 200 m from GIC school ground and Sepaidhara, where the water is being tapped. Therefore, it is required to tap the water near GIC School ground as well which will also help in mitigating the landslide as well as will be helpful in supply of water to lower reaches and will also reduce the load from drawing water from the Naini lake.

Long Term Measures

- Deep seated anchors (with tendens) be provided – to be designed as per site slopes, soil properties, rock strength etc.
- Self-drilling anchors, long enough to penetrate the failure plane (slip circle) be provided. But during this process, surficial erosion shall also be arrested by guiniting and shotcreting.
- Deep Hydro seeding and provision of bio remedial measures be done. A suggestive list of grasses, shrubs and trees, suitable for the area has been given above, however it is time consuming.
- Gabion walls, starting from bed of nalla may be constructed but with inclusion of deep anchors through them.
- Extensive planning of drainage system to avoid water including storm water into the slope mass.
- Micro piling.

In addition to above, measures suggested by Rautela et al. (2011) as detailed under scientific research updates on landslides in Nainital area may also be considered.

Long term measure

As per proceeding of HPC for the meeting held on 29-05-2020, JICA has submitted 3 plan for restoration of Balianala site.

Plan 01, 01 house needs to be shifted from the site & it costs about 235 crores.

Plan 02 requires shifting of 85 houses and costs about 215 crores.

Plan 03, 148 houses need to be shifted & costs about 165 crores.

JICA mention that following work are required to be done in execution of plan.

Top scarp Area- Crib or terracing work (Only difference is Crib work in plan 1,2, &3)

Main Slope area- Slope trimming work with Erosion Controlling mats followed by hydro seeding (Same in plan 1,2, &3)

Channel – Channel will be made in b/w the erosion control mat area and will originate from the two water sources on the two Balianala slides. This will discharge the overflowing water from subsurface properly. (Same in plan 1,2, &3)

Grounsills - Gabion structure will be constructed. (Same in plan 1,2, &3)

Check dam- Two check dams will be constructed to minimize the debris runoff on the steam

Kedarnath temple and surrounding area after the disaster of June 2013

Kedarnath temple and surrounding area after the disaster of June 2013


BEFORE
AFTER

Causes of Floods

Inadequate capacity of the rivers to contain within their banks the high flows brought down from the upper catchment areas following heavy rainfall, leads to flooding. The tendency to occupy the flood plains has been a serious concern over the years. Because of the varying rainfall distribution, many a time, areas which are not traditionally prone to floods also experience severe inundation. Areas with poor drainage facilities get flooded by accumulation of water from heavy rainfall. Excess irrigation water applied to command areas and increase in ground water levels due to seepage from canals and irrigated fields also are factors that accentuate the problem of water-logging. The problem is exacerbated by factors such as silting of the riverbeds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river courses, obstructions to flow due to landslides, synchronization of floods in the main and tributary rivers and retardation due to tidal effects.

There was a catastrophe in Mandakini valley on 16th & 17th June 2013 due to bursting of Chorbari Lake which was situated at an elevation of approximately 3746 m above mean sea level upstream of Sri Kedarnath temple, one of the holiest Char Dham of Uttarakhand, the total area of the Chorbari Lake is 25450 Sq.m. This catastrophe occurred during the very heavy rainfall between 14th June to 18th June 2013 in the catchment area of Mandakini River in District Rudraprayag (The rain fall recorded at Tharali & Jakholi Tehsil Headquarters of the Rudraprayag district was 326 mm & 390 mm respectively. Due to this intense rainfall, the runoff exceeded the storage capacity of Chorbari Lake due to narrow outlet of the Lake, also this very heavy downpour washed away the debris on the hillslopes deposited by the moving glaciers. The runoff due to very heavy rainfall along with the water released due to the bursting of the Chorbari Lake created havoc in the Mandakini Valley, wherein there was a very loss of human life, the pilgrims on way and returning from the divine Shri Kedarnath Dham and also to the properties in the valley. There was an abnormal flow in the Mandakini River due to unprecedented rainfall as well as the very heavy flow of debris washed from the steep mountain slopes. Also, there were innumerable landslides all along the valley at various locations, resulting in the disruption of traffic. The unprecedented flow in the Mandakini river caused heavy erosion along the banks of the river. A lot of debris were deposited in the river bed, at some places, the depth of deposition was even upto 5-8 meters, which further aggravated the situation, wherein even the habitations on the high bank were also eroded. All along the river course of Manadakini River, habitations e.g. Rambara, Gaurikund, Sonprayag, Sitapur, Guptkashi, Kund, Bedubagar, Tilwara etc, were either completely washed away or suffered moderate to severe damages. The right bank of Mandakini River between its confluence to Songanga upto downstream of Sitapur town was severally damaged due to narrow gorge of the river downstream of Sitapur town. The parking ground and house situated approximately 10-15 meter above the river bed was eroded due to rise in the water level of the river in this river stretch.


DEEPAK LODGE

Measures for flood management and erosion control Different measures have been adopted to reduce the flood/erosion losses and protect the flood plains. Depending upon manner in which they work, flood protection and flood management measures may be broadly classified as under.

Non-structural measures

The non-structural methods to mitigate the flood damages are as under:

- Flood Plain Zoning;
- Flood Forecasting, Flood Warning and evacuation of the people;
- Flood Proofing; and
- Living with Floods.

Govt. of India has given model draft for flood plan zoning but unfortunately after lapse of about more than four decade most of the state govt. has not implemented it in true sprite.

Structural measures

The structural measures for flood management/erosion control (may further be classified into long term measures and short term measures) which bring relief to the flood prone areas by managing the flood flows and thereby the flood levels are:

- Creation of reservoir;
- Diversion of a part of the peak flow to another river or basin where such diversion would not cause sizeable damages;
- Construction of flood embankments;
- Channel improvement;
- Watershed management;
- Construction of spurs, groynes, studs etc.;
- Construction of bank revetment along with launching apron;
- RCC porcupines in the form of screens, spurs, dampeners etc.; and
- Vetivers, geo-cells, geo-bags etc.

Flood damages in India

As per record available damage due to flood in India during 1953-2010 are as follow.

Flood damages in India during 1953-2010.

S. No	Item	Unit	Average Annual Damage	Maximum Damage	
				Extent	Year
1	Area affected	M ha	7.06	17.50	1978
2	Population affected	million	36.86	70.45	1978
3	Human lives lost	nos.	1611	11316	1977
4	Cattle lost	nos.	93202	618248	1979
5	Cropped area affected	M ha.	3.46	10.15	1988
6	Damage to crops	Rs crore	703	4247	2000
7	House damaged	nos.	1193877	3507542	1978
8	Damage to house	Rs crore	276	1308	1995
9	Damage to public utilities	Rs crore	828	5605	2001

Planning & Design of River Embankment

GFCC Guide lines has recommends that the embankments shall be designed as per the provisions of IS 12094-2000. This standard covers planning and design of river embankments (levees) on dry land. The salient features/main design aspects covered in this code are described in the following paragraphs:-

Design High Flood Level

Protection of agriculture land- 25 year flood frequency.
Protection of township, Industrial area- 100 year flood frequency

Free Board

1.5 meters over design HFL (for Q<3000 Cumecs)
1.8 m over design HFL (for Q≥ 3000 Cumecs)

Planning & Design of Groynes/Spur (IS 8408-1994)

This standard covers the planning and design of Groynes (Spurs) in alluvial rivers.

Design discharge: should be equal to that for which any structure in close proximity is designed or 50 year flood whichever is higher.

Length of spur:- Normally effective length should not exceed 1/5th of width of flow. Spacing of spur is normally 2 to 2.5 times the effective length.

Top level:- Depends on the type namely submerged, partially submerged and non-submerged and will be best decided by model experiment.

Flood discharge:- It may be worked out from Dickens formula.

$Q = C \times A^{3/4}$

Where, Q = Estimated peak flood in m3/sec ,

A = Catchments sq km

Value of 'C'= (12-14 for Hilly area, 11-14 for North Indian region

The silt factor $f = 1.76 (D50)^{1/2}$

Scour Depth - "D'= $0.473(Q/f)^{1/3}$

where, D = the depth of scour below HFL,

Q = discharge in Cumec,

f = silt factor

Lacey's Waterway (IS Code 6966- Part-I, Clause 10.2): Lacey's Waterway = $4.89 Q^{1/2}$

Computation of velocity of flow

$Q = A \times V$

Spurs may be aligned either normal to flow direction or at angle pointing towards u/s or d/s of the flow. A spur pointing u/s of the flow repels the flow away from the bank and is known as repelling type spur/groyne. When a short length spur changes only direction of flow without repelling, it is known as deflecting spur/groyne. Spur pointing d/s of the flow attracts the flow towards the bank and is known as attracting spur/groyne. Generally repelling type or deflecting spurs are provided for anti- erosion measures. Repelling type spurs may be kept at an angle of 5 to 10 degree against the direction of flow.

Checking for destabilizing forces e.g. hydrodynamics drag & Lift-

As per IS code 14262 (Planning and Design of Revetment- Guide Lines), Stone used in revetment for river bank protection is subjected to hydrodynamic drag and lift forces. Weight of the stone on horizontal bed may be expressed as:

$W = 0.02323 \times Ss \times V^6 / (Ss - 1)^2$

Where, W = weight of stone in kg,

Ss = specific gravity of stone,

V = mean velocity of water in m/s

Computation of 'discharge for non-uniform and composite cross-sections (As per IS Code 2912- Liquid Flow Measurement In Open Channels - Slope-Area Method

The discharge of a stream in a particular reach shall be calculated from the formula (Para 10 of the IS Code)

$Q = K \times S^{1/2}$

$K = 1/n \times (A \times R^{2/3})$,

Where:- Q is the discharge in Cumec,

S is the friction slope in m/Km, and,

n = Manning's Coefficient of Rugosity

Design of launching aprons

As per IS 8408 Clause 5.9.2, the S code, directs that the scour depth at the nose of spur is to be designed for a maximum scour depth of 2.0 to 2.5 times the normal scour depth.

Thickness of protection works

The slope of launched apron is to be taken as 1.5 H: 1V as per the provision in IS Code 10751 (Planning and Design of Guide Banks For Alluvial Rivers).

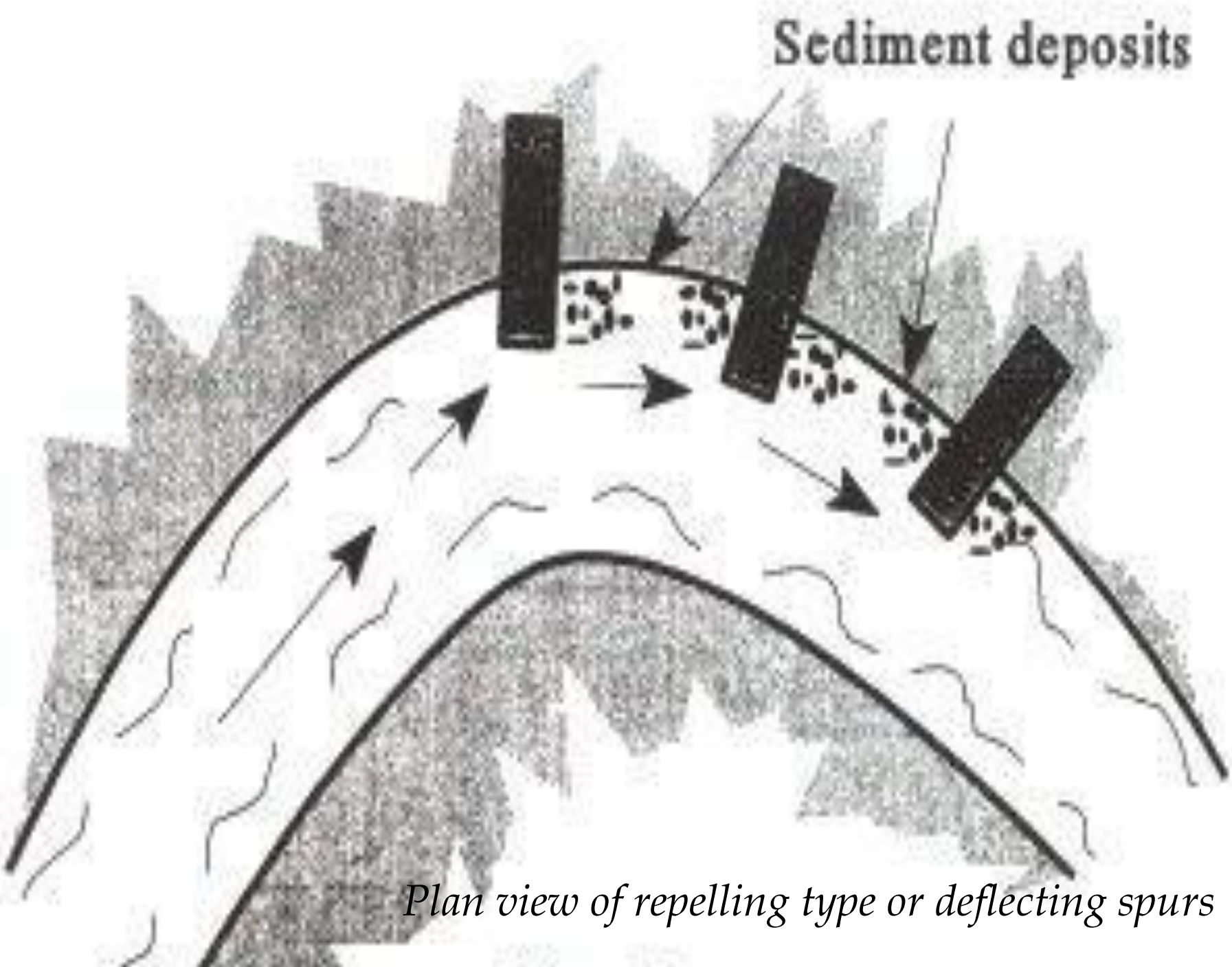
Channelization of Rivers

Some of the States are proposing channelization of rivers, at least in certain reaches, in the context of tackling the extensive meandering problems of the rivers, activating navigational channels and training these rivers into their original courses. While venturing to channelize rivers, thought must be given in allowing the river certain freedom to flow and right of way to pass its flood waters and silt load within its natural waterway. *The dynamic nature of the rivers should be appreciated and preventive measures planned accordingly instead of pinning down the river by channelizing.*

Channel Improvement

The method of improving the channel by improving the hydraulic conditions of the river channels by desilting, dredging, lining etc., to enable the river to carry its discharges at lower levels or within its banks has been often advocated but adopted on a very limited extent because of its high cost and other problems.

Dredging operations of the Brahmaputra, which were undertaken in the early seventies on an experimental basis, were discontinued because of their prohibitive cost and limited benefits. Dredging in selected locations may perhaps be considered as a component of a package of measures for channel improvement to check the river bank erosion subject to techno-economic justification. It may be economically justifiable as a method for channel improvement where navigation is involved. Dredging is sometimes advocated for clearing river mouth or narrow constrictions.



Plan view of repelling type or deflecting spurs


2014


A-15

F.P.W OF VIJAYNAGAR MARKET

F.P.W OF VIJAYNAGAR MARKET

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F.P.W OF BEDUBAGAD

FPW AT KALIMATH IN KALIGANGA RIVER

FPW IN OMKARESHWER

FPW IN BEDULA

Dredging work in Jhelum River after Kashmir flood.

Channelization work of Jhelum river, the river section is being widened and slope is proposal to be steeped from very mild to enhance the discharge carrying capacity of the river, as to avoid the submergence of city population. This can be achieved as the river slope beyond the outfall channel is steeper than that of the Jhelum river in Srinagar city, while as in case of Mandankini river, it is not so & these is every possibility for scouring of bank, movement of debris & dredged bed may be silted in the very first rains/flood so intensive anti-erosion/bank protection works has been executed in Mandakini valley as an protection measure.

Hence it may be stated that various measures may be adopted as per situation which may be different for different locations & it will be decided by the expert of the field.

- Intensive anti-erosion/bank protection works has been executed to protect the area in Mandakini valley.
- Channel improvement work in Jhelum River as an immediate measure.
- Anti-erosion/Bank protection work in Balianala along with channelization of drainage system & various other measure for slope protection work on the slope of Balianala.

THANK YOU