Geological observations on the devastation around Srinagar in Pauri Garhwal district of Uttarakhand on the aftermath of June 2013 floods

A Preliminary Report

Disaster Mitigation and Management Centre
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Uttarakhand Secretariat, Rajpur Road
Dehradun – 248 001
Uttarakhand, India

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Preface

The floods at the very onset of monsoon in the year 2013 devastated the entire state of Uttarakhand. Large number of pilgrims and others having been stranded at various paces en route to the holy Hindu shrine, Kedarnath in Mandakini valley, it naturally remained at the centre of the media attention but then other areas of the state were equally hit hard. Heavy rains in the higher reaches at the onset of monsoon pushed the levels of most rivers to their recorded best and the fast flowing water along the course of most rivers devastated areas close to their bank.

Srinagar located on Rishikesh – Badrinath National Highway on the left bank of Alaknanda river was amongst many towns and habitations that were adversely affected by the floods of June 2013. On the aftermath of the floods field investigations were carried out in the area by Sushil Khanduri and Ashish Rawat in the month of August, 2013. This report is the compilation of the observations made by them team and the suggestions made are preliminary.

Thanks are owed to the district administration for logistics support and colleagues at DMMC are thanked for support and cooperation.

18 January, 2014
DMMC Dehradun

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Introduction

Atkinson (1886) describes the grandeur as also disaster vulnerability of Srinagar town that is located in a wide valley of Alaknanda river. As against the present population of 20,115 (Census of India, 2011), the population of the town is reported by Atkinson (1886) to be 1,835 in 1858, 1,951 in 1865, 2,040 in 1872 and 2,100 in 1881. It is reported that in 1821 the town had 562 houses of which 438 were occupied by Hindus and 28 by Muslims.

Atkinson (1886) has however also reported that the population of Srinagar, that was once the residence of Rajas of Garhwal was much more than at that time. He reports that before the British rule large portion of the town was devastated by floods. Earthquake of 1803 reportedly ravaged the town and in 1808 during Raper's visit to the area only one fifth of the houses were occupied and the rest were in ruins. Even during Mooreroft's visit in 1819 the town had not recovered from the impact of 1803 earthquake and inundation and was occupied by a few manufacturers of coarse linens and woolens. The town as reported by Atkinson (1886) was not a flourishing one and its decay was hastened by shifting of Raja's residence to Tehri and the damage done almost every year by the river and the same, he reports, has the potential of completely destroying the town.

Srinagar, a major city of Pauri Garhwal district, lies in Survey of India toposheet number 53 J/16 and can be approached by Rishikesh – Badrinath national highway (NH 58). Nearest airport is at a distance of 127 kilometers at Jolly Grant while the nearest rail head is 106 kilometers away at Rishikesh. There is also an airstrip at Gauchar that is at a distance of 60 kilometers.

Broad riverine valley with massive flat terraces, abundance of water and unlike the district headquarter being located on the national Highway provided basic ingredients for growth and expansion of Srinagar town and defying the assumption of Atkinson (1886) it became one of the most populous towns of the region. Growth of the town even defied barrier put forth by nature in the form of Alaknanda river as also that by administration; right bank of Alaknanda being in Tehri Garhwal district. The main campus of HNB Garhwal University is located across the river at Chauras.

During the monsoon of 2013 entire state of Uttarakhand received unusually high rainfall and most rivers crossed the danger levels with the onset of monsoon rains in mid – June. Though devastation was massive and all through the state, habitations close to the river banks were hit particularly hard. As if the warning of Atkinson (1886) had come true Srinagar was devastated by floods and ensuing bank erosion. Huge damage was incurred to structures, particularly on the left bank of Alaknanda.

The area around the Srinagar town (Fig. 1) was investigated after the disaster between 27th and 30th August 2013 and traverses were taken around affected sites to examine the geological setup and to investigate the damaged areas for mitigation measures.

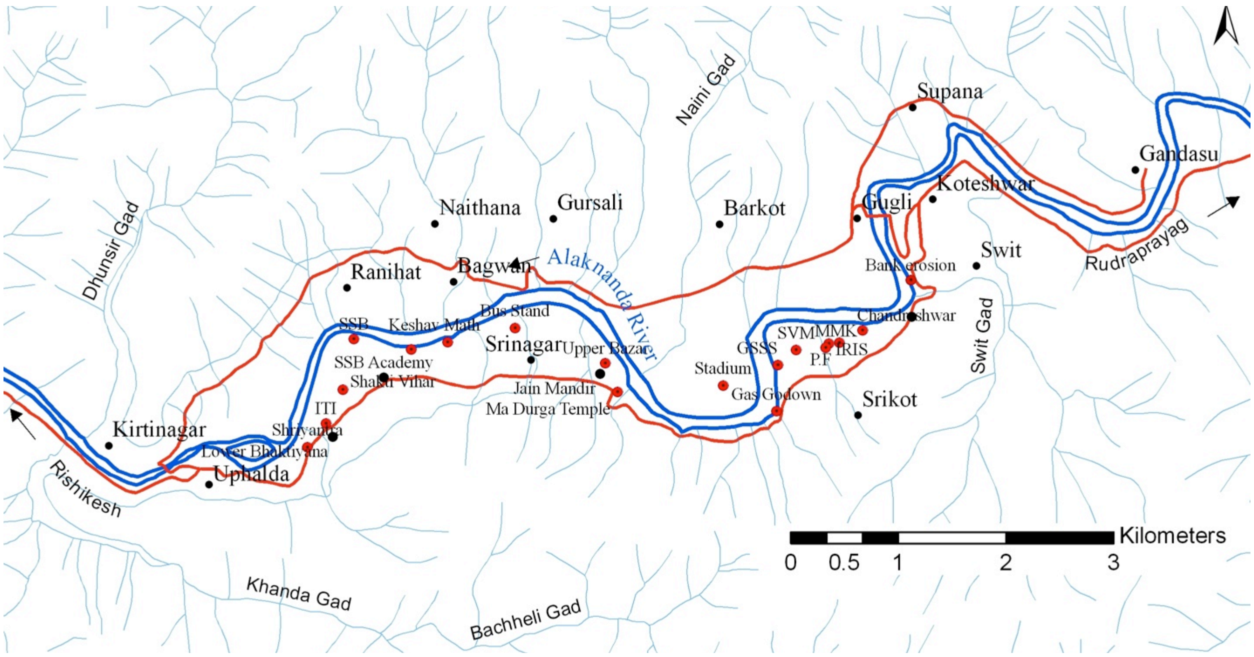

Fig. 1. Location map of the investigated area.

Most buildings in the town were observed to be newly constructed in close proximity of Alaknanda river. Slope stability analysis and monitoring thus becomes important for stability assessment for long term safety of infrastructures as well as river banks. Objective of the present investigations was to focus attention on disaster affected areas and gather data needed for geotechnical/civil planning and for designing of engineering structures and remedial measures.

Geomorphology and Physiography

The area under present investigation lies in the middle-lower part of Alaknanda valley that exhibits characteristically distinct rugged mountainous topography of the Lesser Himalayan terrain and is occupied by rocks of Garhwal Group. The valley slopes in the area are largely controlled by lithology and the same have been modified by structural configuration of the rocks. The rocks exposed in the area are characterized by continuous and steep joints / shears and foliation planes. These features are observed to control rocky and precipitous valley slopes at many places.

The ground elevations in the study area generally vary from about 550 meters to 600 meters above mean sea level (msl). Mountain peaks as high as 1,000 meters in altitude are however also present in the surroundings. The hill slopes in the area are generally observed to comprise of rocky outcrops, rocky cliffs and mantle of colluviums.

Six generations of aggradational fluvial terraces on either side of the Alaknanda river are observed to be carved on phyllites around Srinagar. These terraces are developed on either bank of the Alaknanda river. Fluvial terraces represent former valley floors and flood plains that were abandoned with time. Terrace sequence between Koteshwar and Kirtinagar shows convergent relationship, indicating deposition along the meander loop. The terrace sediments are poorly sorted and dominated by boulders and pebbles with subordinate sand. Each terrace is separated by a scarp that varies between 5m for the youngest to 45 m for the oldest terrace and width varies from a few meters to hundreds of meters. The terraces are best developed in areas between Swit and Chauras, and Srinagar and Uphalda. Gentle undulating slopes that are covered with ancient and recent landslide debris dominate the valley around Srinagar.

The Alaknanda river enters into the basin through a gorge near Koteshwar. After flowing 500 m towards south, takes a westward course around Srinagar and flows as a braid, meandering river with the development of the channel bars. The abrupt change in river course is attributed to the activation of thrust/fault.

The morphology of the Alaknanda river upstream of Kirtinagar and near Uphalda led to increasing sinuosity and deposition upstream. The valley morphology and confinement of the terraces along the meanders suggest their formation during phases of landscape stability.

Climate and vegetation

The climate of the area is sub-tropical (mean annual rainfall between 1000 and 1500 mm) with 80% of the rainfall occurring between mid-June to mid-September. This is also the period during which the Alaknanda carries maximum suspended load contributed both by the glacier melt and south west monsoon precipitation. The vegetation is dominated by *Pinus roxhburghi* (1400 – 700 m from msl), *Dalbergia sissoo* and *Acacia Spp*. (700 m) and its distribution is governed by the altitude and slope aspect.

General geology, structure and tectonics

Srinagar city is located in Lesser Himalayas in Pauri–Garhwal, Uttarakhand, India. In the perspective of regional thrust in the Himalayas, to the north of the study area is Main Central Thrust (MCT) and to the south of the study area is Main Boundary Thrust (MBT). The rock types exposed in the area are observed to belong to Srinagar phyllite, Kilkaleshwar metavolcanics, Sumari quartzite (Chandpur Group), Marora limestone, Garhwal slate and Koteshwar quartzite along with Chamdhar metabasics. The Srinagar phyllite is observed to be thrust over Koteshwar quartzite, Garhwal slate and Marora limestone along North Almora Thrust (NAT).

Lithologically, the area is observed to be dominated by phyllites that merge with the flaggy quartzites towards north. The phyllites are observed to be intercalated with metabasics that are tightly folded and fractured. Contact between the phyllites and flaggy quartzites is marked by southerly dipping North Almora Thrust (NAT), that is characterized by a wide shear zone around Srinagar. NAT is observed to show vertical or even north dipping attitude at some places.

The major structural features observed in the area include NAT, SAT, Koteshwar Fault, the Barkot Fault, and vertical folds, mainly observed near the intersection of river Alaknanda and Koteshwar fault on right bank of river Alaknanda. In general, the NAT dips at 40° to 50° (moderately steep) towards southwest but at places it is 75° to 80° (very steep) towards southwest due to folding of the thrust plane. The SAT in southern part of the area dips 50° towards north. The Koteshwar and the Barkot faults are vertical-to-subvertical and are transverse in nature.

Geological observations around Srinagar

1. Chauras stadium

Chauras stadium is situated at right bank of Alaknanda river on river borne material terrace and connected by Ghasiya Mahadev two wheeler bridge (Chauras bridge).

Geological set up of the area: The area is observed to be largely occupied by overburden material. A rock exposure is observed at the base of the stadium area on the right bank of Alaknanda river. The exposures along the river bed around Chauras bridge are observed to be that of Lesser Himalayan phyllites. The general trend of these rocks is observed to be E -W with moderately steep to steep dips towards south.

Structural discontinuities: The rocks exposed around the area are observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of rock mass and stability of slopes. The Lesser Himalayan rocks exposed in the area are generally observed to strike E - W and dip towards south at angles varying between 45° to 50°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 1.

Table 1: Details of the joint pattern observed in the field.

Joint Set	Dip amount	Dip direction	Strike trend	Remark
I	45° - 50°	180°	90° - 270°	Foliation
II	35° - 70°	310° - 00°	50° - 230° to 90° - 270°	Prominent joint
III	30° - 40°	70° - 90°	20° - 200° to 00° - 180°	Prominent joint

Reconnaissance geological-geotechnical assessment: The area around the stadium was observed to have thick overburden and its thickness is assessed to be up to 18 meters. This overburden material is observed to comprise of river borne material that consists of reddish brown to grayish brown, medium grained sandy matrix with rounded boulders.

The stadium is observed to be severely damaged by bank erosion by Alaknanda river. In this area the river directly hits the base of the Stadium resulting in continuous undercutting and erosion of the same.

Chauras stadium was eroded by about 07 meters due to bank erosion by flood waters (Fig. 2). Just outside of the stadium approximately 30 meters stretch of road connecting Srinagar to Chauras was completely washed off (Fig. 3).

Fig. 2. Photograph showing severely damaged Chauras stadium due to bank erosion by Alaknanda river.

Fig. 3. Photograph depicting completely damaged road outside the stadium.

Mitigation measures: Appropriately designed and anchored concrete curtain wall may be considered for safe execution at this sensitive location. This would help in protecting the affected site as well as bank of Alaknanda river from stream erosion.

2. Chauras bridge to Agency Mohalla area along the river bed

Phyllites are observed to be exposed from Chauras bridge to Ma Durga Mandir (Ganga Ghat) in Upper Bazar area on the left bank of Alaknada river. The rock outcrops in this stretch protect the river bank as also the upslope area. So, at present there is no need of any structural / non – structural intervention for protection of river bank in this stretch (Figs. 4 and 5).

 

Figs. 4 and 5. View of the area from Chauras bridge to Agency Mohalla with phyllites exposed on the left bank of Alaknanda river.

3. Ma Durga Mandir (Ganga Ghat), Upper Bazar

Ma Durga Mandir (Ganga Ghat), Upper Bazar is situated on the left bank of Alaknanda river, just below Agency Mohalla.

Geological set up of the area: The area is observed to be occupied by rocks as well as overburden. Rocky outcrops are exposed along the footpath and river bank, both upstream and downstream of the temple. Phyllites of Garhwal Group are observed to be exposed around this area. The rocks are largely observed to be moderately weathered but at places highly weathered rocks were also encountered. These are observed to be moderately jointed, thinly foliated and dip towards south at moderate angles.

Structural discontinuities: The rocks exposed around the area are observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of rock mass and stability of slopes. The rocks of Garhwal Group exposed in the area are generally observed to strike E - W and dip towards south at angles 35°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are given in Table 2.

Table 2: Details of the joint pattern observed in the field.

Joint Set	Dip amount	Dip direction	Strike trend	Remark
I	35°	180°	90° - 270°	Foliation
II	50°	00°	90° - 270°	Prominent joint
III	75°	075°	165° - 345°	Prominent joint

Reconnaissance geological-geotechnical assessment: Ma Durga Mandir was reportedly filled with silt and sand brought by the flood waters of Alaknanda river. At the time of the field investigations silt and sand material had been safely removed from the temple and nearby area. Ma Durga Mandir is observed to be safe and no damages were recorded (Fig. 6).

Ganga Ghat area and the pathway are also observed to be partially damaged by flood waters (Fig. 7).

Fig. 6. Photograph depicting the situation around Ma Durga Mandir.

Fig. 7. Photograph showing partially damaged Ganga Ghat area and the pathway.

Mitigation measures: Damaged structures at Ganga Ghat area are required to be repaired with suitable design and deep foundation.

4. Upper Bazar below Jain Mandir area

Upper Bazar, below the Jain Mandir area, is situated on the left bank of Alaknanda river and downstream of Ma Durga Mandir (Ganga Ghat).

Geological set up of the area: Outcrops of phyllites of Garhwal Group are exposed in this area along the footpath as also along the river bed. These are observed to be moderately weathered.

Structural discontinuities: The rocks exposed around the area are observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of the rock mass and stability of slopes. The Garhwal Group rocks exposed in the area are generally observed to strike NE - SW and dip towards southeast at angles 60°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 3.

Table 3: Details of the joint pattern observed in the field.

Joint Set	Dip amount	Dip direction	Strike trend	Remark
I	60°	170°	80° - 260°	Foliation
II	82°	310°	40° - 220°	Prominent joint
III	45°	080°	100° - 280°	Prominent joint

Reconnaissance geological-geotechnical assessment: Downstream of Ma Durga Mandir area phyllites are exposed around Jain Mandir area along the footpath and at river bed. This area is already protected by rock outcrops.

Seepage is also observed at this location in flowing condition from rock discontinuities below the habitation. Thereafter river born material is observed.

Around Jain Mandir area the river bank is observed to be protected by retaining structures and oblique RCC cubs/blocks that are observed to be tilted and partially damaged at some places (Fig. 8).

Fig. 8. Photograph depicting tilted and partially damaged retaining structures and RCC cubs / slabs near the river bed.

Mitigation measures: It is advised that repair of tilted and damaged retaining wall and oblique RCC cubs/slabs be undertaken by filling core stone and concrete where ever required.

5. New Bus Stand area

New Bus stand is located to the downstream of Kansverdhani Mandir area on the left bank of Alaknanda river.

Geological set up of the area: The area is observed to be occupied by overburden materialthat largely comprises of river borne material that consists of grayish, medium grained sandy matrix and rounded boulders. No rock outcrops are observed around this area.

Reconnaissance geological-geotechnical assessment: It is reported that the houses, Rainbasera, cremation shed, temple, Police Station and other structures around New Bus Stand were filled by silt and sand materials due to the high floods during monsoon (Fig. 9). From indoors of the buildings silt, sand and other materials are observed to have been removed. No major structural damage is observed in this area.

River side retaining wall near the Bus Stand is observed to be tilted due to high flood water during monsoons (Fig. 10).

Fig. 9. View of houses and other infrastructures overwhelmed by silt and sand due to flood waters near New Bus Stand area.

Fig. 10. View of tilted retaining structure near New Bus Stand on the left bank of river Alaknanda.

Mitigation measures: It is advised that repair/reconstruction of river side tilted retaining structures be undertaken for ensuring safety of the Bus Stand as also the river bank.

6. Nagraja Mohalla and Kehsav Math temple area

Nagraja Mohalla is located towards downstream of Kemleshawar area on the left bank of Alaknanda river. Kehav Math temple is located below the Kemleshwar temple area.

Geological set up of the area: The area is observed to be occupied by overburden materialthat comprises of river borne material that consists of grayish, medium grained sandy matrix with rare rounded boulders. No rock outcrops are observed at and around the area.

Reconnaissance geological-geotechnical assessment: Keshav Math temple that was constructed in close proximity of Alaknanda river is observed to be completely destroyed (Fig. 11).

Bank erosion by Alaknanda river has brought some houses in Nagraja Mohalla area to the edge of vertical cut. High risk is posed to these houses (Fig. 12).

Fig. 11. Photograph depicting completely destroyed Keshav Math temple.

Fig. 12. Photograph showing vertical cut slope and a house close to edge of vertical cut.

Mitigation measures: It is advised that construction of retaining wall/gravity wall with boulder pitching with suitably placed oblique RCC cubs/slabs as per site requirement be constructed from new Bus Stand to Nagraja Mohalla area. Area both upstream and downstream of Keshav Math temple, is required to be protected by appropriately designed RCC retaining structures with desired height.

7. Sashastra Seema Bal (SSB) area

Sashastra Seema Bal (SSB) area is located at Upper Bhakityana area just below Rishikesh – Badrinath National Highway (NH - 58) on the left bank of Alaknanda river.

Geological set up of the area: The area is observed to be occupied by rocks as well as overburden material. Phyllites of Garhwal Group are observed to be exposed on the river bed where buildings have been affected by flood waters. The rocks are largely observed to be moderately weathered but at places these are observed to be highly weathered. These are observed to be moderately jointed, thinly foliated and dip towards southeast to southwest at moderate to moderately steep angles.

Reconnaissance geological-geotechnical assessment: Sashastra Seema Bal (SSB) Academy building is observed to be severely damaged (Fig. 13).A number of tin sheds are also observed to be severely damaged and some structures are observed to be filled with silt and sand (Fig. 14). All the structures that have suffered losses are observed to be constructed close to course of Alaknanda river. At this location river has meandering course and during the high flood the flow of river was diverted towards SSB Academy that was directly hit by floodwaters.

Fig.13. Photograph depicting severely damaged SSB Academy building.

Fig.14. Photograph depicting severely damaged SSB tin shed structures that are completely filled with silt and sand brought by high floods.

Suggested measures**:** Severely damaged SSB Academy building is required to be demolished. This area should be kept free of construction activities.

Silt and sand from some of the buildings on the upslope area should be safely cleared.

8. Shakti Vihar and Industrial Training Institute (ITI) area

Shakti Vihar and Industrial Training Institute (ITI) areas are located in the downstream of Sashastra Seema Bal (SSB) Academy and just below National Highway (NH - 58) on the left bank of Alaknanda river.

Geological set up of the area: The area is observed to be largely occupied with overburden material. No outcrops are observed at and around this area. The phyllites are however observed on the river bed. These are observed to be moderately to highly jointed, thinly foliated and dip towards southwest at moderate angles.

Reconnaissance geological-geotechnical assessment: Area around Sakti Vihar some houses are observed to have suffered losses and filled with silt and sand due to floodwaters of Alaknanda river (Fig. 15).

Most buildings of the Industrial Training Institute (ITI) are observed to have suffered losses and filled with silt and sand. The silt and sand is observed to be piled up for around 2.0 to 3.0 meters (Fig. 16).

In lower Bhakityana area the flood waters even came up to the level of the National Highway (NH- 58) between ITI and Sriyantra Tapoo and water causes damages in a number of houses/structures. It is reported that this stretch of the National Highway was completely filled with silt and sand brought by the floodwaters. The same is however observed to have been cleared and opened for traffic.

Fig.15. View of double storied house in which ground floor was filled with silt and sand.

Fig. 16. Ground floor and the frontal area of the ITI building has as much as two meters thick pile of silt and sand.

Area along the river bank to the downstream of ITI (Fig. 17) and upstream of Uphalda (Fig. 18) is observed to be damaged due to the floodwaters.

Fig. 17. Photograph depicting bank erosion in the area downstream of ITI.

Fig. 18. Photograph depicting bank erosion in the area upstream of Uphalda.

Mitigation measures: Silt and sand deposited in the structures and over nearby lands is required to be cleared so that the same could be put on productive usage.

Appropriate designed retaining structures are required to be constructed along the river on the left bank to the upstream of Uphalda up to ITI. This would help in protecting the bank from further erosion.

9. Plastic Factory, IRIS school and Mahila Milan Kendra

These areas are situated downstream of Chandreshwar Mahadev temple in Dungryo Mohalla and are located on the left bank of Alaknanda river.

Geological set up of the area: Rocky outcrops are exposed around the area along theriver bed. Phyllites of Garhwal Group are observed to be exposed around this area. These are observed to be moderately weathered, thinly foliated and moderately to highly jointed. From Swit Gad to Maheshwar Mahadev temple area phyllites are exposed along the left bank and these help in maintaining the upslope as also protecting the river bank form stream erosion.

Structural discontinuities: The rocks exposed around the area are observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of rock mass and stability of slopes. The Garhwal Group rocks exposed in the area are generally observed to strike E - W and dip towards south at angles 70°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 3.

Table 3: Details of the joint pattern observed in the field.

Joint Set	Dip amount	Dip direction	Strike trend	Remark
I	70°	180°	90° - 270°	Foliation
II	40°	075°	165° - 345°	Prominent joint
III	40°	335°	065° - 245°	Prominent joint

Reconnaissance geological-geotechnical assessment: On the opposite side of Chandreshwar Mahadev temple area excavated muck was washed off due to flooding. Upstream of confluence of Swit Gad and Alaknanda river undercutting by river is also observed below the road level (Fig. 19).

Downstream of Chandreshwar Mahadev temple a Plastic Factory was severely damaged by high flood. The building is observed to be filled with silt and sand (Fig. 20).

Fig. 19. View of the dumped muck on the right bank and road (NH- 58) being undercut on the left bank of Alaknanda river.

Fig. 20. Photograph depicting severely damaged plastic recycling plant building.

Double storied building of IRIS school, located just downstream of the Plastic Factory, is observed to be completely destroyed by floodwaters (Fig. 21) together with some class rooms that have been damaged and filled with 1.5 m to 2.0 meter thick pile of silt and sand materials. Just downstream of IRIS school, Mahila Milan Kendra buildings are also observed to be damaged and filled with silt and sand (Fig. 22). All these structures were built and located in close proximity of the river and within its high flood level.

Mitigation measures: It is advised that wire crate gabion walls be constructed at the tow of muck dumping site located at river bank area. Construction of masonry retaining structures is also recommended below the National Highway along the river bank. This would protect the affected site and reduce bank erosion by the river.

Fig. 21. Photograph depicting completely destroyed IRIS school office building.

Fig. 22. Photograph depicting Mahila Milan Kendra filled with silt and sand materials.

IRIS school that falls within high flood level should however be kept free of anthropogenic activities of any kind.

10. Sarasvati Vidhya Mandir and Government Senior Secondary School area

These areas are located downstream of IRIS School in Nagraja Mohalla along the left bank of Alaknanda river.

Geological set up of the area: The area is observed to be largely occupied by overburden material. No outcrops are observed around this area. Phyllites are however observed on the river bed. These are observed to be moderately to highly jointed, thinly foliated and dipping towards south to southeast at moderate to steep angles.

Reconnaissance geological-geotechnical assessment: Sarasvati Vidhya Mandir is observed to be a new construction in close proximity of the river bed. The structure, though filled with silt and sand (Fig. 23) has not suffered structural damage of any kind.

Government Senior Secondary School area is located on the terrace comprising of river borne material. Below the school the terrace is observed to be eroded by river (Fig. 24).

Fig. 23. Photograph depicting new constructions of Sarasvati Vidhya Mandir in close proximity of river bed.

Fig. 24. Photograph depicting bank erosion near Government Senior Secondary School.

Mitigation measures: Sarasvati Vidhya Mandir area falls in high flood zone and should be kept free of any anthropogenic activity. Masonry retaining structures would however be required below Government Senior Secondary School for reducing further under cutting and erosion.

11. Gas Godown area

Gas Godown area is located before Srikot petrol pump, just below road and on the left bank of Alaknanda river.

Geological set up of the area: Rocky outcrops of phyllites of Garhwal Group are observed to be exposed around the area on the river bed. Theseare observed to be moderately weathered, thinly foliated and moderately to highly jointed. In between Government Senior Secondary School and Gas Godown area phyllites are observed to be exposed all along the left bank of Alaknanda. These provide stability to the upslope area while also protect the river bank form stream erosion.

Structural discontinuities: The rocks exposed around the area are observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of rock mass and stability of slopes. The Garhwal Group rocks exposed in the area are generally observed to strike NE - SW and dip towards southeast at angles 55°. These rocks are well jointed and the details of the prominent joints observed in the field are recorded in Table 3.

Table 3: Details of the joint pattern observed in the field.

Joint Set	Dip amount	Dip direction	Strike trend	Remark
I	55°	170°	80° - 260°	Foliation
II	55°	010°	100° - 280°	Prominent joint
III	70° - 80°	090°	00° - 180°	Prominent joint

Reconnaissance geological-geotechnical assessment:

Downstream of Government Senior Secondary School area bank erosion is observed around New Basti area (Fig. 24).This area is observed to be filled with 3.0 meters thick pile of silt and sand.

Gas Godown area is also observed to be filled with 2.5 meters thick pile of silt and sand (Fig. 25). Slight undercutting is also observed at this location.

Fig. 24. Photograph depicting bank erosion between Government Senior Secondary School and Petrol Pump colony.

Fig. 25. View of freshly deposited sand and silt near Gas Godown.

Mitigation measures: Constructions of adequately designed RCC retaining structure and oblique concrete slabs is recommended along the river bed between Government Senior Secondary School and New Basti area.

Masonry retaining structures along the river bank for reducing further under cutting and erosion are recommended around Gas Godown area.

Conclusion

The observations make it clear that most devastation has taken place on the terraces and unconsolidated material along the course of Alaknanda river. Areas located upslope of in situ rocks have largely been spared from devastation. Traditionally, the river terraces were reserved for agricultural purposes while habitations were restricted to the upslope areas over hard rock.

Water and economic / agricultural activities being restricted to the rive side this however amounted to putting in additional labour for routine household and agricultural chores. This however was acceptable to the inhabitants as survival and safety of the community always attracted higher priority.

With the passage of time traditional land use pattern has certainly been relegated to the back seat and various commercial interests along with changing lifestyles have put forth an incentive for settling down in close proximity of rivers and streams.

Flat terraces at the same time lured relatively new settlers who saw opportunity of erecting huge structures at these places nullifying the cost of site development and transportation of building material. The loose material, which was hitherto subjected only to agricultural pursuits, was thus exposed to large-scale disturbance. Moreover adequate attention was not paid towards safe disposal of wastewater that augmented erosion of the terrace material and had adverse impact on its stability. At the same time scant attention was paid towards bank protection works.

It is therefore no surprise that floodwaters ravaged large portions along the river bank in Srinagar. And it was not Srinagar alone. Mapping of disaster induced destruction clearly brings forth that most areas devastated are located on loose unconsolidated material, be it colluvial or alluvial.

The devastation calls for reviewing the trends of growth and development in the state. It is at the same time warranted that the policy of allowing unrestricted anthropogenic intervention in close proximity of streams and rivers, as also that on alluvial and colluvial terraces, be reviewed. Moreover, if adequate bank stabilisation measures are not taken along the banks destabilized by the floods of 2013 next monsoons can well be more devastating. It is therefore urgently required that the destabilized banks in the proximity of human habitations be treated on high priority basis.