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Cause and mechanism of the Seti River flood, 5th May 2012, western Nepal

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ABSTRACT

A catastrophic flash flood has occurred in the Seti River in the morning of May 5, 2012. An attempt has been made to find out the cause of the flood which originated form very remote inaccessible area lying in the Western slope of the Annapurna IV peak. Comparative Analysis of the Landsat ETM satellite images of 20th April, 2012 and 6th May, 2012 revealed that the area of about 32000 square meter of the southern ridge 1.5 kilometer away from the Annapurna IV peak failed in the north western direction. The impact of descending mass of the failed mountain from 6850 meters to 4500 meters almost vertically pulverized the ice, sediment and rock. The impact even triggered seismicity at 9:09.56 AM. local time which was recorded all over the 21 stations of National Seismological Centre. The closest seismic station at Dansing which is 32 km. south west from the area recorded the high signals for 70 minutes which corresponds to the duration of the debris flow. Lab analysis of the flood water sample revealed the density of the flow as 1.88 gm/cc. Analysis of the satellite based hourly rainfall GSMaP NRT from the period form 20th April -6th May 2012 revealed that there were just 4 occurrences of rainfall which amounted less than 1 mm/hour in the source area of the avalanche. The rainfall > 6mm/hour which occurred in the Kharapani area on 4 May was localized rainfall which did not extend to the avalanche area. Lack of systematic disaster preparedness caused huge loss of life and property even though the early warning message was received from the Ultralight pilot who was flying close to the area. The avalanche triggered high intensity floods which have similar characteristics to glacier lake outburst floods (GLOFs) have emerged as a new hazard in the Himalaya.

Key words: Nepal, Seti Flood, avalanche,

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INTRODUCTION

A catastrophic flash flood has occurred in the Seti River in the morning of May 5 2012 and has killed 72 people and has caused tremendous damage to the lives and livelihood in Sadi Khola and Machhapuchhre VDCs of Kaski district (Fig. 1).The southern slopes of Annapurna range have been experiencing avalanche-triggered high intensity floods also in the past. On August 15, 2003, the Madi River had experienced an unprecedented flash flood which destroyed the recently built rural road and triggered many landslides along its course and killed 5 people (Dwivedi 2005). Both floods occurred during clear days and no glacial lake of significant size were spotted in the satellite images captured before the flood event.

Flash flood and debris flow triggered by mountain collapse has occurred in Russia in the past. The Kolka Glacier glacial disaster occurred on 20 September 2002 in the mountains of North Ossetia is assumed to be the biggest glacial disaster in the Russian history (Zaporozhchenko 2005). A huge ice-rock-water mass rushed down the Genaldon River valley with a velocity of 320 km/h from the Kolka Glacier. Having covered a distance of 18.5 km, it was stopped by the narrows of the Skalistyy Range and filled the Karmadon hollow with 120 million m^3 of deposits. The material moved beyond the hollow as a debris flow, which went down the valley (10 km) devastating all the constructions in the riverbed. A total of 125 people were reported dead or missing.

An attempt is being made here to find out the cause and mechanism of the initiation of the Seti Flood by analysing the Landsat ETM satellite images and aerial photos captured before. During field visits during the event samples of suspended sediment were collected and analysed.

The Seti River source area

The Seti River originates from a huge bowl-shaped valley surrounded by the peaks Machhapuchhre (Fishtail) in the southwest, Annapurna III in the northwest, and Annapurna IV in the east. The circular valley is glaciated in the higher altitude: the examination of the satellite images of the area

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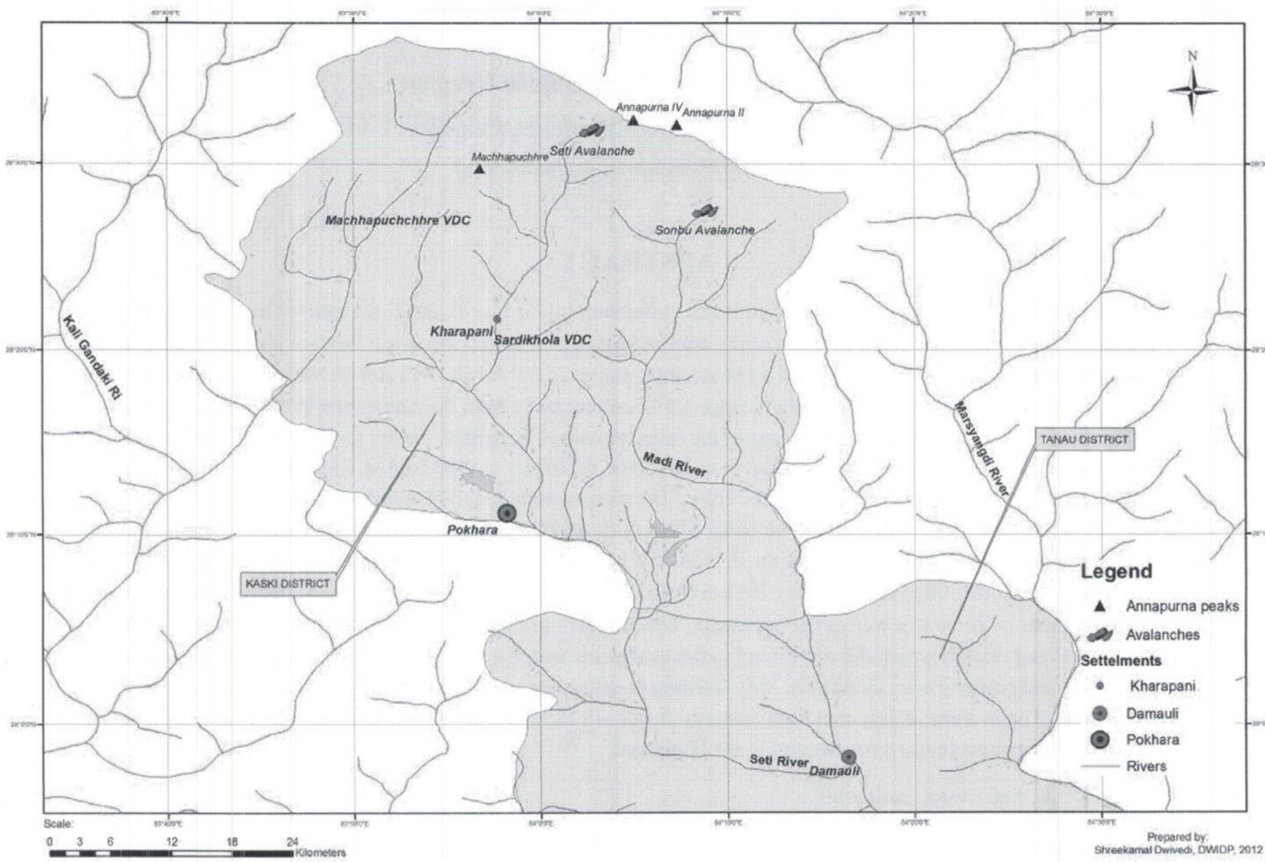

Fig. 1: Avalanche-triggered floods in Kaski District.

reveals sloping glacial terraces and glaciers at about 5000 meters altitude on the western slope of the Annapurna IV (Fig. 2).

CAUSE AND MECHANISM OF THE FAILURE

From the comparison of the Landsat ETM satellite images of April 2012 and 6th May 2012, it reveals that an area of about 32000 square meters of the southern ridge 1.5 kilometres south of the Annapurna IV peak is missing at the edge (Fig. 2). The mass descended from 6850 meters to 4500 meters almost vertically; at the major impact point apparently it pulverised the ice, sediment, and rock forming depression (Fig. 4). This pulverized mass formed the dark brown cloud which was captured by the ultra-light aircraft video camera. The main direction of the failure was towards the West. The impact triggered seismicity (at 9:09.56 a.m. local time, Petley and Stark 2012) which was recorded all over the 21 stations of National Seismological Centre (Sapkota and Duvadi 2012) Fig. 3. The seismicity was equivalent to magnitude 3.8-4 in Richter Scale. The closest seismic station at Dansing, which is 32 km. southwest of the area, recorded the high signals for 70 minutes which corresponds to the duration of the first surge of the debris flow. The seismic signals were recorded even by the global seismological network station located in Lahsa, Tibet (Petley and Stark 2012).

The huge vibration and the heat generated by the impact caused the glaciers on the slope to fail. This whole mass descended further downslope in southwest direction to 3300 meters to the spillway of the huge depression from where the Seti River starts (Figs. 4 and 5). The huge mass of debris along with ice chunks rushed down the river as a debris flow for 20 kilometres downstream at Kharapani in just 28 minutes (almost 12 meters/second). The flood arrived at Kharapani, where most of casualties occurred, at 9:38 AM

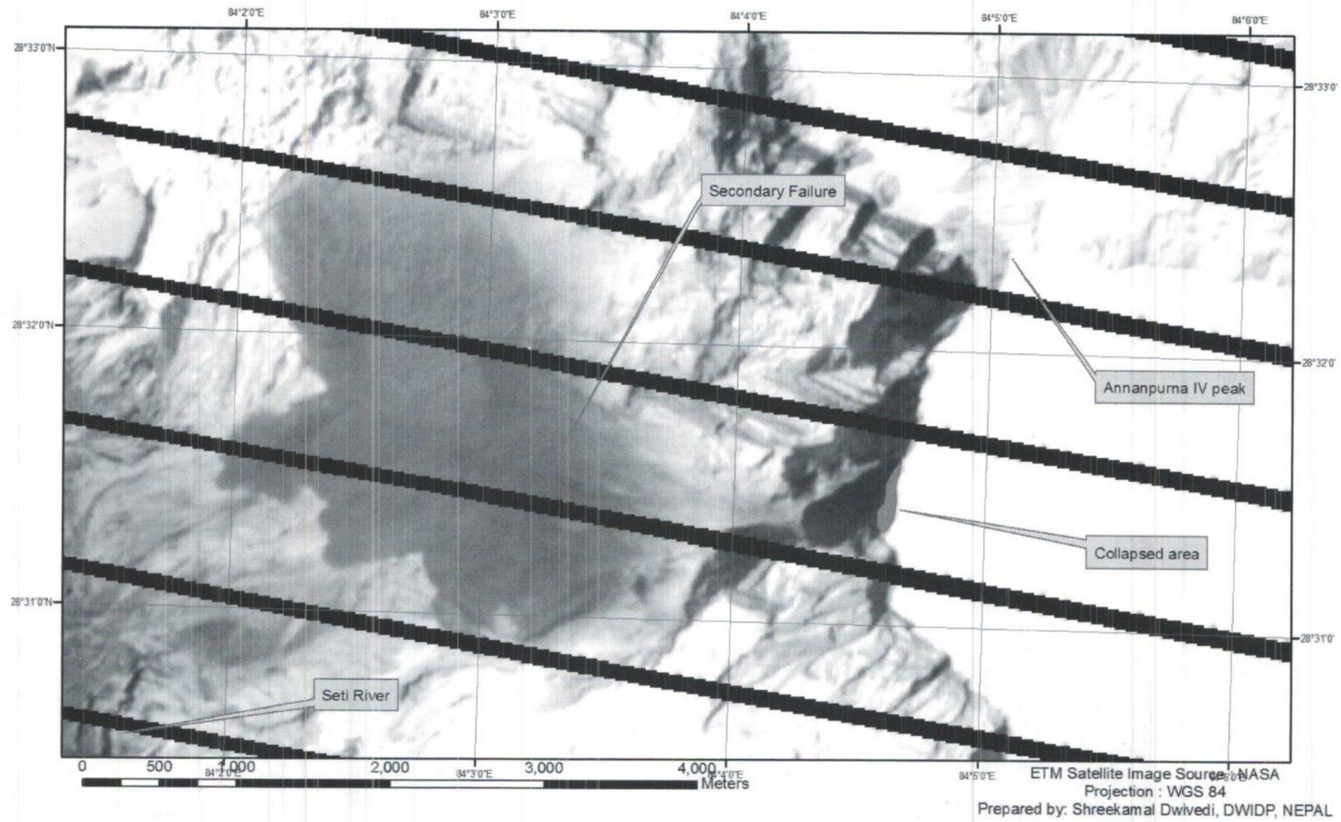

Fig. 2: Satellite image by NASA of May 6, 2012 showing the collapsed portion of the ridge.

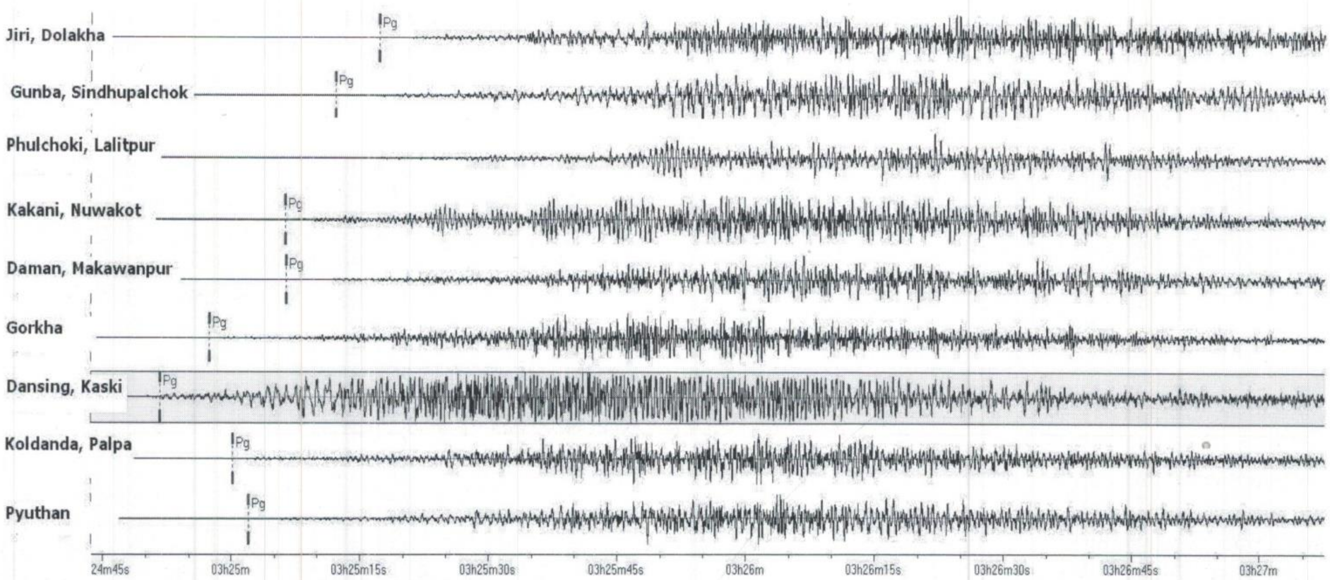

Fig. 3: Seismic signals recorded at different seismic stations. The station at Dansing (third from the bottom) recorded the surface wave for 70 minutes (From: Sapkota and Dwivedi 2012).

and reached the dam of the Seti irrigation system at 10:35 AM (Dwivedi and Neupane 2012).

SATELLITE BASED RAINFALL ANALYSIS

Analysis of satellite based rainfall from the period of 21st April to 6th May 2012 was done using GSMaP NRT hourly data (Global Satellite Mapping of Precipitation-Near Real Time). The hourly data was analysed applying Integrated Flood Analysis System (IFAS) software. The analysis of the area where the collapse occurred has revealed low >1mm/hour rainfall in the morning of 20th April, morning to afternoon of 22nd April, in the evening of 24th April and in the morning of 26th April. The satellite based rainfall data has given the very interesting fact that the heavy rainfall on 3rd and 4th May reported by the local people was concentrated to the lower catchment area only but not at the source area (Fig. 6). This concludes that rainfall was not the cause of the failure.

FLOOD WATER SEDIMENT ANALYSIS

The flood water sample collected 100 meter downstream of the irrigation dam in Pokhara was analysed. Laboratory analysis of the flood water sample revealed the density of the flow as 1.88 g/cm^3. The result of the sieve analysis of the dried suspended sediment sample showed that it mostly contains fine sand and silt (Fig. 7). Visual examination the

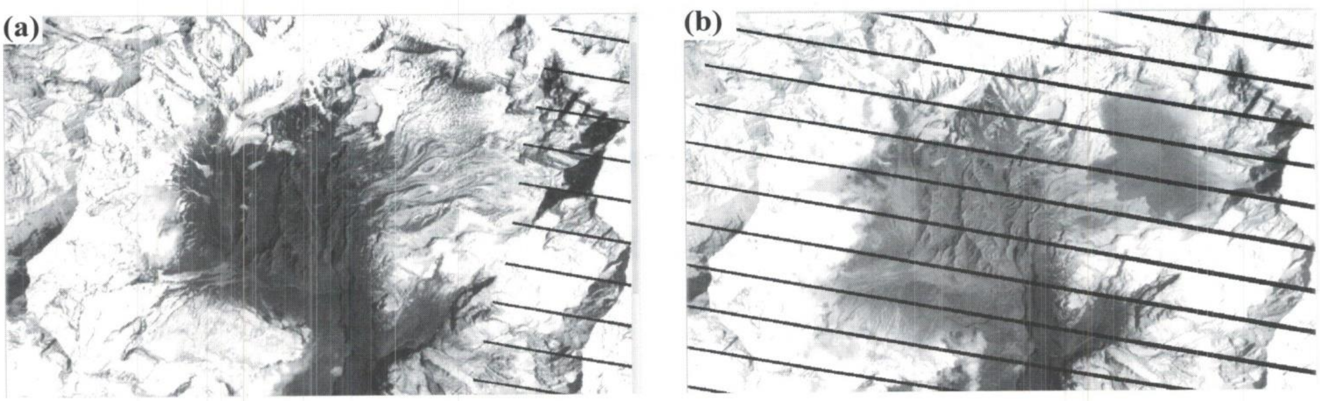

Fig. 4: (a) Landsat Satellite Image of 20 April 2012. (b) Landsat Satellite Image of 6 May 2012 which shows the dark patch (middle right position) of deposits of the ridge collapse and light brown colour of the whole area of mid-left part is due to the avalanche triggered there after. Some of the glaciers located in between the two patches and in the area where the collapsed mass landed have vanished in the right image.

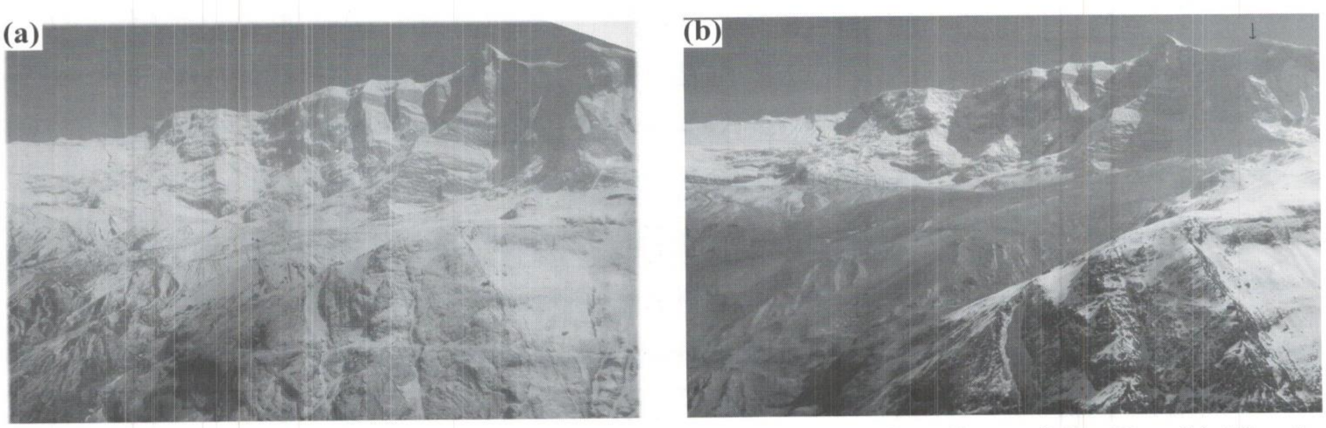

Fig. 5: Photos taken form ultra-light aircraft on 4th May 2012. (a) Before the collapse of the ridge, (b) After the collapse. The triangular peak is the Annapurna IV, huge area overrun by the avalanche. Photos courtesy: Avia Club Nepal.

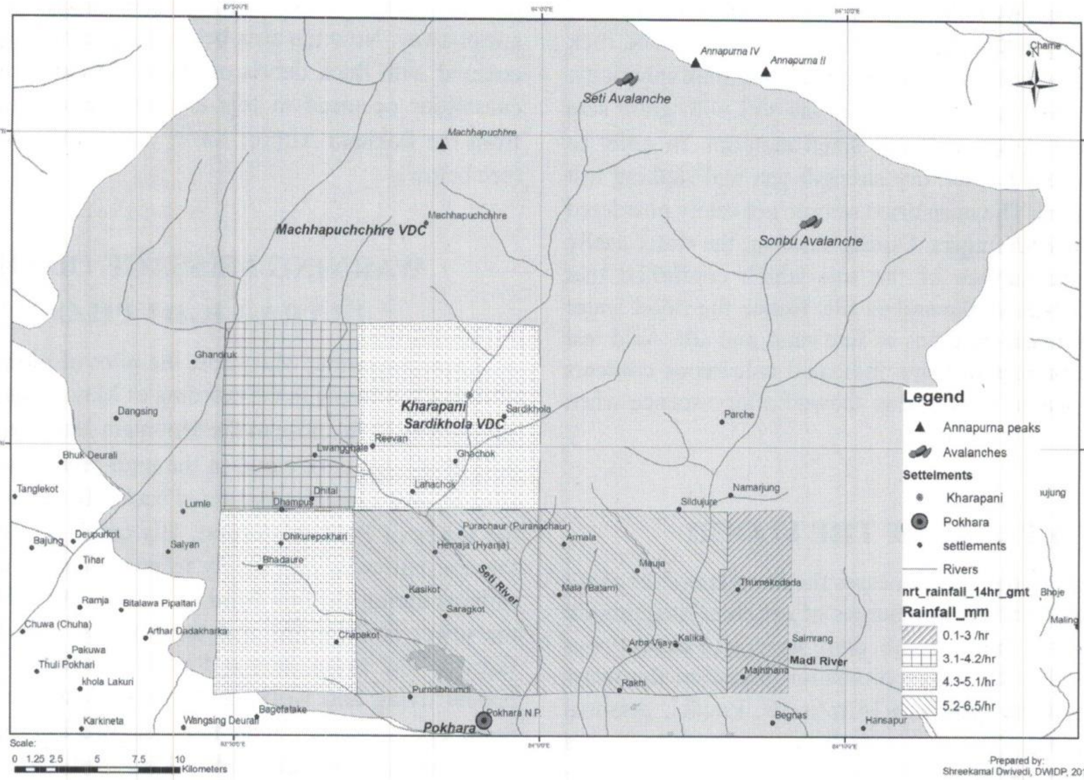

Fig. 6: Rainfall distribution map derived from the Global Satellite Mapping of Precipitation (GSMaP) Near Real Time data at 14:00 GMT on 4th May 2012.

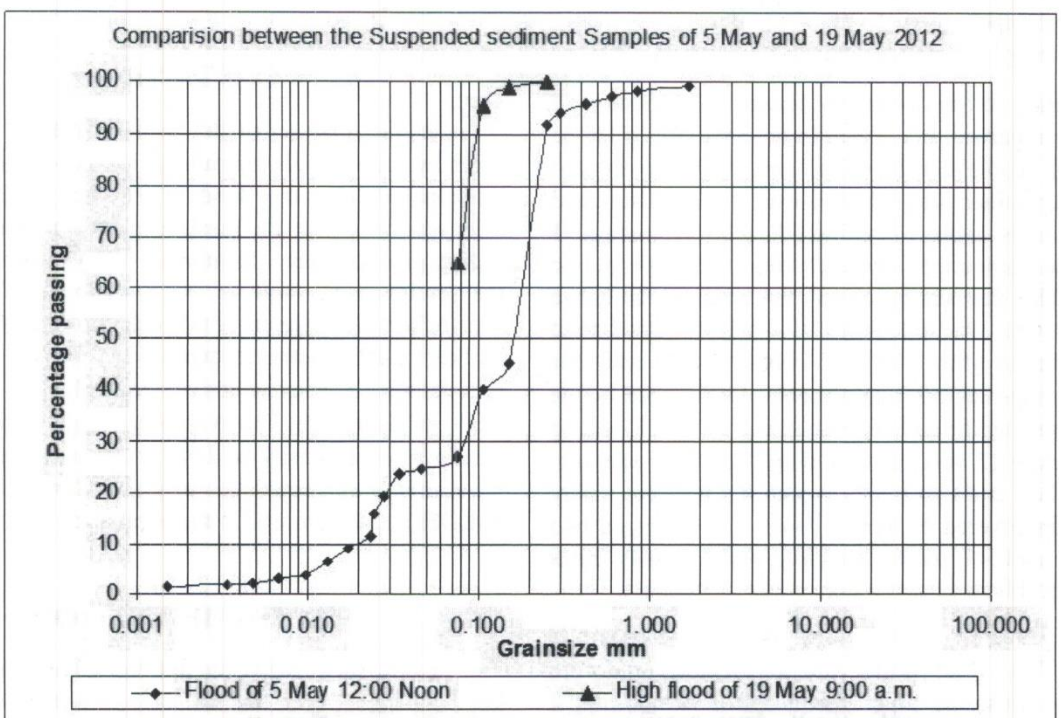

Fig. 7: The result of the sieve analysis of the dried suspended sediment sample.

coarse grains showed that it comprised of rock fragments of dolomite along with grains of quartz and micas. The rock fragments are angular to sub angular with medium sphericity. The sample also contains 27% of fine soil with grain size <0.075 mm, i.e., silt and clay sized material. In order to distinguish them further, dry strength test and shaking test were performed. The oven dried sample got easily powdered by rubbing it with fingers. During shaking, the water easily drained at the surface of the soil which confirmed that the finer material in the soil is silt. Hence the flood water contained bimodal particles of fine sand and silt. Acid test done in the dried sediments indicated calcareous contents in the flood water. Dark grains showed effervescence when powdered.

IMPACTS OF THE FLOOD

According to the eye-witnesses the flood lasted for about 5 hours with about 20 high surges of different magnitudes. The high-water level at the dam weir at Pokhara was 2.15 meters. The discharge estimation based on the water mark revealed the peak as 935 m^3/s (B. Poudel, personal communication). The eye-witnesses in Kharapani area reported huge ice blocks floating in the flood. They felt vibrating ground and heard very loud sound similar to flying of several helicopter together. The smell of the flood water was muddy. Eye-witness account during Tampokhari and Dig Tsho Glacier Lake Outburst Flood (GLOF) events have shared similar experiences (Dwivedi et. al. 2000; Mool et. al. 2001; Vuichard and Zimmerman 1986; Yamada 1998).

The flooding in Seti River has caused great damage to the life and properties. According to the Ministry of Home Affairs, forty people lost their lives and thirty two are still missing (all presumed dead) and five were injured. Estimated economic loss is about 82 million Rupees including 33 million private properties and remaining 49 million public properties. The devastating flood damaged seven house and seven shops. One kilometre of blacked topped road two kilometres of gravel road, 25 electric poles, and four suspension bridges at different places were damaged by the flood thus affecting the daily operation and traffic. Flooding also swept away 12 vehicles including 7 tractors, one van, two motorbikes, and two trucks. About 9.5 hectares paddy field has been covered by sand. Flood also damaged two water mills and 45 meter drinking water supply lines resulting in problems on the water supply of Pokhara.

Kharapani was a popular spot for picnic and natural hot spring bath. There were people just arriving and some were already in the hot spring ponds. The ponds were located just below the terrace seen in photograph (Fig. 8b), close to the river. The pre-existing 6-8 meters high terrace above the river is now covered with debris of about 1.5 meters. The houses located on the terrace and below the terrace are all swept away. Now the area below the pre-existing terrace is covered with thick debris of about 5 meters. Most of the causalities occurred in this area as the warning message from the Pokhara Airport tower could not reach this area (see below).

WARNING MESSAGE OF THE ULTRA-LIGHT PILOT

Capt. Alexander Maximov, the pilot of ultra-light plane of Avia Club Nepal in the morning of May 5 was in a regular sightseeing flight close to the Mountain Machhapuchhre. He noticed a huge dark cloud in the high-mountain depression (Fig. 9) and immediately turned back. He sent a message to the tower of Pokhara Airport. His quick understanding of the unusual event and timely response has saved hundreds of lives during the Seti flood of 5^{th} May 2012. He informed the tower at 9:16 AM and the message was broadcasted through FM radio; police forces evacuated hundreds of people living and working in the bank of the Seti River. Some eye- witnesses in the field said that information about the flood was also received in Kharapani bazar by mobile calls from the people who saw the flooding in the upstream area. This message has helped many people to run to safety. However there was no organized approach of the warning dissemination in the ground.

CONCLUSIONS

After the analysis of the satellite images, photographs taken by the ultralight aircraft and the eye-witness accounts, we conclude that the flood of 5^{th} May 2012 in the Seti river was caused by the massive avalanche which occurred in the glaciated area located at 4500 meters a.m.s.l. on the southwestern slope of the Annanpurna IV peak. The avalanche was triggered by the rock failure of the ridge at an altitude of 6850 meters located 1.5 km south of the peak; the rock fall caused seismic activity equivalent to 3.8-4 Richter Scale in magnitude. The avalanche triggered high intensity floods (having density of 1.88 gm/cc in this event) which have similar characteristics to glacier lake outburst floods (GLOFs) quite common in the Himalaya.

RECOMMENDATIONS

1. Experience during the Seti flood have shown that the large scale disaster of this intensity cannot be averted, hence a effective and functioning early warning system must be installed in human settlements and in the areas where people gather for recreation purposes.

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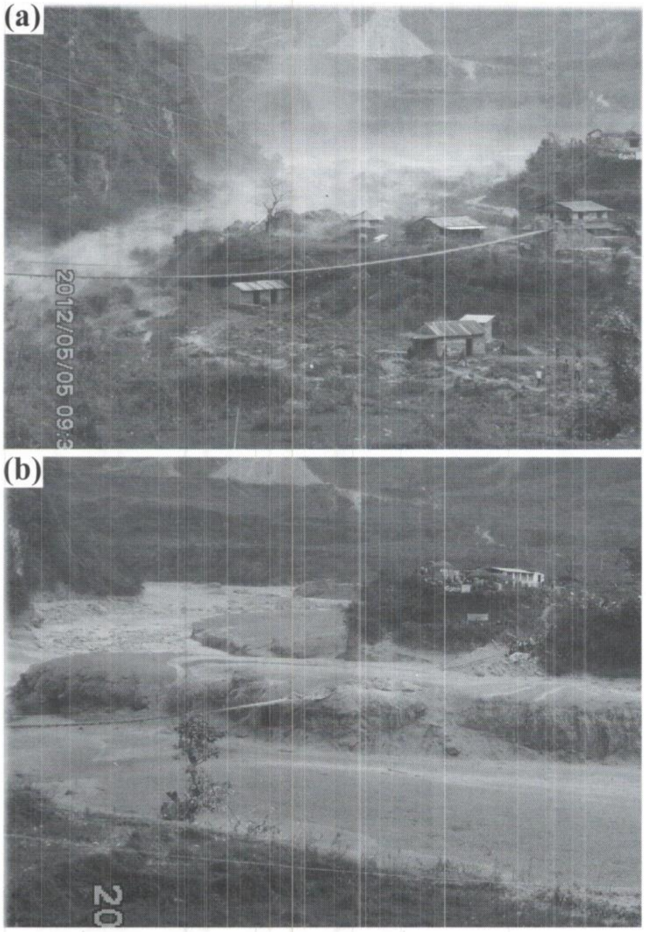

Fig. 8: (a) Photograph showing the approaching debris flow in Kharapani Bazar. People and houses seen in the photograph (except in the high standing terrace) were swept away by the flood. (b) Same view with some extension towards right after the devastation. (This photograph is made available by Mr. Shiva Acharya, who was in picnic group and lost 2 of his friends in this disaster).

2. There is a strong need of disaster information dissemination in the settlements along the rivers originating from the Annapurna Area. Hazard maps must be prepared in the vulnerable areas with evacuation routes clearly displayed in public places.

3. The early warning message reached Pokhara within 10 minutes of the initiation of the disaster but due to lack of preparedness in warning dissemination, the warning could not reach touristic area of Kharapani in an organized way through the responsible authorities; hence there is need of disaster preparedness in the authorities.

4. People have been observed entering in the river to collect logs and dead fishes. Eye-witnesses reported

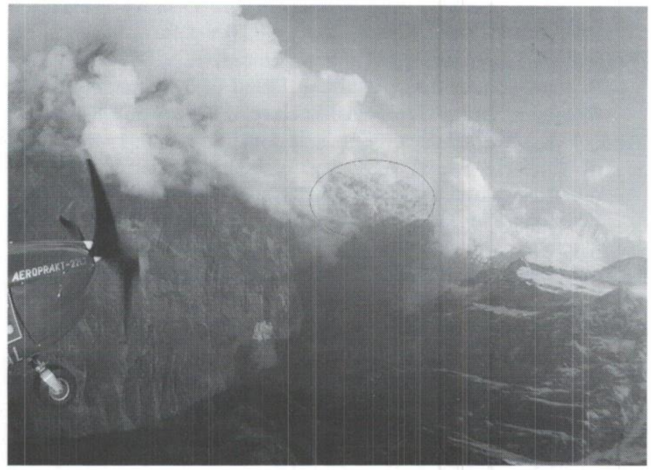

Fig. 9: The dark brown cloud indicated by the circle observed by Capt. Maximov. (Photo courtesy: Avia Club Nepal).

that some people who were already in the safe place ran towards the river to see the flood and were swept away. Such practices should be discouraged by conducting public awareness campaigns.

5. In future occasions, people should not be allowed to enter in the flood plain till the authorities announce end of the flooding as surges may occur with time intervals.

6. The vibration caused by the debris flow could be recorded by the seismic stations, the signals received at Dansing seismic station and other stations should be studied further to find out the possibility to develop an early warning system for the debris flow of larger extent like as caused by GLOFs.

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