Avalanche and mudflow situation in the Republic North Ossetia-Alania

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Abstract. Snow avalanches and mudflows cause great damage to federal and domestic roads, economic facilities and, most importantly, they are dangerous to people's lives within the mountainous territory of the Republic of North Ossetia-Alania. Avalanches represent the greatest danger on the northern section of the Transcaucasian highway from the village of Buron to the Northern portal of the tunnel through the main Caucasus ridge, which is 28.3 km long. The number of avalanches is directly dependent on the amount of snow that fell during the winter. During the season of 2011–2012 due to the large amount of snow that fell, there were 371 avalanches (including 270 forcible avalanches and 101 avalanches by self-rising). During the anomalously low snow season of 2013–2014, there were only 13 avalanches, which came off. Therefore, that is the lowest index since the avalanche period of 1986–1987. During the study period, the road was closed from 1 to 17 times per season, which also depends on the number of avalanches. Mudslides pose a great danger to the population of the republic, roads and objects of the national economy. There are mudslides after heavy precipitation on the territory of the republic.

1. Introduction

Snow avalanches and mudflows are one of the hazards in the mountainous areas and pose a greater threat to the lives of people and economic objects.

In the Republic of North Ossetia-Alania, avalanches on the northern section of the Transcaucasian highway from the village of Buron to the Northern portal of the tunnel through the main Caucasus ridge, which is 28.3 km long, represent the greatest danger.

To study avalanche and mudflow situations on the territory of North Ossetia-Alania, the materials of the annual reports of the Ministry of Emergency Situations of the Republic from the 2009–2010 season to the 2016–2017 season [1–8] were used. The data on avalanche situations are presented in Table 1.

The number of avalanches is directly dependent on the amount of snow that fell during winter. During the season of 2011–2012 due to the large amount of snow that fell, there were 371 avalanches (including 270 forcible avalanches and 101 avalanches by self-rising). During the anomalously low snow season
2. Formation of avalanches

Foehn winds have a significant effect on avalanche formation. The distribution and intensity of foehn winds in Greater Caucasus varies widely. The number of days with foehn winds is observed at settlement Nizhniy Zaramag – 17, Kobi – 15, and in the high-mountain settlement Kazbegi – 58. Thus, the number of days with foehn winds in the mountains increases dramatically when the height increase.

The melting of snow at foehn winds and avalanches are not so much due to the increase in temperature as the duration of foehn winds. The duration of foehn winds in the study area varies from several hours to 10–14 days. Foehn winds particularly frequent here in late February - early March.

The main factor in the accumulation of large amounts of snow on the leeward slopes in this area is the prevailing southwestern wind.

Table 1. Avalanche situation in Republic of North Ossetia-Alania from 2009–2010 to 2016–2017

| Years      | Avalanches, which came down | Maximum snow height (cm) | When road was closed during the season (days) |
|------------|----------------------------|--------------------------|---------------------------------------------|
|            | total          | self-rising | forcibly |                                  |                                           |
| 2009-2010  | 240           | 190         | 50       | 102                               | 17                                        |
| 2010-2011  | 234           | 189         | 45       | 108                               | 6                                         |
| 2011-2012  | 371           | 270         | 101      | 107                               | 10                                        |
| 2012-2013  | 216           | 129         | 87       | 100                               | 9                                         |
| 2013-2014  | 13            | -           | 13       | 6                                 | 1                                         |
| 2014-2015  | 169           | 114         | 55       | 143                               | 3                                         |
| 2015-2016  | 200           | 103         | 97       | 106                               | 11                                        |
| 2016-2017  | 127           | 103         | 24       | 91                                | 3                                         |

During the winter, there were 45 days with southwestern wind, which was blowing at the speed of 5–12 m/c at the altitude above 2500 m above the sea level. Wind gusts, reaching up to 20 m/c, are usually in December, January and February. Below the altitude 2000 m above the sea level, wind speed and its direction vary as well as the terrain peculiarities. Vegetation has a great influence on wind transfer of snow, for example, dense forest in Tsei gorge contributes to the accumulation of snow masses, while rare shrubs in the upper reaches of other gorges cannot significantly affect the nature of the wind transfer of snow.

The period of formation of sustainable snow cover as well as changes in its structure is greatly influenced by air temperature [9].

The threat of snow avalanches also exists on another important highway - the Georgian Military Road near the Cross Pass (Upper Lars checkpoint). In accordance with Russian and Georgian agreements, when there is a threat of an avalanche, the traffic through the pass is limited or terminated completely. In this case, there are up to several hundred heavy vehicles that are harmful to the environment due to long-running engines on the territory of the republic.

Avalanches bring not only material damage to highways, but also they take people’s lives. In 2008, a snow avalanche caused the death of four people in the area of Zaramagskaya hydroelectric power station.

The task to ensure avalanche safety in the northern part of TransKAM from the village of Buron to the Northern portal of the tunnel through the main Caucasian ridge is assigned to the Roki avalanche unit (RVPLO) under the North Ossetian militarized unit of the FASM of Roshydromet. Its base and location are in the village of Nar and on the North portal. There is also a weather station on the North
Mudflows pose a great danger to the population of the republic, roads and objects of the national economy. As a rule, there are mudflows after heavy precipitation on the territory of the republic.

North Ossetia-Alania is one of the most mudflow areas of Russia. Mudflows happen annually due to the contrasted relief, and significant precipitation [10]. In the mountainous part of the republic, there are 145 mudflow basins. The total area affected by mudflows is approximately 2165 square kilometers, which is 25 % of the total area of the republic. The average area of the mudflow basin is 29.4 square kilometers. The total length of the mudflow channels is approximately 792.7 kilometers; the average value is 11.4 kilometers. The largest area affected by mudflows in North Ossetia is in the valley of the Ardon river (937 square kilometers) [11].

Mudflows on the territory of North Ossetia can have not only a natural character, but also the so-called “hand-operated”, for example, in case of emergency discharge of water from the reservoir of the Zaramagskaya hydroelectric power station [12]. Zaramagskaya hydroelectric power station itself also represents a great danger due to its location in a seismic zone [13]. During the study period, the following mudslides were noted.

In March 2010, Dzaurikau-Tskhinval gas pipeline, which supplies South Ossetia with Russian gas, was damaged by mudflows that came down on TransKAM. A powerful snow mud flow of more than 1000 cubic meters came down at 3:00 a.m. in the area of Nizhny Zaramag and covered the territory of Zaramag gas measuring station (GIS). As a result, the structures of the metering unit were damaged and two of the three sections of parallel technological branching of the GIS with a diameter of 159 mm each appeared under the obstruction. The destruction and ignition of the main gas pipeline with a diameter of 420 mm did not occur. There was no interruption in the supply of natural gas.

At 11:40 pm on July 16, 2011, 1 km below the Victoria Hotel, Tseyiskoe Gorge, Alagirsky District, North Ossetia-Alania, 2 mudflows descended with the roadway overlapping; there were no victims and injuries. Energy and water supply was not disrupted.

In 2012, the following mudflows were observed on the territory of the republic:

- the right side of the river Mamisondon, a nameless water stream 1 km above the river Khalatsa caused deformation of the technological road through the gas pipeline L=20 m, V – 5000 m³;
- the river Kuatedon - road blocking on the Mamison L=20 m, V-3000 m³;
- on June 18, the river Kasaikom, 71 km of TransKAM – road blocking L=150 m, V–2000 m³;
- on August 23, the river Kasaikom, PK 52 on TransKAM – road blocking L=250 m, V – 1500 m³; the river Andorrag, PK 438 on TransKAM – temporary overlap of the road section L=50 m, V – 1000 m³;
- on July 6, the river Andorrag (the left tributary of the Ardon river in Mizur) - TransKAM overlap L=50–70 m, V – 1000 m³;
- on August 20, Kolota water stream (the right tributary of the Fiagdon river) - Harisjin-Hilak road blocking L=30 m V–10 000 m³; the river Lamardon (the left tributary of the Gizeldon river) – the bridge deformation at Lamardon settlement, V-5000 m³; the river Fardon (the right tributary of the river Genaldon) – a mudflow descended into Saniban lake with no damage, V-10000 m³; highway Gizel – Koban, PK 110,5 (the area of a new bridge) – deformation of a shore protection dam L=40 m, V – 1200 m³; water stream Dzhanukadzhin PK 65,5 along the Georgian Military Road, V – 2000 m³.

In 2013, the following mudflows were observed on the territory of the republic:

- on July 4, water stream Dallagkom (the left tributary of the river Zakka), V – 1000 m³; on July 5, Kozidon river basin, starboard, 2 beams 2,5 km from the river mouth, V – 1000 m³;
- on July 5, the river Kozidon, starboard, 2 beams 3,1-3,3 km from the river mouth, V – 2000 m³; on July 8, the valley Kaikomkondon, starboard ~ 3,5 km from the river mouth, V – 1500 m³;
- on July 5, the river Zemegondon, the left side ~ 2950 m from the river mouth, V – 2000 m³; on July 1-2, the river Kasaikom, TransKAM (71 km), V – 5000 m³ with overlap and deformation of the road, which length is 200 m;
on July 19, the river Kasaikom, TransKAM (71 km), V – 1000 m³ with overlap and deformation of the road, which length is 200 m;
- on July 21, Wills beam, the right side of the river Skazdon valley, V – 9000 m³;
- on July 21, nameless beam to the north of Wills beam, the right side of the river Skazdon valley, V – 1000 m³;
- on August 26, the river Tsatadon (headwaters) V – 9000 m³; on September 24, water stream North Kasaik (the right source of the river), V – 1500 m³.

In 2014, the following mudflows were examined on the territory of the republic North Ossetia - Alania:
- on June 6, Darg-Shuardon (the right tributary of the river Dzamarashdon, 3 km from the river mouth), V – 1500 m³;
- on June 23, beams on the right side of the river Mamisondon (gas pipeline Dzuarikau - Tkshinval, 81,4 – 81,6 km), V - 200 m³, 500 m³, and 1000 m³, the threat of deformation of the pipeline, the overlap of the technological road, which length is 50 m;
- on June 25, Bezimyannaya beam (Dzuarikau - Tkshinval gas pipeline, 83 km), V-3000 m³, the overlap of the technological road, which length is 50 m;
- on June 27, the river Labagom (Dzuarikau - Tkshinval gas pipeline, 62 km), the overlap of the technological road, which length is 20 m in spring time;
- on September 2, beam on the left side of the river Genaldon, which is 8 km above the river mouth of the Kanidon, V – 2000 m³ in spring and summer time; on September 2, beam on the left side of the river Genaldon 8,7 km higher of the river mouth Kanidon, V – 2500 m³;
- on September 23, the river Vilsadon, 1,5 km from the river mouth, V – 2000 m³ in summer time; on September 23, the left tributary of the river Vilsadon, 1,9 km from the river mouth, V – 1500 m³;
- on September 25, beam on the right side of the river B. Dur-Dur, 0,4 km higher from the river mouth M. Dur-Dur, V – 2000 m³, damage of forest land;
- on October 11, water stream Kolota (the right tributary of the Fiagdon river), 40 m of the road to Hilak mineral springs were destroyed;
- on October 11, the river Lartsikom (the right tributary of the Midagrabin river), V – 10000 m³, the road to Midagrabinsk waterfalls, which is 100 meters long, was destroyed.

On April 15, 2015, as a result of a mudflow of 1500 m³ on the river Bezimyannay (the right tributary of the river Mamison), 1 km above the river Khalatsa, there was the overlap of a 50 m long road; traffic on TransKAM was stopped for 20 hours; on June 14, the result of a mudflow of 3000 m³ - the left side of the river Zaika, beam between the brooks Toa and Uallagk, there was the overlap of technological serpentine roads about 150 m long; on June 20, as a result of a mudflow of 1500 m³ the southern outskirts of the settlement Mizur, 56 km of Dzuarikau-Tkshinval gas pipeline, the technological road 300 m long was deformed; on August 6, as a result of a mudflow from 4000 to 5000 m³ on the river Kasaik, the right tributary of the river Ardon, there was an overlap of TransKAM with a length of 100 m, the traffic was stopped for 16 hours;

On August 6, as a result of a mudflow of 5000 m³ on the river Kolota (the right tributary of the Bugultadon river, 2.5 km from the river mouth), there was an overlap, which is 15 m long.

On September 26, the river Bartui (the left tributary of the Karaug river) there was a mudflow of more than 10000 m³; on September 30, as a result of a mudflow on the Skazdon river, which was 50000 m³ the re was a deformation of a ski slope of 500 m, the water intake was destroyed, the right flank was 30 m long; on November 6, as a result of a mudflow at the settlement Badashia (the right tributary of the Ardon river, the south of the settlement Nuzal), TransKAM was blocked, the traffic was stopped for a day, the gas pipeline was deformed.

On June 15, 2016 at 7 p.m., after intense precipitation during two days, on the river Kasikak (the right tributary of the Ardon river, 71.5 km of TransKAM) there was a low-density mudflow (V - up to 2000 m³) with predominance of water component. Pipe water passage was immediately clogged with debris, after which the stream broke out onto the road and rushed down right along the roadway, and
deformed the asphalt and filled it with stone material for more than 200 m. Water gradually flowed down to the lower slope of the road, where there was a site for storing technogenic soil, on which large gullets were formed with the demolition of loose detrital material in the river Ardon.

In 2017, mudflows in the republic were represented by the following events:

- on July 5, the river Kasaikom (the right tributary of the river Ardon, 71 km of TransKAM), a mudflow (V-3000 m³) blocked TransKAM L=100 m c with erosion man-made dump;
- on July 10, water stream Wills (the right tributary of the river Skazdon), there was a mudflow, V - 8000 m³. As a result, the ski trail was damaged and blocked by detritus L=100 m. On the same day, there was a mudflow on the river Orakhkom (the left tributary of the river Tseidon), V= 5000 m³, which destroyed hiking trail to the glacier L=300 m;
- on August 5, starboard of the river Urukh opposite the settlement Kussu, a mudflow, V - more than 10000 m³ blocked the river bed Urukh. There was forest destruction in the flood plain, S=1 hectare;
- on October 20, Kolot beam (the right tributary of the river Fiagdon along 12 km), a mudflow. V - 5000 m³, destroyed the highway Fiagdon – Khilak L= 40 m.

To provide anti-avalanche and mudflow hazards, it is necessary to use modern methods for detection of avalanche-prone and mudflow foci, including drones and other equipment. In places of constant avalanches and mudflows, we should build anti-avalanche galleries and tunnels on the roads.

3. Conclusions
Avalanches and mudflows in the mountainous territory of the Republic of North Ossetia-Alania is a threat to the lives of people, federal and inter-republican roads and economic facilities.

To prevent damage and ensure the safety of people from snow avalanches and mudflows, it is necessary to introduce modern methods of monitoring dangerous natural processes, as well as build avalanche galleries and tunnels on dangerous sections of roads.

4. References
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