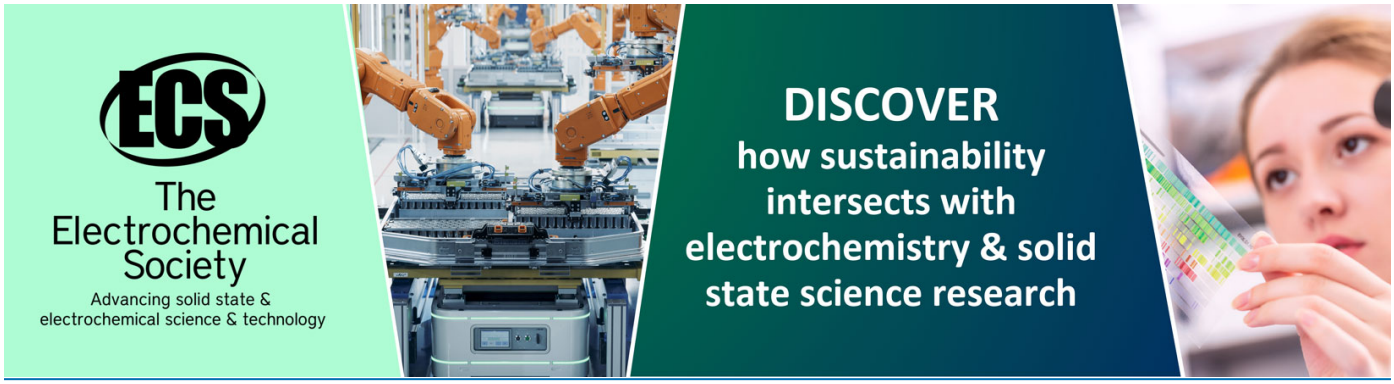
# The Debris-hazardous Areas' Research Methods (on the Republic of Ingushetia Example)





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# The Debris-hazardous Areas' Research Methods (on the Republic of Ingushetia Example)

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**Abstract**. The research methods of mudflow hazardous areas in the North Caucasus region are determined by the indicators that are priority in the development and study of similar areas. Mudflows require constant updating of their development territories' maps, as well as the various parameters used to predict the mudflow threats and develop the anti-mudflow measures. The authors of the article present the indicators, values and air regime temperature, amount, composition, intensity, and also the precipitation mode, as well as the size and intensity of the modern glaciation and snow cover melting, the territorial moisture content, the presence of small rivers with large channels slopes and their flood regime. The analysis of the proposed research methods, on the basis of reliable materials and collected as a result of the mudflow phenomena study in the mountainous territory in the Republic of Ingushetia, divides the areas into three categories of mudflow hazard, and presents a medium-scale map of the mudflow hazardous areas in the Republic of Ingushetia at a scale of 1: 500 000.

## Introduction

Being a complex dynamic system, mudflows require constant maps updating of their development territories, as well as the various parameters used to predict the mudflow threats and develop the anti-mudflow measures. In the North Caucasus region, mudflows are determined by orographic, the following indicators: air temperature values and regime, amount, composition, intensity, as well as the precipitation mode, size and intensity of the modern glaciation and snow cover melting, territory wetness, the presence of small rivers with large channel slopes and their flood regime.

In the mountainous zone, mudflows are formed everywhere. They are observed in the altitude range from 400 to 4000 m. The mudflows bulk (71%) originates above 2000 m in the subniveal and alpine zones.

In the North Caucasus region, mudflows are unevenly distributed, but the mudflow hazard areas can be clearly traced: I high, II medium, III low, IV very low, or potential [1,2].

The work related to closing the "white spots" on the mudflow maps, even of the economically well-developed areas has been completed. In modern conditions, when for the territory of the Russian Federation (RF) as a whole, the general laws, development areas and scales of mudflow phenomena are established, the most urgent task is to study them at the medium-scale level, regional or constituent entities of the Federation.

The main work objective is to evaluate the activity and danger of the mudflow basins in the selected mudflow areas in the Republic of Ingushetia on the basis of a comprehensive study. The authors made an attempt to give a detailed description of the mudflow activity in each district.

## Material and research methods

The mudflow phenomena zoning in the mountainous territories in the Republic of Ingushetia is based on the areas with varying degrees of mudflow hazard identification within the main morpho-structural zones. The methodological basis for identifying the mudflow hazardous areas was the development of the Kazakh Scientific Research Hydrometeorological Institute, namely, the criteria for the mudflow hazard categories in mountainous regions, taking into account the development of the mudflow outbreaks, mudflows and their parameters' certain genesis types within them, and is also based on the research, scientific and technical reports , generalizing documents and publications of the North Caucasus DHEM data on screening contained in the literary sources, on the archival and reference materials of the mudflow parameters taking into account the peculiarities of debris events in Eastern Caucasus.

## Research results and discussion

The mudflows are formed on the northern slope of the Main Ridge and its spurs, the southern slope of the Alpine Rocky Range, in the North Jurassic Depression between them, on the mid-mountain Pasture Ridge and the low-mountain Lesisty, Tersky and Sunzhensky Ranges in the Republic of Ingushetia.

The mudflow pools are unevenly distributed in the Republic of Ingushetia, but it is clearly possible to distinguish the mudflow hazard 3 categories areas (II-IV), the category I region, the region of high mudflow hazard, is absent (Figure 1) [2,3].

The II category area, the territory of the moderate mudflow hazard, is confined to the Main Range and its spurs, the southern slope of the Rocky Range and the North Jurassic Depression between them. It is characterized by:

- the medium size foci presence: incisions 1-3 km long, potholes 2-3 km long, with the areas of their catchments 3-4 $km^2$, rocky foci, foci of the dispersed mudflow formation, mudflow catchments or drainage surfaces of the medium activity with a filtration coefficient 0,01-0,05 mm/min.;
- sedimentary short-lived mudflow 250-100 $m^3/s$;
- one-time removal of mudstone mudflows more than 100 thousand $m^3$;
- low potential for the glacial-rain mudflows formation due to the glaciers and buried ice melting.

The river basin Armkhi has 12 mudflow basins, in which 58 mudflow outbreaks operate, 4 of which are the mudflow basins with fifty outbreaks located within the Main Range and its spurs: 44 rocky, 4 dispersed mudflow formation, 1 incision and 1 pothole. Rocky centers prevail here, forming at elevations of 2000-3970 m, which have catchment areas 0,3-5,7 $km^2$. Their rock collections are located on the slopes of ancient kars and troughs.

The dispersed mudflow formation foci are a system of potholes in the ancient glacial deposits and couloirs in primary clay shales. Despite the abundance of the loose material left by the intensely retreating small glaciers in the upper Shondon river, only one cut-out 1.2 km long at an altitude of 2930 m and one pothole 0.9 km long at an altitude of 3160 m were formed in glacial deposits. Their average depths are 10 and 3 m, respectively, and the average slopes is 13-17°. The main accumulation of mudflow occurs at absolute altitudes from 2200 to 1400 m. Another 8 mudflow basins located on the right side of the Armkhi river, confined to the northern side of the North Jurassic Depression and the escarpment of the Rocky Range. In six of them there are the dispersed mudflow formation foci, in one there is mudflow catchment and in one there is a rocky mudflow center [3,4].

The dispersed mudflow formation foci, in addition, represent a dense network of furrows, potholes, trays of microcells developed in alluvial crushed-clay, landslide and landslide-talus sandy-carbonate sediments. They are located at heights of 1800-3000 m, have the catchment areas 0,5-20,0 $km^2$, the watersheds average slopes 11-33°. The bulk of loose material for the formation of mudflows is supplied by the scree-streams and rock-type microseli, widely developed on the rocky ridge of the Rocky Range, landslide-streams in the upper selenose streams and numerous mudflows along their channels. Accumulation of mudflow occurs in the Armhi valley at altitudes from 1300 to 900 m.

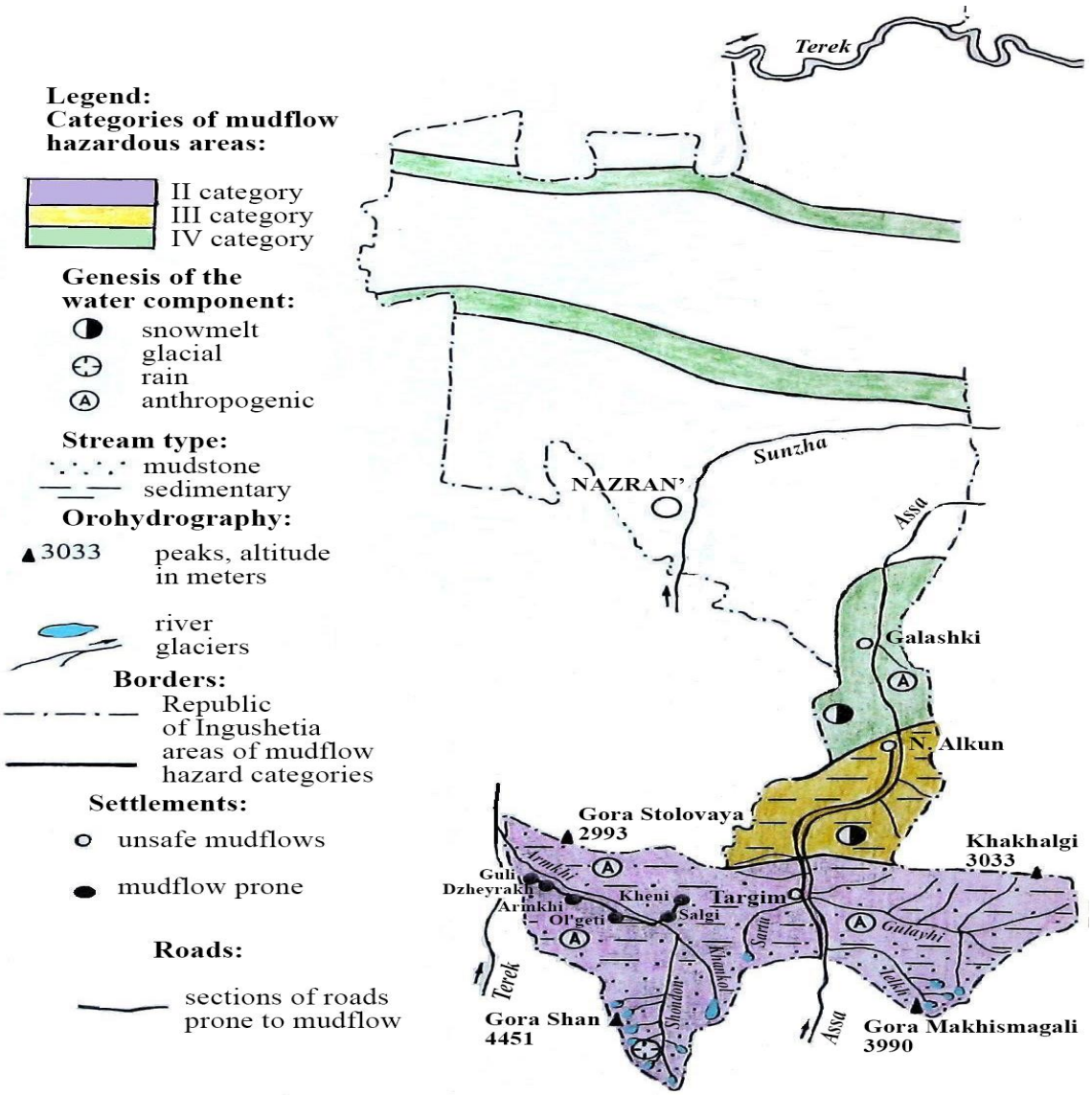


**Figure 1.** The mudflow hazardous areas in the Republic of Ingushetia Map-scheme

The river basin Assa has 10 mudflow basins with 45 mudflow centers. 2 mudflow basins and 25 outbreaks (23 rocky and 2 dispersed mudflows) of these are confined to the Main ridge and its spurs, 8 mudflow basins and 20 outbreaks (8 dispersed mudflow formation, 6 rocky, 3 cuts, 2 mudflow catchments, 1 pothole) - in the North Jurassic Depression territory.

Rocky foci are observed at the places where the intrusive bodies reach the surface. They are formed at heights of 2600-3650 m, have the catchment areas 0.3-1.2 km$^2$ and average slopes 34-45˚ [5,6].

The dispersed mudflow formation centers are confined to the northern side of the North Jurassic Depression and the foot of the Rocky Range. They are located at heights of 1800-2900 m, have the catchment areas 0,7-12,0 km$^2$ and the average slopes 12-22°.

Cuts and potholes are concentrated near the mouth of the Sartu river and on its port side in the clay deposits of the large landslide massifs confined to the fault zone of the submeridional direction. The

cuts have a length of 0.9-1.5 km, a width of 30-60 m and a depth of 10-25 m. The foci have the catchment areas 0,3-0,8 $km^2$, the characteristic biases 13-18° located at absolute altitudes of 1200-1800 m.

The mudflow catchments are located at absolute heights of 1500-2200 m. Their area is 2,6-3,8 $km^2$, the average slopes - 11-18˚.

Clear alpine relief with the developed glacial forms and altitudes of more than 3,000 m, unaffected, weakly grained, highly active drainage surfaces of mudflow foci with the slopes exceeding 25-30° a significant precipitation amount contributes to the development of very active mudflow activity within the Main Ridge and its spurs. In the Lyazhginsky and Olgitsky gorges, in the valleys of the Shondon, Hankol rivers (Armkhi basin), the right tributaries of Sartu, the left tributary of the Gulaihi, in the valley of the river Nelkh is dominated by the mud-stone flows of the medium volumes rain genesis (10-100 thousand $m^3$). There is a possibility of the glacial-rain mudflows' formation due to the melting of small kar glaciers and buried ice of significant volumes (more 100 thousand $m^3$) in the river valley Chondon (Armhi pool).

The climate is very dry due to the presence of a "rain shadow" south of the Rocky Range, small differences in absolute heights (1500-2000 m), the presence of the slate Jurassic shales, the weathering products of which are the small-sized plates washed away by the precipitation, which rarely occur, but with high intensity, not having time to be accumulated in any significant size; almost continuous afforestation and sodding determine the weak development of the mudflow activity within the North Jurassic Depression [6.7]. Above the Rocky Range, on the starboard side of the Armhi Valley, from the mouth to the confluence of the Salga tributary, and along the Assa Valley, as well as its tributaries Sartu and Gulaihi, both mudstone and suspended streams of small volumes (up to 10 thousand $m^3$) rain genesis. Mud-stone mudflows often do not reach the main channel or are transformed into the suspended streams as they move along the main channels. The formation of limnogenic and snow-rain mudflows is possible, and in the areas of logging, road construction and cattle grazing - man-made mudflows, especially in the assimilated Targim depression in the Assy valley.

The mudflow hazard period is April-September, and the period of the highest mudflow for the predominant rainfall mudflows is May-June, which is associated with a maximum of atmospheric precipitation.

The average mudflows recurrence is once every 5-10 years.

In this mudflow hazard area, mudflows periodically threaten 6 settlements, 1 health institution and 3 road sections: Guli, Dzheyrah, Armhi, Olgeti, Salgi, Heni, health-improving complex in Armkhi and the following sections of roads: Guli - Dzheyrakh - Armhi - Olgeti - Salgi - Henie; Armhi - Targim; Targim village - border with Georgia.

The III category area, low mudflow hazard, is orographically confined to the Rocky and Pasture ranges. It is characterized by:

- the development of predominantly small foci and weakly active drainage surfaces with a filtration coefficient 0,05-0,1 mm/min.;
- suspended streams' rates 100-10 $m^3$/sec;
- mudstone mudflows' lumps 100-10 thousand $m^3$.

Despite the sharply dissected relief, the great steepness of the slopes, their lack of forest, the abundance of loose material and the large amount of precipitation falling in the warm period, mainly in the form of showers, mudflows here form locally, rarely and of low power, due to the large number of karst forms, absorbing most of the rainfall. On the ridges, the predominantly rocky foci are developed, located in limestone cliffs, foci of dispersed mudflow formation, which are a network of furrows, couloirs, talus trays and mudflow potholes less than 1 km long.

In this mudflow hazard area, three mudflow basins were noted.

One mudflow pool – Lamytchu river - located on the left side of the Assy Valley between the two spurs of the Rocky Range, in the upper part of the Assinovsky Gorge. The mudflow center is a branched system of potholes passing in rocks and gravitational accumulations. The extension cone has the following dimensions: length - 200 m, width - 100-150 m, overgrown with pine forest, does not

reach the Assa channel. The Lamytchu mudflow basin is characterized by a very rare occurrence - once every 40-60 years, which is explained, on the one hand, by the lithological composition of the rocks that make up the basin (limestones, sandstones), resistant to denudation processes and, on the other hand, the basin is located in the "rain shadow" created by the high spurs of the Rocky Range, as well as the karst of the massif.

Two more small nameless mudflow basins are located on the right side of the Assy Valley, respectively 4 and 6 km above the village Lower Alkun. Clear streams of the small capacity descend along both streams, the drifts of which reach the Assa channel.

The formation of mudflows is associated with rainfall and spring snowmelt.

Mudflow hazard - March-October.

Mudflows form on average 1 time in 5-10 years or less.

In this mudflow hazard area, mudflows periodically threaten a section of the highway between the village Lower Alkun - Targim Village.

***The IV category area, very low or potential mudflow hazard***, is orographically confined to the low-mountain Tersky, Sunzhensky and the advanced Wooded ranges. It is characterized by:

- suspended stream rates less 10 $m^3$/sec.;
- mudstone mudflows volumes less than 10 thousand $m^3$.

This category of mudflow hazard also includes the poorly studied areas or the areas where mudflows were not previously noted, but due to changes in the natural environment, they can occur.

Wide distribution of easily destructible rocks and conglomerates making ridges; the presence of permanent and temporary watercourses valleys with the development of erosion forms: beams, logs, ravines, systems of potholes and landslide processes on the clay slopes of their channels; a sufficient amount of precipitation, 80% of the annual norm of which falls in the warm period with a maximum in May-June, creates favorable conditions for the mudflows formation. [6.7]. At the same time, the presence of limestones composing the Woody Range, rocks very resistant to the denudation processes; small absolute heights of the ridges with gentle slopes, their karst and afforestation do not contribute to the widespread mudflow processes' development. In direct connection with a similar combination of these mudflow factors is a small number of mudflow basins in the territory under consideration, as well as a very rare occurrence of mudflows.

In this mudflow hazard area, one mudflow basin was noted, located within the axial zone of the Forest Range, opposite to the village Galashki. [7,8] The mudflow center is a branched system of mudflow potholes, embedded in semi-carbonate rocks, eluvial, eluvial-deluvial and proluvial-alluvial accumulations. The drainage basin of the mudflow basin is covered with dense deciduous forest, shrubs form a dense undergrowth. The mudflow deposits' width is 50-60 m, the length is 1 km. The deposits are small and medium clastic. The one-time volume of mudflows does not exceed 3-5 thousand $m^3$, most of them fall into the riverbed Assa without threatening the village Galashki.

In the territory under consideration, the occurrence of mudflows, mainly of a low-water-type suspended stream type, is associated with rainfall, less often with spring snowmelt. Due to logging in the area of the Forest Range, the mudflow activity may increase due to the anthropogenic mudflows.

The mudflow hazard period is March-October.

The ability to form mudflows is very rare - once every 15 years or less.

In the coming decades, in the North Caucasus, including the Republic of Ingushetia, due to climate warming, the duration of the mudflow season and the activity of mudflow activity at the altitudes of more than 2000 m will increase due to an increase in the length of the period with positive air temperatures, an increase in the amount of precipitation, and an increase in snow lines, increasing the river flow. [8,9] These phenomena will lead to an increase in the area of mudflow sites, and the processes of frost weathering will increase the influx of the loose fragments' significant masses into the river beds necessary for the mudflows' formation. As a result of the landscape zones' shift to the higher elevations, the economic load in the most elevated parts of the Republic will increase, which will strengthen the anthropogenic mudflows there.

**Summary**

Based on the analysis of the vast material accumulated as a result of the mudflow phenomena investigations, in the mountainous territory of the Republic of Ingushetia, three mudflow hazard areas are noted: II medium, III low, IV very low, or potential; 000. The studies were performed on the scientific and technical reports, general documents and publications of the high-altitude hydrometeorological research department of the North Caucasus DHEM.

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