

# Assessment of damage during the formation and passage of mudflows in the Tashkent region

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**Abstract.** Mountainous and largely foothill areas of the Republic of Uzbekistan are mudflow hazardous. In the Tashkent region, there are two mudflow river basins (dangerous concerning the manifestation of mudflows): the Chirchik river basin and the Akhangaran river basin. Based on the results of long-term observations of the Uzhydromet service, a digital map of the mudflow hazard in the Tashkent region for a century was compiled. The method for determining the damage from the action of mudflows on a specific object consists of determining the equivalent mudflow pressure according to its initial parameters. According to the methodology for assessing damage in the event of a natural emergency, the main parameters of the damaging factors were determined during the passage of a mudflow in the event of intense rainfall. The calculations were performed for two scenarios: 1) with dangerous rainfall with an intensity of 30 mm per day; 2) in case of especially dangerous rainfall with an intensity of 60 mm per day. Based on the calculations performed, the amount of damage to the national economy of the Tashkent region was determined during the passage of a mudflow caused by intense rainfall.

## 1 Introduction

In the Tashkent region, there are two mudflow river basins (dangerous concerning the manifestation of mudflows): the Chirchik river basin and the Akhangaran river basin.

Based on the results of long-term observations of the Uzhydromet service, a digital map of the mudflow hazard in the Tashkent region for a century was compiled (Fig. 1).

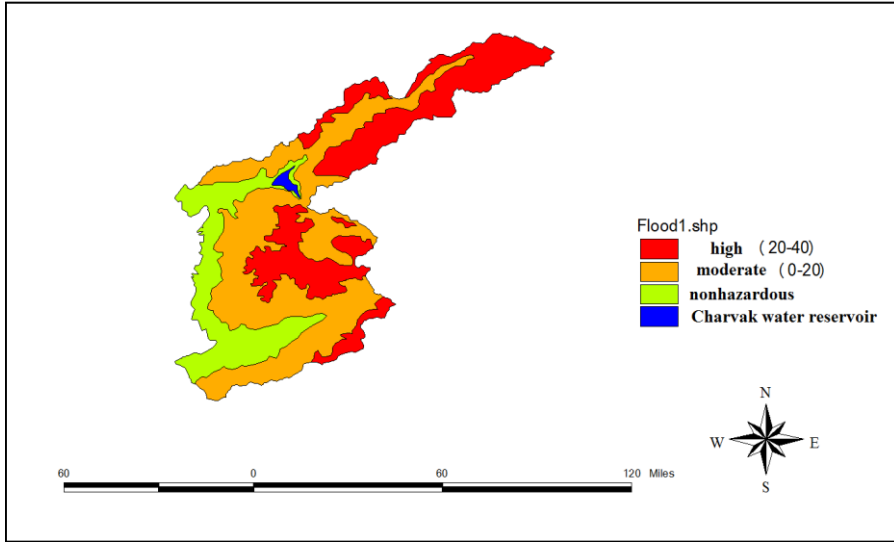
Based on a digital map made on the Arc View 3.2 and ArcGIS 10 platforms, the most dangerous areas of mudflow manifestations were identified, and settlements located in the area of high mudflow activity were identified [1-15].

Below in Table 1, the names of settlements that fall into the high-risk zone are given.

**Table 1.** Settlements falling into the high-risk zone

High-risk types	Place names
Mudflow hazard	Kumyshkan, Hisarak, Zarkent, Sukok, Nazdak (Nevich), Jartish, Yangiabad, Sayazar, Chinar, Chatau, Koksaray, Ertash, Beshkul, Nishbash, Pskem, Jaujurek, Takayangak, Tepar, Kushbulak, Mulala, Aktash.

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**Fig. 1.** Map of mudflow hazard in Tashkent region for a century.

The employees of the Ministry of Emergency Situations of the Republic of Uzbekistan provided information on the number of population in the above-mentioned settlements, the number of farms, the number of public facilities, the number of multi-storey houses of residence of the population, and information on the building materials used for buildings.

## 2 Methods

In the presence of certain initial data on the mudflow basin, it seems possible to predict by calculation the processes of movement and transformation of mudflows based on mathematical models describing these processes.

The maximum flow rate  $Q_c$ , the volume  $W$  of the outflow, the velocity  $V_c$  of the mudflow and the distance of its advance  $L_c$  can be approximately estimated analytically.

The maximum flow rates of mudflow-forming breakthrough  $Q^n$  and rainfall  $Q^d$  floods and their volumes  $W^{n(d)}$  are determined depending on specific conditions [16-20].

Due to the absence in the study area of the formation of mudflows due to the breakthrough of the ice (ice-ground) bridge formed by natural moraine lakes, further in the calculations, only the case of mudflow formation due to the intense fallout of liquid precipitation (rains) will be considered.

The value of  $Q^d$ ,  $m^3 / s$  of a rain flood, at a precipitation layer height of a given provision, is calculated by the formula:

$$Q^d = K_c H_1 \lambda F \quad (1)$$

Where:  $K_c$  is rainfall runoff coefficient, determined from the table. 2;  $H_1$  is maximum daily precipitation layer of 1% availability, determined according to the data of the nearest meteorological station;  $\lambda$  is transition coefficient from layers of rainfall runoff of 1% availability to layers of runoff with a different probability (Table 3.);  $F$  is catchment area,  $km^2$ .

For streams with a short observation series, it is possible to recommend the dependence of the distribution parameter  $\lambda$  on the average height of the river basin ( $Z$ ):

$$\lambda = 0.09Z^2 + 0.52Z - 0.40 \tag{2}$$

**Table 2.** - The value of the rainfall runoff coefficient  $K_c$  and the transition coefficient  $\lambda$  for the area under consideration

Area	The quantity $\lambda$ , % with the probability of exceeding equal to				$K_c \times 10^{-3}, s^{-1}$
	p, %				
	0.1	1.0	5.0	10	
Middle Asia	1.5	1.0	0.70	0.56	2.52

The foothill zone of the Tashkent region covers the Tien Shan mountain system in the range of heights from 300-400 to 600-1000 m above sea level. The intra-annual distribution of precipitation here is almost the same as in the desert - the maximum in March-April [1]–[29]. The mountainous zone extends above 600-1000 m above sea level. The average annual precipitation exceeds 400mm, in the upper zones of the mountains, on separate windward slopes, more than 2000mm can fall. Precipitation falls here all year round, but the maximum is in April-May. More precipitation falls in the mountains on the windward slopes of the Western Tien Shan; at high altitudes, the annual amount of precipitation exceeds 2000 mm. The number of days with precipitation on the flat territory averages 35-60 per year, and in the foothill and mountainous areas is 70-90. Heavy precipitation is quite rare: precipitation of 15mm / 12h and more on the plain is not observed annually, and in the mountains, the number of cases increases to 10-15.

Precipitation is considered dangerous, the amount of which in 12 hours or less exceeds 15 mm in case of rain and 7 mm in case of snow. The corresponding criterion for especially hazardous precipitation, which is considered a natural phenomenon, is considered to be fallout for the same period of 30mm with rain and 20mm with snow [21-28].

Summarizing the results given in, it can be noted that:

1. With the expected increase in precipitation, a slight increase in the frequency of mudflows should be expected;
2. For the same reason, an increase in the maximum discharge of mudflow floods is possible;
3. An increase in air temperatures will lead to a decrease in the proportion of mudflows of snow genesis, which, accordingly, will lead to an increase in the proportion of mudflows of rain origin.

In general, there is no reason to expect mitigation of the mudflow hazardous situation in the future.

We carry out calculations for two scenarios:

- a) for the case of dangerous rainfall 30mm per day;
- b) for the case of especially dangerous rainfall - 60mm per day.

Considering the above, the magnitude of the rain flood  $Q^d, m^3 / s$  along the Pskem and Koxsu rivers in the Chirchik river basin and the Akhangaran river basin obtained from formula (1) were:

along the Pskem river -  $Q^d, m^3 / s$

- a) in case of dangerous rainfall  $Q^d = 288.036 m^3 / s$
- b) in case of especially dangerous rainfall  $Q^d = 576.072 m^3 / s$

on the river Koxsu -  $Q^d, m^3 / s F = 174 km^2$

- a) in case of dangerous rainfall  $Q^d = 19.73 m^3 / s$
- b) in case of especially dangerous rainfall  $Q^d = 39.46 m^3 / s$

on the river Akhangaran -  $Q^d, m^3 / s$

- a) in case of dangerous rainfall  $Q^d = 125.874 m^3 / s$
- b) in case of especially dangerous rainfall  $Q^d = 251.748 m^3 / s$

The volume of water flood  $W^d$ ,  $m^3$ , flowing out in case of precipitation with a layer of a given provision, is determined by the formula:

$$W^d = 9,5 \times 10^2 H_1 \lambda F \quad (3)$$

- on the river Pskem –  $W^d$ ,  $m^3$
- a) in the event of dangerous rainfall  $W^d = 108585000 m^3$
  - b) in case of especially dangerous rainfall  $W^d = 217170000 m^3$
- on the river Koksus –  $W^d$ ,  $m^3$
- a) in the event of dangerous rainfall  $W^d = 7438500 m^3$
  - b) in case of especially dangerous rainfall  $W^d = 14877000 m^3$
- on the river Akhangaran -  $W^d$ ,  $m^3$
- a) in the event of dangerous rainfall  $W^d = 47452500 m^3$
  - b) in case of especially dangerous rainfall  $W^d = 94905000 m^3$

Maximum consumption  $Q_c$ ,  $m^3/s$ , of mudflow is determined by the formula:

$$Q_c = (1 + 0,12 \sin^2 \alpha) Q^d \quad (4)$$

Where:  $l$  is the length of the mudflow,  $m$ ;  $\alpha$  is slope of the mudflow center, degrees;  $Q^d$  is the maximum flow rate of the water flow entering the mudflow center,  $m^3/s$ .

- on the river Pskem –  $Q_c$ ,  $m^3/s$
- a) in the event of dangerous rainfall  $Q_c = 2403027 m^3/s$
  - b) in case of especially dangerous rainfall  $Q_c = 4806054 m^3/s$
- on the river Koksus -  $Q_c$ ,  $m^3/s$
- a) in the event of dangerous rainfall  $Q_c = 59227.49 m^3/s$
  - b) in case of especially dangerous rainfall  $Q_c = 118455 m^3/s$
- on the river Akhangaran -  $Q_c$ ,  $m^3/s$
- a) in the event of dangerous rainfall  $Q_c = 587589 m^3/s$
  - b) in case of especially dangerous rainfall  $Q_c = 1175178 m^3/s$

Volume  $W_c$ ,  $m^3$ , mudflow is calculated by the formula:

$$W_c = (1 + 0,12 \sin^2 \alpha) W^d \quad (5)$$

- on the river Pskem –  $W_c$ ,  $m^3$
- a) in the event of dangerous rainfall  $W_c = 1,08706E+12 m^3$
  - b) in case of especially dangerous rainfall  $W_c = 2.17412E+12 m^3$
- on the river Koksus -  $W_c$ ,  $m^3$
- a) in the event of dangerous rainfall  $W_c = 26791898780 m^3$
  - b) in case of especially dangerous rainfall  $W_c = 53583797561 m^3$
- on the river Akhangaran -  $W_c$ ,  $m^3$
- a) in the event of dangerous rainfall  $W_c = 2.65805E+11 m^3$
  - b) in case of especially dangerous rainfall  $W_c = 5.31609E+11 m^3$

Advance speed  $V_c$ ,  $m/s$ , mudflow can be calculated using the formula:

$$V_c = 11,4 \sqrt{h} \times \sqrt[3]{v_0 \sin \alpha} \quad (6)$$

where:  $v_0$  is relative hydraulic size of stone materials involved in the flow;  $\alpha$  is mean slope of mudflow channel, degrees;  $h$  is average flow depth, m. For a quick assessment, the value  $h$  usually taken: for low-power flow 1.0 ... 1.5 m; for an average power flow of 2 ... 3 m; for powerful flow 3 ... 5 m;  $v_0 \sim 0.7...1.0$ ;

When determining the speed of the mudflow, we take for two cases:

for slopes  $10^\circ$

a) in the event of dangerous rainfall ( $h=2$ )  $V_c = 10.0$  m/s

b) in case of especially dangerous rainfall ( $h=3$ )  $V_c = 14.0$  m/s

for slopes  $20^\circ$

a) in the event of dangerous rainfall ( $h=2$ )  $V_c = 12.8$  m/s

b) in case of especially dangerous rainfall ( $h=3$ )  $V_c = 16.0$  m/s

The movement distance  $L_c$  of mudflows is determined in two stages.

At the first stage, the distance of  $L_1$  advance is calculated, m, mudflow in the river valley

$$L_1 = \frac{12 \cdot W_c i}{dB} \tag{7}$$

where  $W_c$  is mudflow volume,  $m^3$ ;  $i$  is mean slope of the valley;  $d$  is average diameter of anchoring debris, taken: for mudflow incisions 0.5...0.8 m, for potholes 0.3...0.4 m and for foci of dispersed mudflow formation 0.1...0.2 m;  $B$  is average distance between mudflow coastal ramps.

At the second stage, the advance distance is calculated  $L_2$ , m, debris flow. The calculation is made under the condition  $L_1 > L_d$  According to the formula:

$$L_2 = \sqrt{36,6 \frac{(W_c - dBL_d) i_k}{d}} \tag{8}$$

where:  $i_k$  is average taper slope;  $L_d$  is distance from the end of the seedbed to the tops of the fan, m.

Mudflow advance range  $L_c$  defined similarly  $L_1$ , if  $L_1 > L_d$ . If  $L_1 < L_d$ , then the value  $L_c$  is defined as the sum  $L_c = L_d + L_2$ .

The consequences of mudflows impact on objects are assessed taking into account two indicators: mudflow hazard and mudflow activity using a complex criterion called reduced mudflow activity:

$$\bar{P} = \sum \frac{W_T}{T} \tag{9}$$

where  $\Sigma W_T$  is the total volume of mudflows over a certain long period of time  $T$ .

Due to the lack of data on the total volume of mudflows in the basins of the rivers under consideration, we apply the classification of basins available in the literature according to the height of the sources of mudflows, according to which there are the following zones:

1- Alpine mudflow zones. The headwaters lie above 2500m, the volume of outflows from 1  $km^2$  is 15-25 thousand  $m^3$  per mudflow.

2- Mid-mountain mudflow zones. The sources lie within 1000-2500m, the volume of removal from 1  $km^2$  is 5-15 thousand  $m^3$  per mudflow;

3- Low-mountain mudflow zones. The sources lie below 1000m, the volume of outflow from 1 $km^2$  is less than 5 thousand  $m^3$  per mudflow.

According to this classification:

• the valleys of the considered rivers Pskem, Koxsu and Akhangaran pass through the middle-mountain mudflow zone. The volume of removals per mudflow is 5-15 thousand m<sup>3</sup>;

According to fig. 1 the frequency of occurrence of mudflows over hundred years along the Pskem river is 10-20 mudflows on the river Koxsu 20-40 mudflows; along the Akhangaran river 5-10 mudflows.

Considering the above, you can calculate the volume of mudflows:

on the Pskem river basin  $\Sigma W_{100} = 15000\text{m}^3 \times 20 \text{ селей} = 300000 \text{ m}^3, \bar{P} = 3000 \text{ m}^3;$

on the Koxsu river basin  $\Sigma W_{100} = 15000\text{m}^3 \times 40 \text{ селей} = 600000 \text{ m}^3, \bar{P} = 6000 \text{ m}^3;$

on the Akhangaran river basin  $\Sigma W_{100} = 15000\text{m}^3 \times 10 \text{ селей} = 150000 \text{ m}^3, \bar{P} = 1500 \text{ m}^3.$

According to the above classification in terms of the reduced mudflow activity, all the river basins under consideration belong to the second class - a highly mudflow zone.

The category of mudflow hazard determines the type of mudflows, the passage of which is most typical for a given area. So, for the II category, medium-strong and powerful mudflows are characteristic.

To assess the consequences of the impact of a mudflow on specific types of buildings and structures, the value of the equivalent pressure P on the walls is used as the main criterion. At speeds of mudflow movement, usually not exceeding 20 m / s, the impact on the structure is quasi-static. The total pressure P is determined by the hydrostatic pressure, the velocity head of the flow, and the object's geometry (i.e., the initial impulse of the collision of the mudflow front with the object can be neglected).

When a debris flow acts on the plane of an object perpendicular to the direction of flow, the pressure P at a point at a depth of Y is determined by the formula

$$P = P_c + P_g \quad (10)$$

where:  $P_c = \rho g Y$  is static pressure,  $\rho$  is flux density,  $g$  is acceleration of gravity,

$$\rho = 1.9 \cdot 10^3 \text{ kg/m}^3 \\ g = 9.81 \text{ m/s}^2$$

static pressure  $P_c$  we define for conditions:

a) in the event of dangerous rainfall ( $h = 2\text{m}$ )  $Y = 2\text{m}$

$$P_c = 0.037278 \text{ MPa} (0.37278 \text{ kG/cm}^2).$$

b) in case of especially dangerous rainfall ( $h = 3\text{m}$ )  $Y = 3\text{m}$

$$P_c = 0.055917 \text{ MPa} (0.55917 \text{ kG/cm}^2).$$

$P_g$  is the mudflow pressure head is determined by the formula:

$$P_g = \frac{C \rho V_c^2}{2} \quad (11)$$

where:  $C$  is interaction coefficient;  $V_c$  is seed advance speed, m / s.

Here we consider the case of the action of the mudflow along the normal to the wall  $C = 1$ . for slopes 10°

- a) in the event of dangerous rainfall ( $h=2$ )  $V_c = 10.0$  m/s

$$P_g = 0.095 \text{ MPa}$$

- b) in case of especially dangerous rainfall ( $h=3$ )  $V_c = 14.0$  m/s

$$P_g = 0.1862 \text{ MPa}$$

for slopes  $20^\circ$

- a) in the event of dangerous rainfall ( $h=2$ )  $V_c = 12.8$  m/s

$$P_g = 0.155648 \text{ MPa}$$

- c) in case of especially dangerous rainfall ( $h=3$ )  $V_c = 16.0$  m/s

$$P_g = 0.2432 \text{ MPa}$$

The total displacement force acting on the object is determined by the formula:

$$N = F(P_{average} + P_g); P_{average} = \frac{\rho g H}{2} \quad (12)$$

where:  $F$  is the area of the projection of the streamlined part of the object onto the plane perpendicular to the direction of the mudflow movement,  $H$  is flow depth.

### 3 Results and discussion

According to the performed calculations, the value of the equivalent mudflow pressure according to its initial parameters for two possible scenarios:

- In the event of dangerous rainfall (30mm / day) changes from 0.909112 to 1.394296 MPa

In the event of a particularly dangerous rainfall (60mm / day), it changes from 2.569902 to 3.253902 MPa

With the passage of a mudflow and pressure, low-rise brick buildings, frameless, covered with reinforced concrete elements, have sat down with such a load.

Considering the above and considering that most of the private farms located in the mountainous area are a one-story brick building, they will all completely collapse.

From the information provided by the employees of the Ministry of Emergency Situations of the Republic of Uzbekistan, there are also multi-storey buildings with steel and reinforced concrete frames in the high-risk zone.

**Table 3.** The main results of the calculations carried out to assess the cost of damage when the mudflow passes through the mountainous regions of the Tashkent region

Name city and district	number of destroyed farms	assessment of the cost of damage (million sums)	number of destroyed public buildings	assessment of the cost of damage (million sums)	number of destroyed buildings	assessment of the cost of damage (million sums)	final estimate of the cost of damage (million sums)
Parkent district	6279	55462.41	18	1075.75	50	3579.32	60117.48
Angren	623	5502.96	3	179.29	67	3688.70	9370.95
Akhangaran region	793	7004.57	6	358.58			7363.15
Bostanlyk district	2541	22444.65	5	298.82			22743.47
Total for Tashkent region							99595.05

## 4 Conclusions

Summing up, the following can be noted:

1. With the formation of the passage of a mudflow, formed by intense rainfall on the territory of the Tashkent region, two dangerous areas are distinguished:
  - open to the west valley of the Chirchik river, where the maximum average frequency of heavy precipitation is 2-3 cases (half a day) per year;
  - open to the southwest valley of the Akhangaran river with a maximum average frequency of 3-6 cases per year.
2. The foothill zone of the Tashkent region covers the Tien Shan mountain system in the range of heights from 300-400 to 600-1000 m above sea level. The intra-annual distribution of precipitation here is almost the same as in the desert - maximum in March-April. The mountainous zone extends above 600-1000 m above sea level. The average annual precipitation exceeds 400mm, in the upper zones of the mountains, on separate windward slopes, more than 2000mm can fall. Precipitation falls here all year round, but the maximum is in April-May. More precipitation falls in the mountains on the windward slopes of the Western Tien Shan; at high altitudes, the annual amount of precipitation exceeds 2000 mm.
3. Based on a digital map made on the platforms Arc View 3.2 and ArcGIS 10, the most dangerous areas of mudflows were identified, and settlements located in the area of high mudflow activity were identified.
4. According to the methodology for assessing damage in the event of a natural emergency, the main parameters of the damaging factors were determined during the passage of a mudflow flood with intense rainfall. The calculations were carried out for two scenarios: 1) with dangerous rainfall with an intensity of 30 mm per day; 2) in case of especially dangerous rainfall with an intensity of 60 mm per day.
5. To assess the economic damage during the passage of the mudflow, the ANNEX to the National Standard for Property Valuation of the Republic of Uzbekistan (NSOI No. 12) "Assessment of the value of the real estate by mass valuation methods"



- 6 According to the calculations:
  - a) during the passage of a mudflow, formed as a result of especially dangerous rainfall with an intensity of 60 mm per day, the damage will be 99.59505 billion sums.
  - b) during the passage of a mudflow formed from dangerous rainfall with an intensity of 30 mm per day, the damage will be: 97.3773 billion sums.

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