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HAZARD MITIGATION FOR LANDSLIDE DAMS IN MAILUU-SUU VALLEY (KYRGYZSTAN)

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INTRODUCTION

The area in the midstream of the Mailuu-Suu River is the most landslide-prone and vulnerable of the entire Kyrgyzstan territory. More than 200 landslide sources distinct by genesis, age and development stages have been fixed at present in the outskirts of the Mailuu-Suu town within an area of 80 km^2 only.

The main reasons of mountain slopes instability in this area are the geologic conditions and geodynamic peculiarities of the region. Seismic, climatic and man-caused factors play a role of rather a trigger mechanism for landslide initiation and development.

Among the general geologic factors that lead to the intensive development of landslide processes in the area besides the Mailuu-Suu valley specific topography and erosion processes are the following:

- composition, characteristics and bedding conditions of rocks and soils on the slopes, specifically the most active landslides are developed in loess-like loamy soils of the Quaternary period (Q_1 - Q_3), as well as in slightly consolidated Mesozoic-Cenozoic sediments, layered by strata of weakly stable fissured limestones and sandstones alternating with interlayers of clays and siltstones;
- watering of soils and rocks which are components of unstable slopes either by large quantity of atmospheric precipitation infiltration or by groundwater impact including the ones coming along tectonic failures from the remote mountainous feeding areas of the Boobash-Ata mountain range (Fergana ridge);
- structurally-tectonic and geodynamical features of the area, namely tectonic dislocations and folds.

The studied region is characterized by high seismicity (M»7) associated with modern geodynamic activity and continuous orogenic processes. Contemporary recent horizontal (up to 10 mm/year) and vertical (up to 5 mm/year) earth crust movements are actively developed here. Besides, the area of the development of numerous and active landslides in the eastern mountain framing of Fergana valley coincides spatially with the zone of the intensive compression caused by the south-north pressure from the Pamirs side (Wetzel *et alii*, 2000).

Along the Mailuu-Suu River valley edges and its main tributaries 40 landslides at a stage of the main movement or their preparatory phase have been registered. The most hazardous from them with relation to landslide river blockage with possible catastrophic effects are the large-sized Koi-Tash and Tectonic landslides located close by (Figure 1). These landslides generation started in 1954 on the left edge of the valley within the zone of the regional Central (Arslanbob) fault and the Main anticline. The detailed description of these and other landslides of considered area is presented in a series of papers (c.f. Torgoev *et alii*, 2001).

LANDSLIDE DAMS IN MAILUU-SUU

From the beginning of the current landslide activation period in Mailuu-Suu in the late 80th and in the early 90th 7 episodes of partial and complete river blockage triggered by landslides were fixed. Moreover,

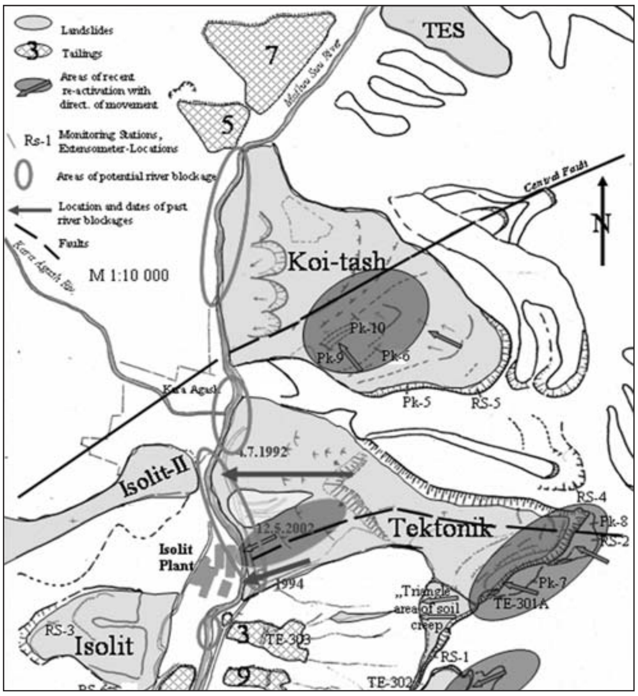

Figure 1 - Landslides and tailings in the Mailuu-Suu and areas of potential river blockage

5 of them were observed at the large Tectonic landslide site. The master data of landslide dams at this site are given in Table 1.

The most disastrous effects provoked river blockage in June 1992 when about 1.5×10^6 m^3 of landslide masses caved into the valley. The ground mass of the Northern tongue collapsed during 10-15 minutes with initial velocity approximately 5 m/s, after that the whole mass displacement continued for another 30 minutes. River valley on the blocked site has trapezoid profile with sufficiently wide bottom (90 m), therefore dam height didn't exceed 15 m and the river with maximum water fillup overtopped the landslide dam at the right edge of the valley gradually eroding the dam. However, regardless of that and of the relatively low water discharge in the river $Q \cong 20\text{-}25$ m^3/s (Q_{max}=108 m^3/s in 1969) the accumulated reservoir was about 6 m deep and flooded area affected two-storeyed dwellings, industrial buildings and constructions, transport and engineering services. Near the Isolith factory Southern landslide tongue passed through the saddle and reached valley bottom partially blocking the river. General damage caused by the landslide and flooding amounted almost 40 mln. US dollars. In 1994 as a consequence of repeated movements of the southern landslide tongue rather small tailing No 17 containing about 7000 m^3 of radioactive waste was carried away into the river and again it blocked the river located nearby the factory.

RISK ASSESSMENTS IN CASE OF POSSIBLE RIVER BLOCKAGE

It is worth noting that landslide potential on the Tectonic site has not completely exhausted yet. Besides, in 1993-94 landslide processes activation started at the Koi-Tash site with total volume of mass movement about 5×10^6 m^3 and with possibility of the river blockage.

In the head part of the Tectonic landslide, specifically on the Southern anticline flank there is more than 0.5×10^6 m^3 of soil and large amount of limestone debris in an unstable state. In case of further shearing at this part of the slope and simultaneous sliding of the entire unstable mass there is a possibility of repeated river blockage North of the Isolith factory. Besides, the most hazardous environmental threat is related to the sliding of about 80 thousand m^3 of debris towards tailings No 3, 9 and 18.

The main hazard during landslide-caused destruction of unstable tailing No 3 containing 120 thousand m^3 of high-activity radioactive waste is associated with its release into the river channel with subsequent radioactive contamination of flood-plain and river debris cone on the territory of Kyrgyzstan and Uzbekistan.

Thus, in case of possible landslide masses collapse onto the tailings No 3 and 18 hazardous processes may develop in two following ways:

"tails" gradually creeping into the river and their washout by river water where river water-level will neither flash and nor exceed the bounds of flooding zone as it was observed in April 1958 during tailing No 7 failure process;

volley (instantaneous) tails outburst into the river with riverbed blockage by tails and landslide masses triggering water accumulation above the dam level (Figure 2) and inundation of the Isolith factory territory. Unavoidable consequent dam breach will affect valley downstream by flooding and respective radioactive contamination.

The most substantial results of catastrophic phase modeling of tailings No 3 and 18 collapse caused by landslide are the following: in any variants of landslide collapse about 50% of high-activity tails and landslide masses will fall into the river flood-plain. They will form a dam 10-15 m high and 60 m wide (see figure 2). Maximum speed of landslide mass movement may amount up to 36 m/s and the catastrophic movement phase may last from 14 to 17 seconds. Total volume of accumulated water will be 120000 m^3 with river discharge average rate about 50 m^3/s during spring season. Dam will be overtopped in 40 minutes; in the extreme case (100 m^3/s discharge rate) it will take 20 minutes. Thus, the territory with absolute marks below 986 m, left-bank highway and the Isolith factory area will be inundated (Aleshin *et alii*, 2002).

Recently high probability of landslide masses increase and river blockage at the Koi-Tash site (see figure 1) was found. In such a case it will be possible that hazardous flooding can affect not only tailings No 5 and 7, but also outburst wave after dam breach with cause severe destruction and radioactive contamination of the river downstream. Recent landslide formation on the ancient landslide slope at Koi-Tash began in sixties. Shearing activation was fixed here in 1993-1994 when 22 dwellings lying on the landslide body have been deformed and destroyed.

According to the preliminary estimates the total volume of the

Data	Landslide volume (m^3)	Maximum height of dam (m)	Length of dam along its bed (m)	Landslide movement time	Material of dam	Commentary
28.02.1988	500 000	3.0	100	Minutes	Loamy soils	Northern part
04.07.1992	1 500 000	15.0	800	10-15 min.	Mixture of loam, detritus and gruss	Northern and Southern parts
15.05.1994	400 000	8.0	15	Minutes	Damped loamy soils	Southern part
May 1998	100 000	10.0	30	5 days	Mixture of loamy soils and debris	Northern part
12.05.2002	400 000	4.5	90	Minutes	Clays, detritus, limestone	Southern part

Table 1 - Landslide dams on the Tectonic landslide site

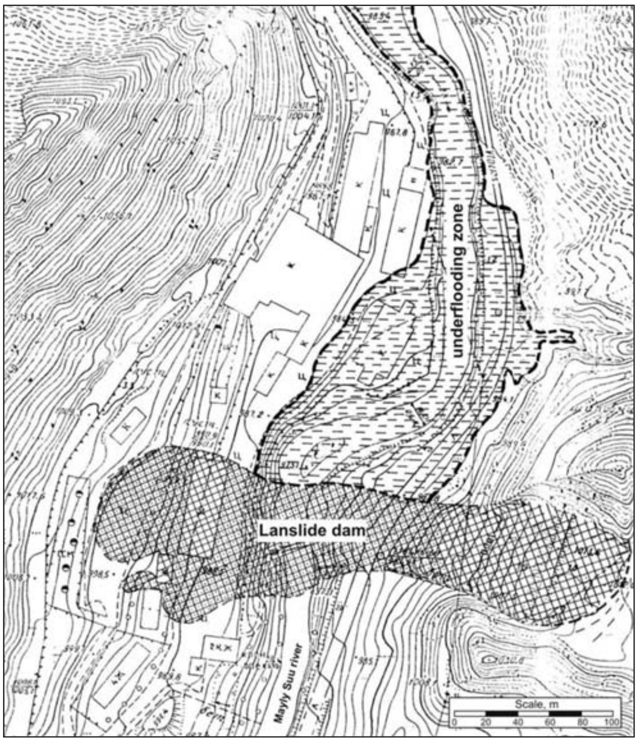

Figure 2 - Map of a zone of a sliding defeat and flooding at tailing No 3 destruction

Koi-Tash unstable part of the Koi-Tash slope is about 5×10^6 m^3 with average thickness of landslide body of 15 m and the landslide area of 330000 m^2. Landslide body is composed of loess-like loamy soils characterized by high porosity and low effective cohesion. The landslide is confined to the active central (Arslanbob) fracture zone branching from structurally dominating Talas-Fergana regional transorogenic fault.

According to the geophysical data substantial watering of landslide body usually takes place in July at the expense of groundwater coming along the central fault zone from the remote feeding terrain. In 1996 landslide movement monitoring was initiated using extensometers (TORGOEV *et alii*, 2001). Monitoring results testify the continuous movements beginning during moisture-abundant spring season in 1998, and their speed increased to 3-5 mm/day in February 2001 after earthquake series fixed within a radius of 200 km from Mailuu-Suu town. The total magnitude of landslide head movement over a period from 1998 to 2003 came to 3 m.

The main hazard of Koi-Tash landslide simultaneous failure is the complete riverbed blockage and dam formation. In such a case the dam's height may reach 15 to 20 m. The riverbed will be blocked for more than 200 m. If maximum river discharge rate will be 100 m^3/s, than approximately within 3-5 days about 1×10^6 m^3 of water will accumulate and overtop the dam. In case of uncontrolled dam's breach the outburst discharge may exceed 600 m^3/s and the rate of flood wave may reach 5 m/s.

Such disastrous events and most of all the flood wave with more than 600 m^3/s of water discharge rate may lead to catastrophic consequences, specifically to tailings washout and to collapse of downstream civil, industrial buildings and objects of infrastructure (bridges, pipelines). Flood wave transformation inti destructive debris flow can not be excluded.

Another indirect effect of flooding and dam breach may be the destruction of large tailings No 5 and 7 in the time of rapid reservoir emptying with subsequent radioactive contamination of the valley and the river alluvial fan. This scenario is the most probable in case of considerable water saturation of tailings No 5 and 7 due to their inundation during a period of more than 6-7 days. If water discharge in the time of breach will exceed 600 m^3/s radioactive contamination can reach densely populated and highly productive Fergana valley on the territory of Uzbekistan.

ECOLOGICAL CATASTROPHE MITIGATION MEASURES

In terms of hazard identification of possible river blockages and tailings destruction risk assessments the team of the International and National experts within the framework of the preliminary stage of the World Bank Project "Kyrgyz Republic. Natural Disaster Mitigation Project" have proposed the following arrangements:

On the Tectonic landslide site – to remove some portions of landslide masses approximately 80000 m^3 in volume to decrease landslide impact risk for tailings No 3 and 18 and/or to transfer the tailing No 3 into safer place.

On the Koi-Tash landslide site owing to the impossibility to stabilize substantial volume of landslide masses for a long period of time and taking into consideration unavoidable river blockage in case of landslide activation the various engineering decisions have been proposed. The main goal of the decisions is to avoid the total river blockage in case of large landslide and thereby to prevent flooding of the tailings No 5 and 7 and outburst wave (VANDENHOVE *et alii*, 2003). It can be done by construction of the derivation tunnels on the rivers' right bank, in particular. River canalization as the more low-cost solution is possible to implement by reinforced-concrete pipes or canals covered by concrete wall restraining landslide masses that finally will provide for free river flow preventing flooding hazard for tailings No 5 and 7.

CONCLUSIONS

Slopes of the Mailuu-Suu River valley that pass through the radioactive waste warehousing area of the former uranium mine are affected by large-scale landslides, which develop actively owing to specificity of geologic and natural conditions, of high seismic and geodynamic activity of the region and due to results of intensive man-caused impact.

During the last 10 years the phenomena of complete or partial damming of Mailuu-Suu River was studied and monitoring of the landslide-prone slopes have been performed. It was found that activation of large-scale landslides could lead to river damming with disastrous consequences due to possible radioactive waste tailings destruction. It is concerned to the Tectonic landslide which directly threat tailings No 3 and 18, and, especially to the Koi-Tash large-scale ($V=5\times10^6$ m^3) landslide. In case if the latter with collapse entirely, the formation and subsequent catastrophic breach of landslide dam may occur causing radioactive waste tailings collapse and large areas within the river valley and its alluvial fan contamination, which may affect both Kyrgyzstan and Uzbekistan.

To avert disastrous effects of river damming a series of engineering decisions have been proposed. The most effective and reliable are the Tectonic landslide cut off and drainage and/or the derivation tunnels (canals) construction at the Koi-Tash landslide site.

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