Conference Paper, Published Version

Beguš, Tomaz; Kocevar, Marko; Likar, B.

Risk assessment of uranium mill tailings disposal Boršt affected by a landslide

Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/99575

Vorgeschlagene Zitierweise/Suggested citation:
Beguš, Tomaz; Kocevar, Marko; Likar, B. (2011): Risk assessment of uranium mill tailings disposal Boršt affected by a landslide. In: Vogt, Norbert; Schuppener, Bernd; Straub, Daniel; Bräu, Gerhardt (Hg.): Geotechnical Safety and Risk. ISGSR 2011. Karlsruhe: Bundesanstalt für Wasserbau. S. 275-280.

Risk assessment of uranium mill tailings disposal Boršt, affected by a landslide

T. Beguš & M. Kočevar
Geoinženiring d.o.o., Ljubljana, Slovenia

B. Likar
Rudnik Žirovski vrh, Todraž, Slovenia

ABSTRACT: Risk analysis tools were implemented during closing activities on radioactive mill tailings disposal Boršt, affected by a landslide. The probability of landsliding before and after remediation works was calculated and expressed through relaiability index *β*. Choosing between three possible variants of redeposition of radioactive waste material was presented by a decision tree. When the closing construction activities were completed, all possible outcomes were determined by event tree diagram based on influence diagram construction. The geological elements that can cause adverse impact on mill tailings were determined and selected by geognostic map. The tools are very useful and outcome is clearly understandable to all the clients in the remediation process.

Keywords: Mill tailings, Landslide, Risk management, Probability of failure, Geognostic map

1 INTRODUCTION

Mining in the only uranium mine in Slovenia, Žirovski vrh, together with research and construction activities lasted for 30 years, from 1960 to 1990. In 1990 the mine was closed due to economic reasons and decomissioning and remediating activities begun. But just before the start of closing activities the landslide, consisting of Carnian clastic rocks and mill tailings material, occurred due to great autumn precipitation in 1990. A problem arised and besides environmental problems the landslide mitigation was of great interest as well. During planning certain risk management activities were implemented in two main steps:

- selecting the most suitable variant for radioactive mill tailings treatment and determining the reliability of calculating the stability of the landslide and
- determination of possible risk scenarios at the disposal site after the closure of the mine.

2 DESCRIPTION OF THE AREA

The mine closing activities included also the treatment of mill tailings disposal situated on hill Boršt, where landslide occurred. A volume of nearly three million cubic meters moved at average velocity of 1,2 mm/dy. Landslide is about 400 m long, 200 m wide and extends 36 meters in average depth (Beguš, 1994). The main remedial measure was the construction of an underground drainage tunnel, from the bottom edge of the landslide in the hinterland, and a construction of vertical drainage wells that diverted groundwater flow outside the landslide (Beguš et al., 1996).

Because of the landslide several alternatives for mill tailings (re)deposition were studied. Three possible variants were established (Figure 1).

- Variant A: Mill tailings stay on the Boršt location. The site must be improved as much as possible with all remediation and environmental protection measures;
- Variant B: Mill tailings and contaminated subsoil will be removed to the underground openings of the abandoned uranium mine;

- Variant C: Mill tailings and contaminated subsoil will be removed with transport into the mine waste disposal site Jazbec.

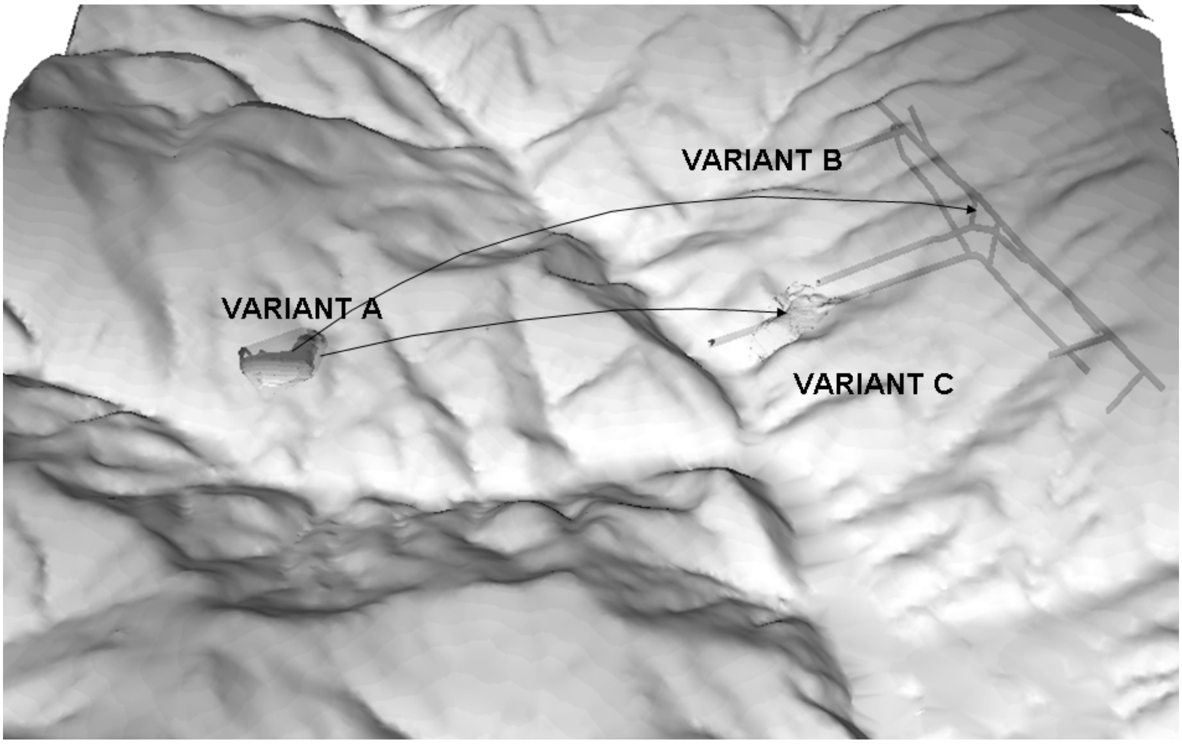

Figure 1. 3D view on the mill talings disposal Boršt, view toward southeast.

Choosing the most appropriate variant was carried out by means of decision-making matrix UMTRA (UMTRAP, 1988, Beguš, 2001). It was necessary to ensure that the level of knowledge for all areas of interes was the same, so we could compare the parameters of the same level. According to the evaluation of parameters the most suitable was variant B (move into the underground mine), but later variant A was accepted.

3 SELECTION OF THE MOST SUITABLE VARIANTS FOR MILL TAILINGS DISPOSAL AND CALCULATION OF RELIABILITY INDEX OF LANDSLIDE

Since sliding is a phenomenon that dictated selection of the site, the evaluation of the stability of disposal site was the most crucial task of the selection. Also the UMTRA matrix recommendations suggest examination of stability of the application by probabilistic approach. The stability of mine tailings disposal Boršt was evaluated with calculation of or reliability index β and calculation in available slope stability software (Rocscience, 2003).

The position of failure plane is well defined by cutted inclinometer boreholes on site. We used two situations: first, the situation in November 1990 when watertable in disposal and in bedrock were merged (Beguš et al., 1996, IBE, 1993) and the second with lowered watertable by drainage facilities, built in 1994. Also the stability of another possible site Jazbec was evaluated. The results are presented in table 1.

Table 1. Calculated factors of safety and probabilities of failure.

Case	Factor of safety – F_{ver}	Probability of failure %	Reliability index β, normal distribution	Reliability index β, lognormal distribution
Boršt in the time of sliding	0,999	50,570	-0,010	-0,058
Boršt after dewatering	1,147	9,570	1,318	1,365
Mine waste disposal Jazbec	1,964	$<10^{-5}$	3,604	4,911

When water levels decreased after dewatering works the probability of failure falls to 9.6%. The results show that the construction of a drainage tunnel in Boršt significantly improved the situation, but reliability index is still below recommended values (β > 3), so special additional and monitoring measures should be undertaken.

The landslide governs the decision, so we developed a example decision tree for the three variants with included probability of failure. According to this diagram the most favorable is variant A followed by variant B and the last is variant C, although the values are close one to another.

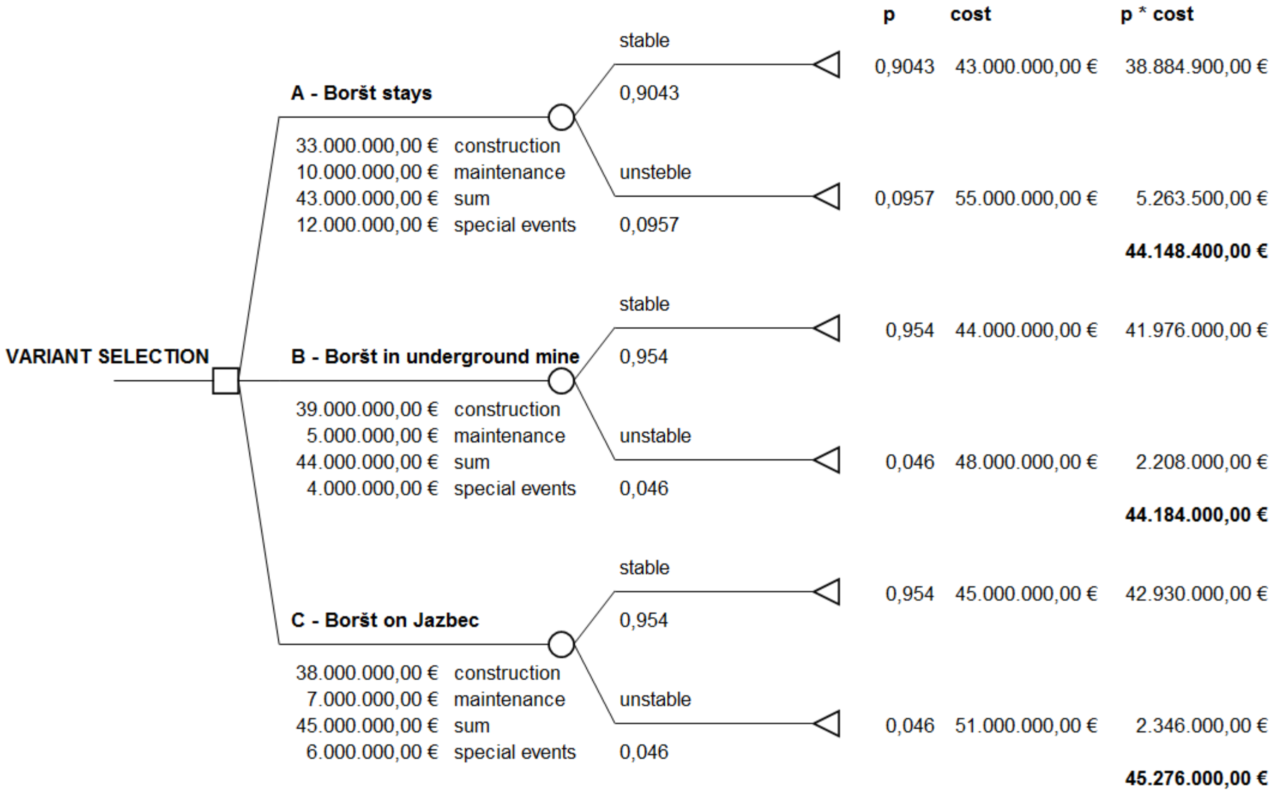

Figure 2. Decision tree for proposed variants of mill tailings material treatment.

4 RISK ANALYSIS AFTER THE MINE CLOSURE - GEOGNOSTICAL MAP

After the closure of the mine it was necessary to look at possible adverse scenarios. These were defined by a careful study of relevant areas of interest (Beguš et al., 2008). Studies were carried out on two levels:

- First level - looking at elements of geology: geological maps, hydrogeological maps, engineering geological map, map of construction, map of all objects etc. The presentation in 3D is a very important part of this level. In this level we were trying to present and process in 3D. Figure 3;
- Second level - evaluation and presentation of knowledge about the problem. We searched for the elements that adversely lead to the potential failure and the product is prepared in a manner that will be clearly understandable for all participants in the process. We called this level geognostic map.

According to Slovene dictionary (SAZU, 1980) geognosy is an archaic word for geology. The term can be refreshed to use as a preparation map about geological factors in a broad sense before risk analysis. In our case we were trying to express the processes about landsliding on Boršt area. The basic brick in geognostic map is geological map of the site. It was made by re-mapping and using all data, generated during research works before and during the construction. Some additional thematic maps representing possible outomes of landslide were made. Afterwards we made a model of the area with main characteristics that could lead to understanding of possible outcomes. For clarification, geognostic map is the synthesis that represents main factors and possible outcomes in a way that could be understandable to wide audience. This product may be the basis for determining the prognosis of possible further developments of phenomena and introduction to risk analysis.

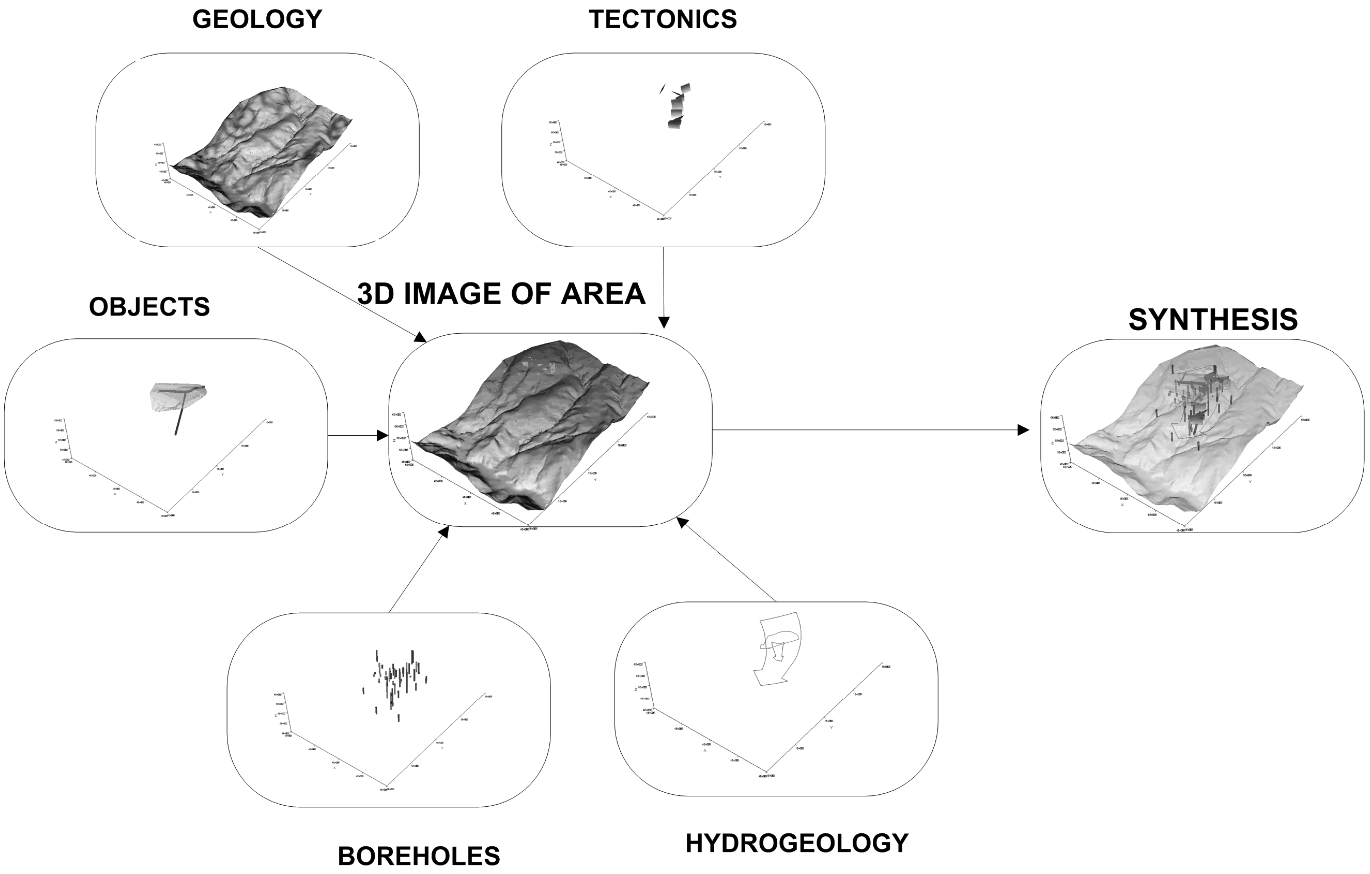

Figure 3. 3D images of disposal Boršt site.

This means that geognostic map searches for images regarding the site and unfavorable factors in the broadest sense and identify possible scenarios of adverse events. In the case of existing mill tailings and landslide we expose following factors:

- geology and tectonics
- hydrogeology and description of water flow,
- engineering geological factors,
- morphology of the terrain,
- movements on the landslide area.

Geognostical map contains a list of knowledge about a phenomena in terms of geological parameters that were determined during process by mapping the terrain, literature review and knowledge of the phenomena. We identify these factors which show clear causal links between parameters leading to landsliding. A graphic presentation of the using the major building blocks in making geognostic map for Boršt disposal site is given in figure 4.

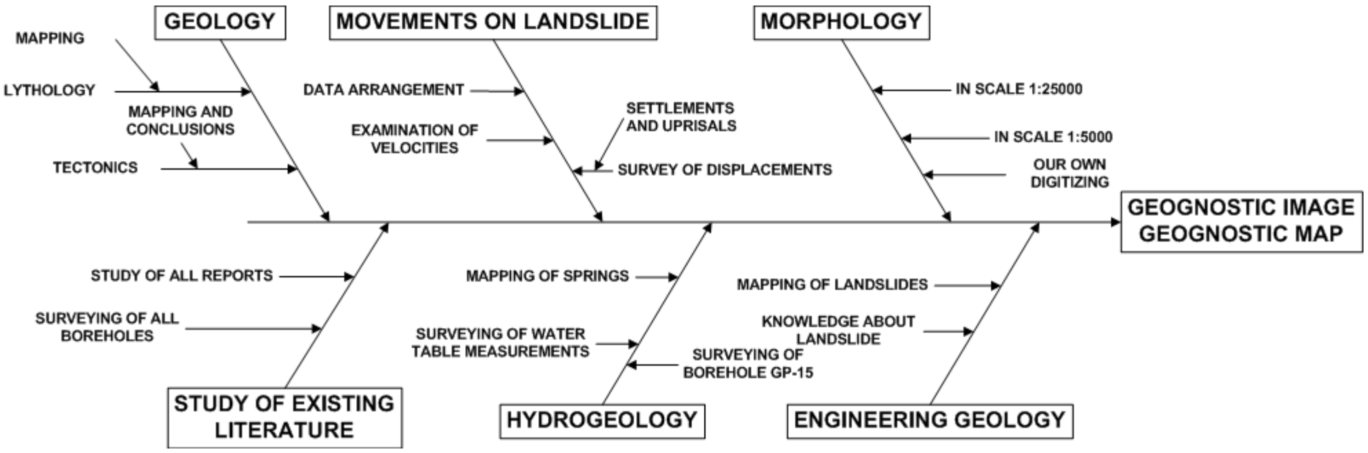

Figure 4. Construction phases in geognostic map construction.

The main factors that are most influental in Boršt area are as follows:

- Geology: geomechanically soft Carnian clastic rocks prevail, the area is interlaced with faults, where fractured zones of open fissures appear;
- Displacement on landslide: landslide is devided to five blocks bonded by faults which are moving separately;
- Morphology: Morphology is strongly dependent on the geology, deep erosional gullies show events in the landslide area in the past;
- Hydrogeology: two levels of ground water exist: in the mill tailins and in the bedrock. The water in cracks and water, that act on sliding surface also plays an important role.

Main parameters, that determine adverse events in broad sense, can be determined from geognostic map. We were especially interested in triggering factors, possible outcomes of landslide reactivation and in mitigation measures.

Based on determined triggering factors the influence diagram was constructed as a basis for event tree development (Baecher and Christian,2003, Hartford and Baecher,2004). Main concern was to determine

- main triggering factors,
- possible consequences of reactivated landslide
- coutermeasures for mitigation of undesirable scenarios.

From the above mentioned demands influence diagrams (Baecher and Christian, 2003, Hartford and Baecher, 2004) were constructed. It is clear that besides proper remediation works carefully selected monitoring is of great importance.

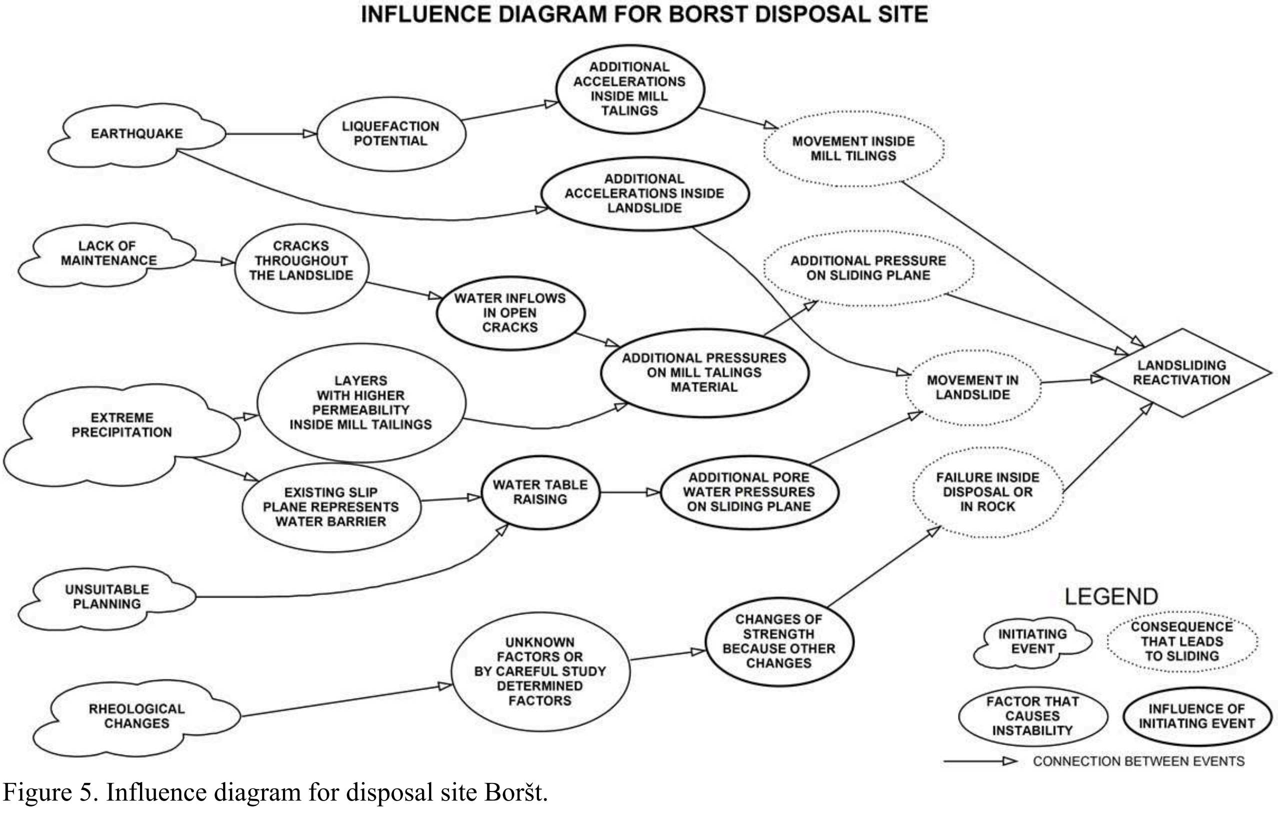

Figure 5. Influence diagram for disposal site Boršt.

5 EVENT TREES

Final issue of implementation of geognostic map and from influence diagram is developing the events into event trees according to triggering factors. The expected triggering factors were earthquake, extreme precipitation, lack of maintenance, unproper design and rheological changes in the landslide body. The presentation in figure 6 is qualitative.

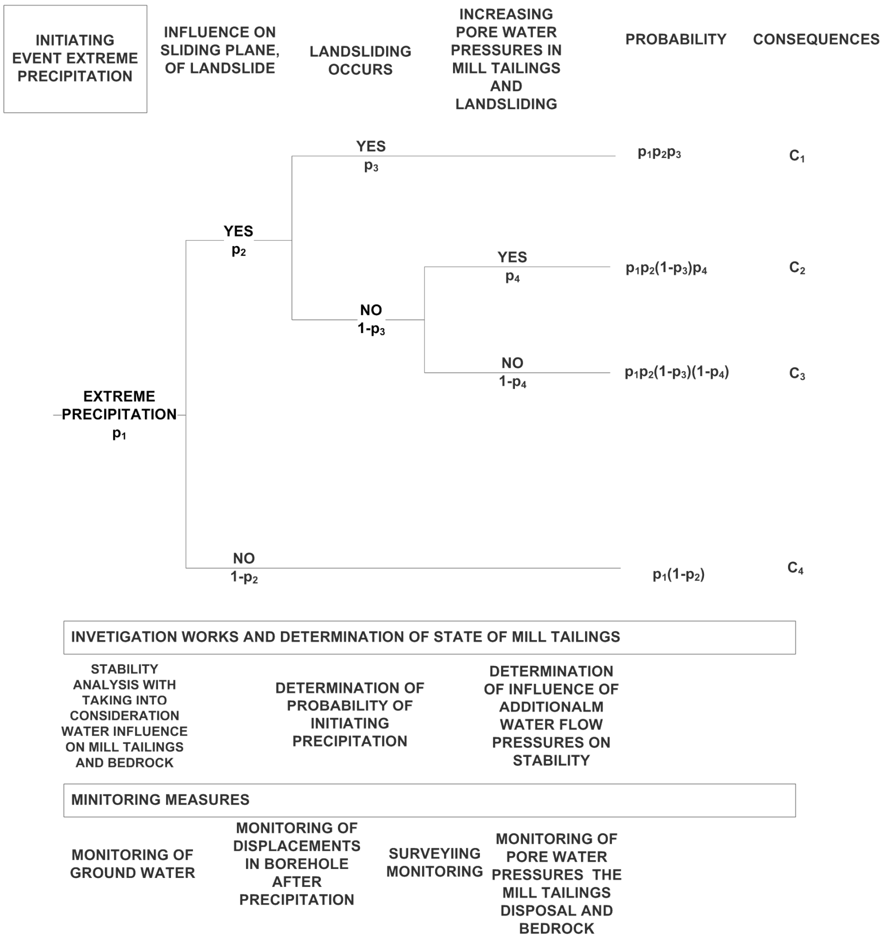

Figure 6: Event tree diagram – an example in occurence of extreme precipitation.

6 CONCLUSION

In large and environmentaly sensitive projects such as radioactive mill tailings disposal, risk analysistools should be included in every phase of operation of the facility. To get an idea about spatial relationships between geological features a three-dimensional picture of elements of risk is of great importance as well as a good knowledge of the areas concerned is basis for proper decision-making. Connection between good knowledge and presentation in a way that provides a knowledge and understanding of the problem is geognostic map - a compilation of data and knowledge, which is processed and presented in an understandable form.

REFERENCES

BAECHER, G. B. in CHRISTIAN, J. T. *Reliability and Statistics in Geotechnical Engineering.* Jonh Wiley & Sons Inc., 2003, 605 pages

BEGUŠ, T. Plaz na jalovišču hidrometalurške jalovine Boršt rudnika urana Žirovski vrh. In *Zbornik prvega slovenskega posvetovanja o zemeljskih plazovih*. Idrija, 1994.

BEGUŠ, T. *Izbira najprimernejše lokacije odlagališča hidrometalurške jalovine v rudniku urana Žirovski vrh: magistrsko delo*. Izdelano na Naravoslovnotehniški fakulteti, Oddelek za geologijo, Ljubljana, 2001, 141 str.

BEGUŠ, T., BUSER, I., ČADEŽ, F. in VIDMAR, S. Landslide stabilization of a mill tailing disposal by a drainage tunnel at the uranium ore mine Žirovski vrh, Slovenia. V *Proc. VII international symposium on landslides,* Editor Senneset, K. A.A. Balkema, Rotterdam, 1996, str. 1651-1656.

BEGUŠ, T., KADUNEC, K. in JAKOPIN, D. *Geognostična karta območja Boršt rudnika Žirovski vrh*. Report Geoinženiring Ljubljana, 2008.

HARTFORD, D. N. D. in BAECHER G. .B. *Risk and uncertainty in dam safety.* CEA Technologies Dam Safety Interest Group, Thomas Telford, 2004, 391 pages.

Rocscience Inc., *SLIDE 2D limit equlilbrium slope stability for soil and rock slope*. User's Guide. Rocscience Inc. 2003.

SAZU. *Slovar slovenskega knjižnega jezika.* Državna založba Slovenije, Ljubljana, 1980.

UMTRAP. *Alternate site selsction process for UMTRA Poject sites*. United States Department of Energy, 1988.