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Projects' achievements

Probabilistic risk assessment and mapping of pit lakes instabilities



M. Galetakis, V. Deligiorgis, E. Steiakakis, S. Raka-Technical University of Crete, TUC, Greece,



M. Al Heib - Institut national de l'environnement industriel et des risques, INERIS, France



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RAFF

Risk Assessment of Final Pits During Flooding

Grant Agreement No-847299-RAFF

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Introduction

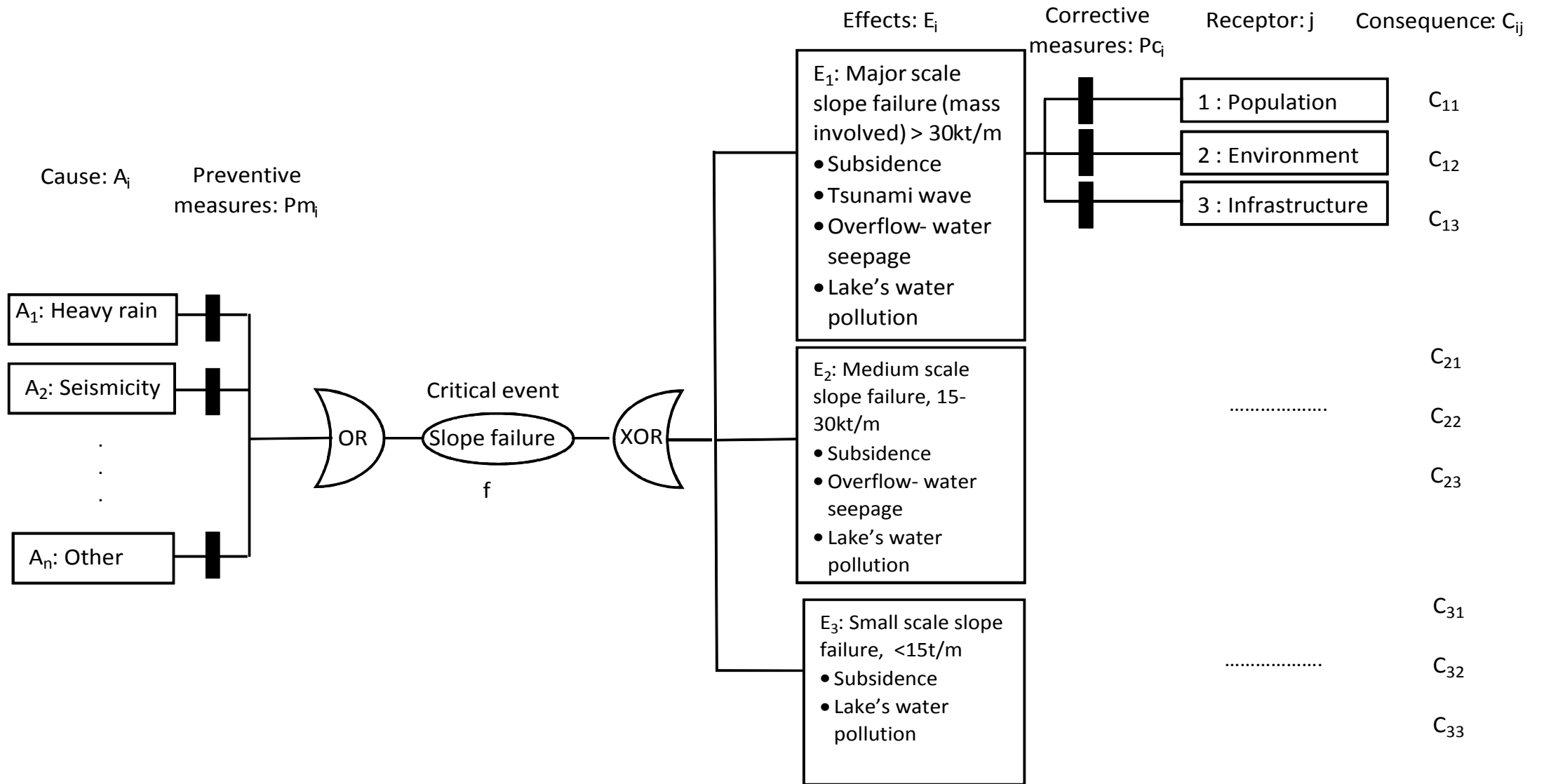
- Lake formation as a post-mining land use.
- Emerging problems from flooding can appear in the:
 - Population.
 - Environment.
 - Infrastructure.
- Assessing the risk from flooding large voids with:
 - Bow-tie analysis.
 - Systemic risk assessment.



Development of probabilistic risk assessment (PRA) methodology

- Boundary definition.
- Bow-tie method for hazard analysis.
- Systematic risk assessment methodology for risk estimation.
- Spatial analysis and risk map creation.

Bow-tie analysis of slope failure of pit lake



Systemic risk assessment (SRA) methodology

The risk R_{ij} of effect E_i on receptor j is:

- $R_{ij} = f P E_{ij} C_{ij}$ (1)

- f is the probability the initiating critical event.
- $P E_{i j}$ are the probabilities of effect E_i on receptor j .
- C_{ij} are the consequence of effect E_i on receptor j .

- $R_{ij} = f P C_i V_{ij} C_{ij}$ (2)

- Vulnerability V_{ij} of receptor j on effect E_i multiplied with the probability of failure of the corresponding protective measure $P C_i$ is equal to $P E_{i j}$.

The risks R_j for receptor j and R_i for effect i are:

- $R_j = f \sum_{i=1}^m P C_i V_{ij} C_{ij}$ (3)

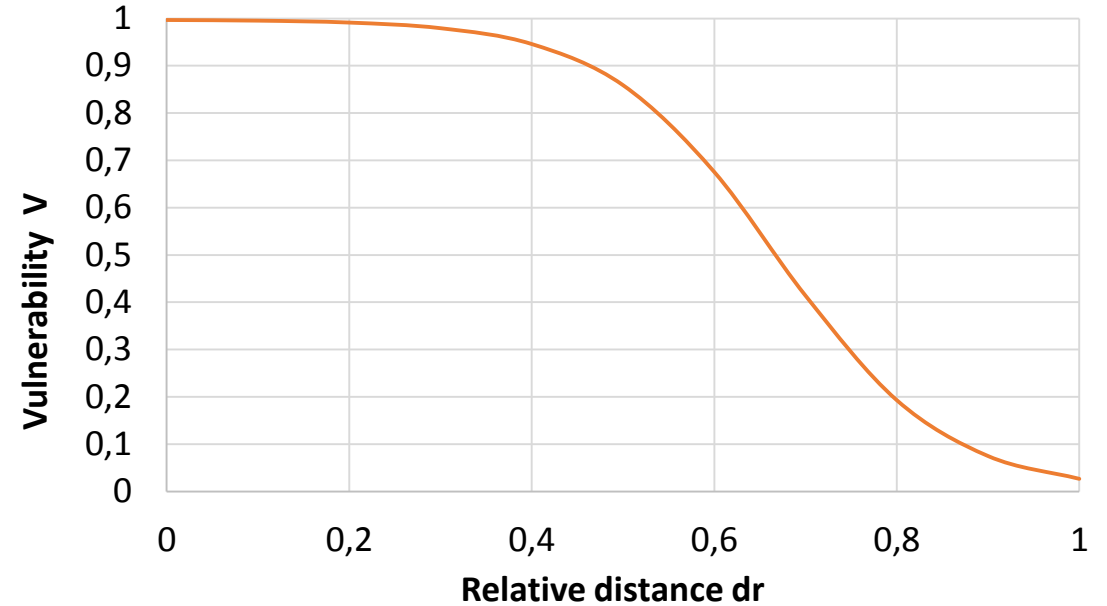
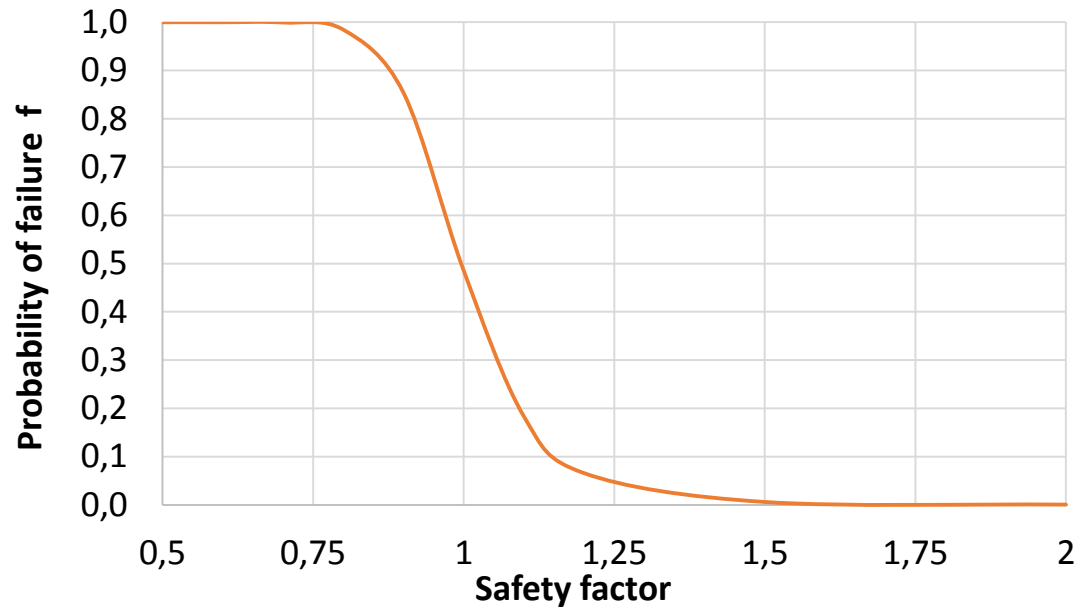
- $R_i = f \sum_{j=1}^n P C_i V_{ij} C_{ij}$ (4)

- where: $i=1,2,..n$ are the effects and $j=1,2,..m$ are the receptors. Eq. 3 is valid when effects E_i are mutually exclusive.

- Finally, the total risk R for all receptors and effects is:

- $R = \sum_{j=1}^m R_j$ (5)

Probability of failure and vulnerability estimation



Vulnerability parameter estimation
(inverted logistic S curve)

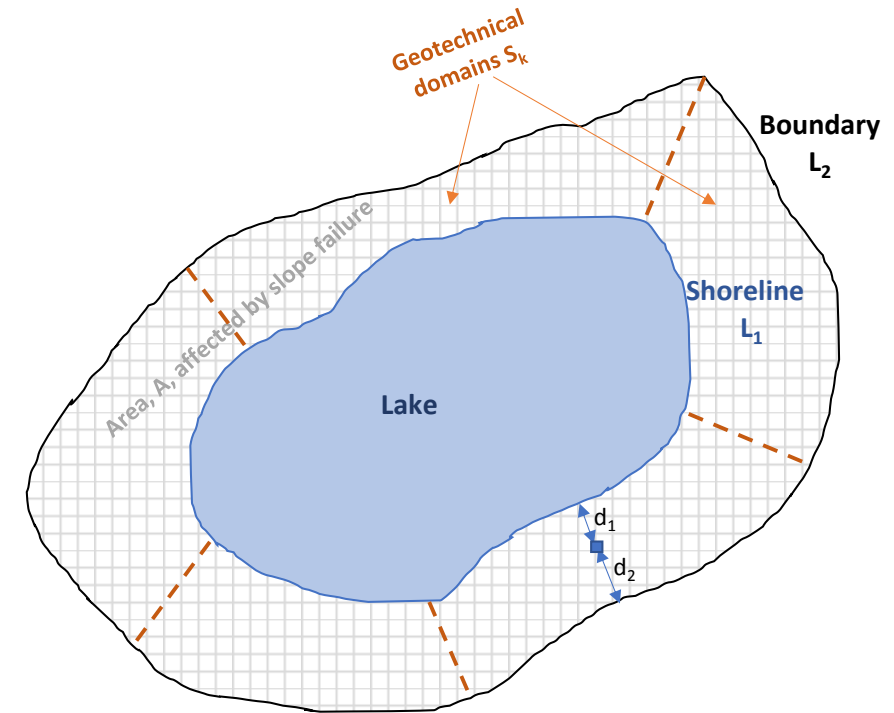
$$V = \frac{1}{a + be^{-cdr}}$$

Consequence scale for SRA

| Class | Linear scale [-] | Logarithmic Scale [€] | Description |
|--------------|-------------------------|------------------------------|---|
| 1 | 0.0-0.2 | $<10^4$ | Low (Negligible impact to human, to infrastructure and to environment) |
| 2 | 0.2-0.4 | 10^4 - 10^5 | Serious (Injuries, limited damages to infrastructure and to environment) |
| 3 | 0.4-0.6 | 10^5 - 10^6 | Very serious (Injuries with permanent disability, damages to infrastructure and to environment) |
| 4 | 0.6-0.8 | 10^6 - 10^7 | Severe (Limited fatalities, severe damages to infrastructure and to environment) |
| 5 | 0.8-1.0 | $>10^7$ | Catastrophic (Multiple fatalities, large-scale and severe damages to infrastructure and to environment) |

Spatial analysis and creation of risk map

- Determination of affected area A from the boundaries L_1 and L_2 .
- Discretization of area A into small squares $20 \times 20 \text{m}^2$ and relative distance $d_r = d_1 / (d_1 + d_2)$ calculation.
- Division of area A to k domains (S_k) based on geotechnical criteria.
- Estimation of risk for every square and creation of risk contours.



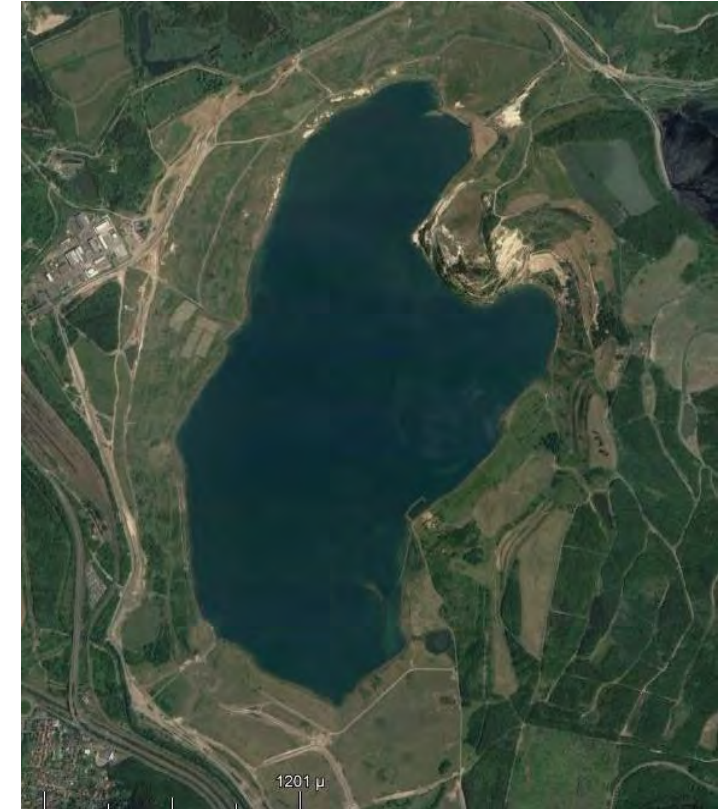
Boundaries, geotechnical domains and discretization of pit lake and affected area.

Lake Most location and characteristics

- The surface level of the lake is 199 m above sea level with maximum depth at 75m. It covers an area of 310 ha, with a perimeter of 8956m.
- The internal dump of the former Most mine forms the southern and eastern slopes of the lake.
- The mine benches form the northern and western slopes.
- The main instabilities are expected in northern due to dumping material and additionally to more steep slopes.



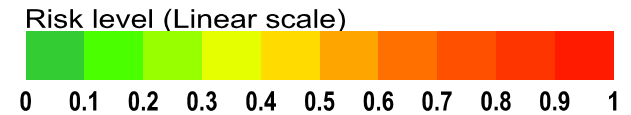
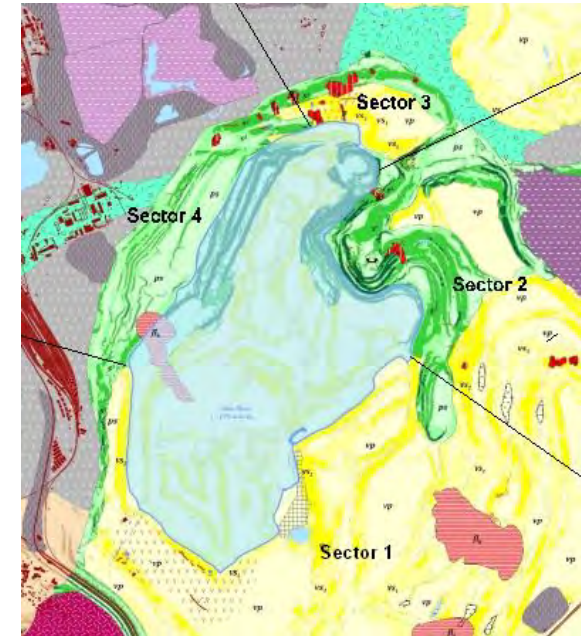
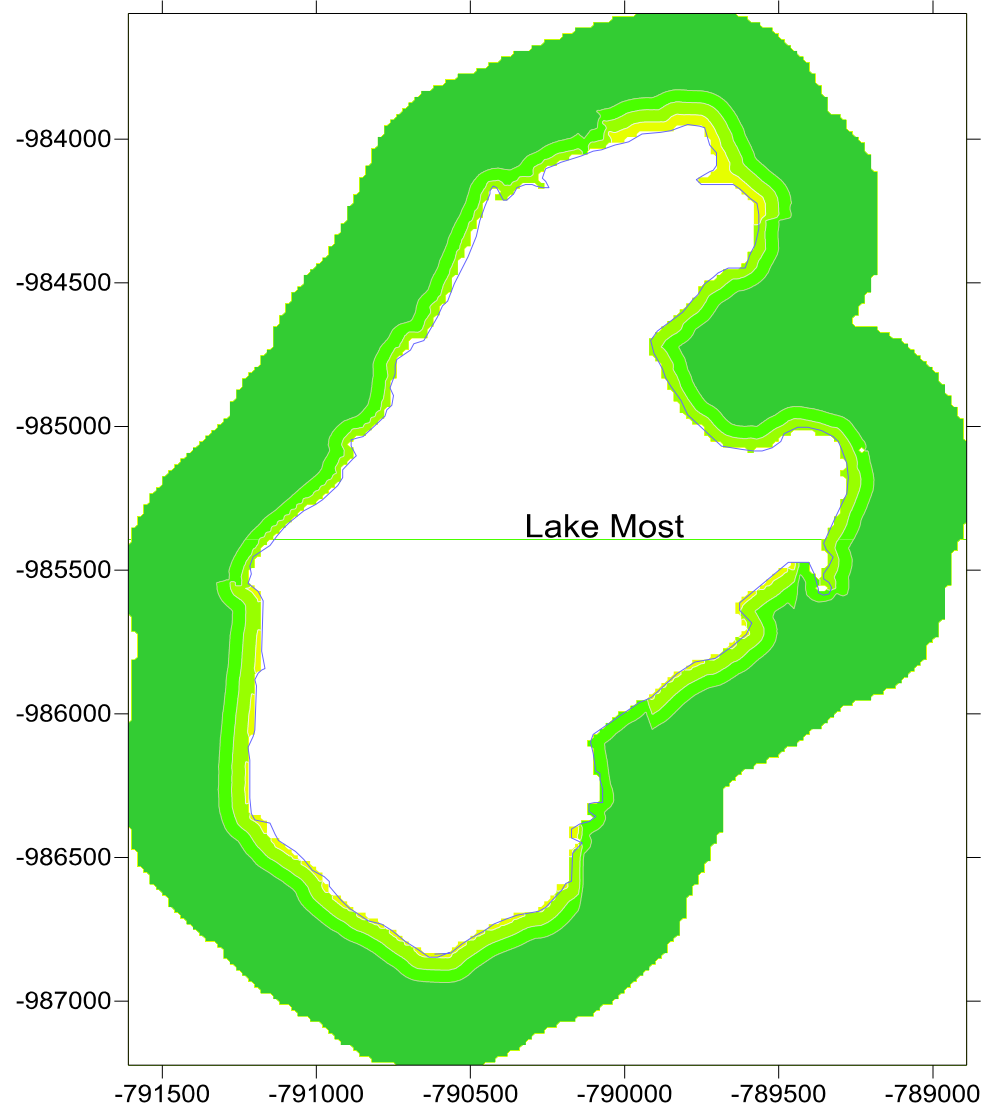
Location of lake Most in Czech Republic



Map of lake Most

Application of PRA methodology in Most pit lake

- Area A was divided into four geotechnical domains.
- Risk was estimated for each square without any corrective measures applied.
- A zone approximately of 75m is in class 2 of risk (0.2-0.4) for sectors 1 and 2.
- In sector 3 this zone is extended to 100-125m.
- In sector 4 is limited to 25-50m.



| Linear scale | Risk description |
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Conclusions

- The developed generic methodology for the assessment of risks related to slope failures of pit lakes was proven helpful since it allows comprehensively analyzing the hazards and estimating the associated risk.
- The spatial analysis of risk and the created risk maps allow the identification of high risk locations in the examined area. Moreover the methodology allows the reassessment of risk considering protective and corrective measures in order to evaluate the effect of measures on risk mitigation.
- The risk assessment performed in Lake Most, without considering any corrective measures, indicated that the northern part of the lake has the highest risk for all receptors.

Acknowledgments

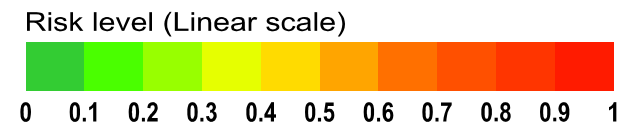
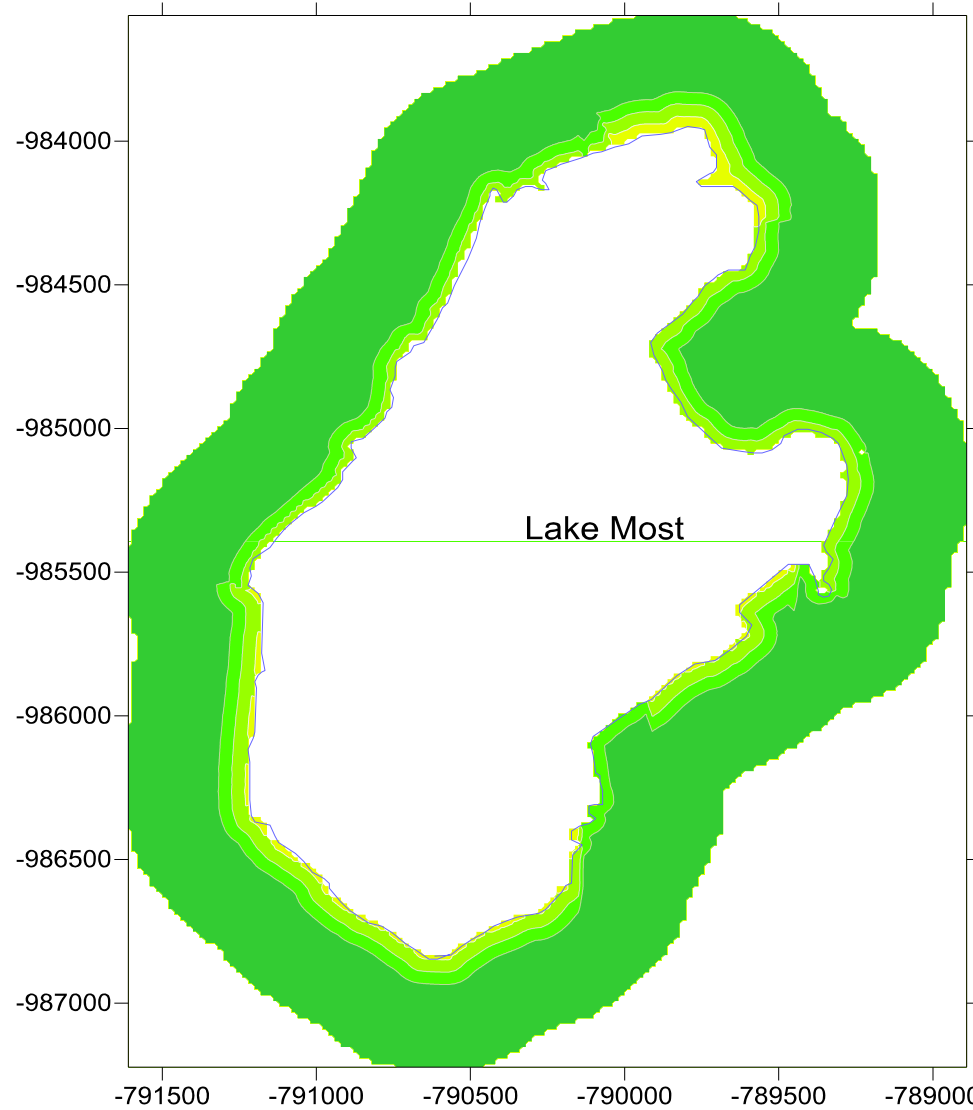
We acknowledge VUHU Institute of Czech Republic for providing us the required information and data related to Lake Most.

END

Thank you for your attention !

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