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- COP to the convetion of the transboundary effects of Industrial Accidents
- Workshop on the safety of Tailings Management Facilities
- November 12 2007
- Yerevan, Armenia

Avoiding tailings dam failures

Good practice in prevention

Philip Peck

UNEP GRID Arendal and IIIEE at Lund University

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Not an ordered, detailed or exhaustive overview of this topic

- *A general 'scene-setter' for discussions enfolding the guidelines under development*
- *Most focus upon the role of the TMF operation phase in ensuring Safety*
  - *Application of checklist, procedures, proper maintenance – for the achievment proper safety management*

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Some more brief background

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Why are we here?

Tailings management facilities can and do fail!

This can almost universally be prevented … one key area that helps is

Good practice in management & operations

But please note the whole best practice lifecycle is intrinsicably interlinked.

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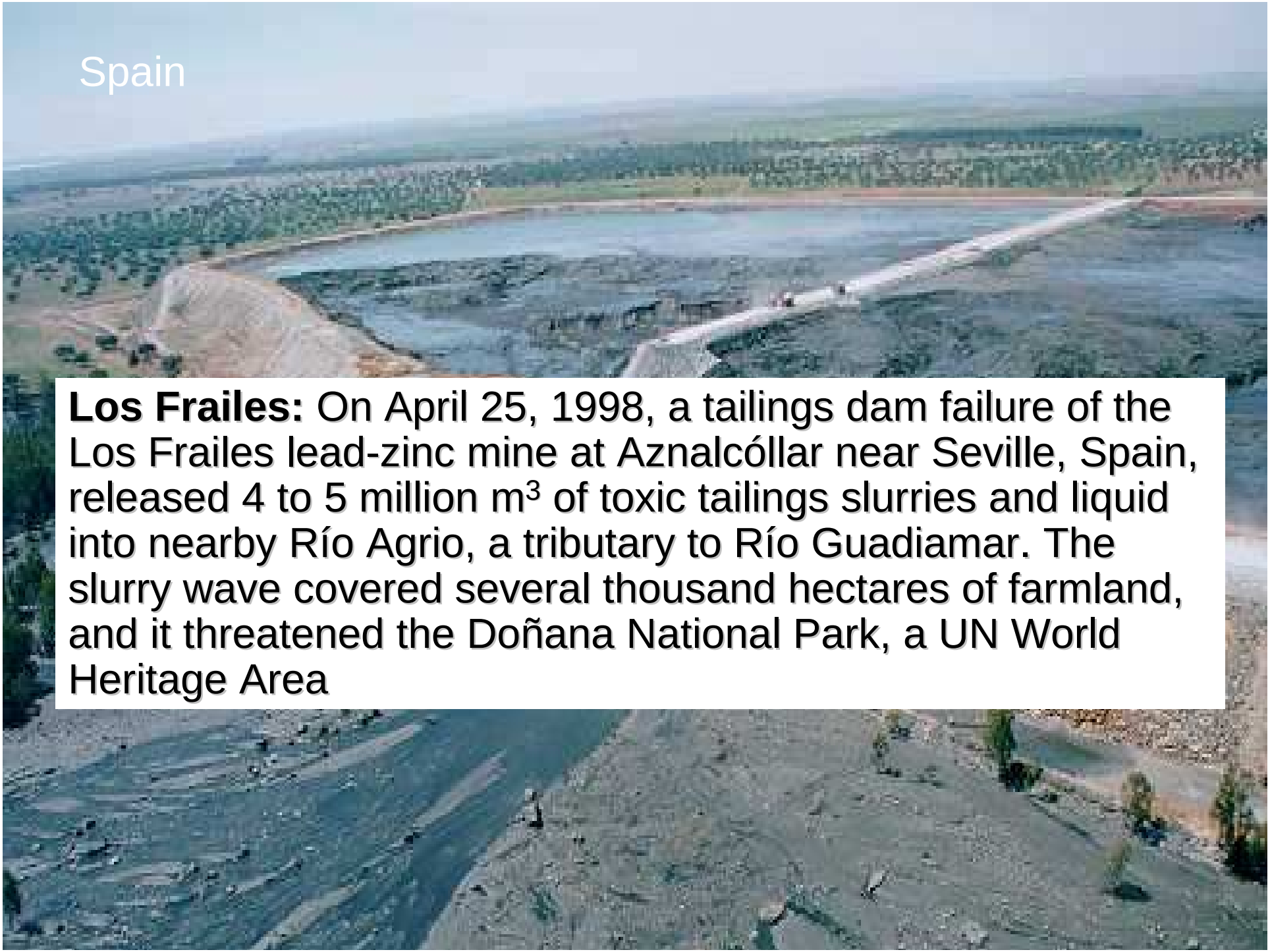
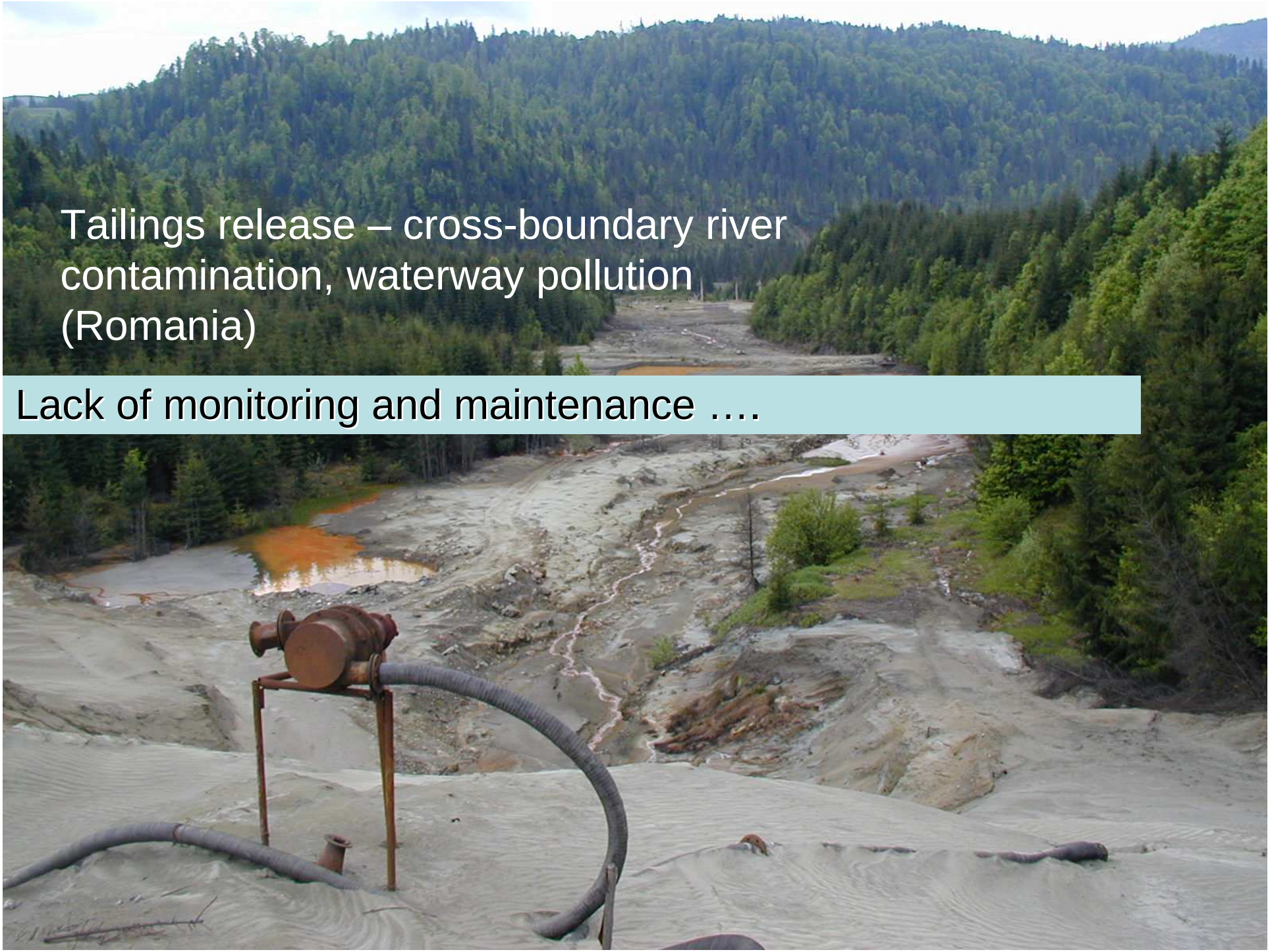


Spain

Los Frailes: On April 25, 1998, a tailings dam failure of the Los Frailes lead-zinc mine at Aznalcóllar near Seville, Spain, released 4 to 5 million m^3 of toxic tailings slurries and liquid into nearby Río Agrio, a tributary to Río Guadiamar. The slurry wave covered several thousand hectares of farmland, and it threatened the Doñana National Park, a UN World Heritage Area


Tailings release – cross-boundary river contamination, waterway pollution (Romania)
Lack of monitoring and maintenance ….

As I understand the procedure for development of these guidelines ……

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This workshop is intended to review the first steps taken for this guideline in the light of:

- Comprehensive documentation that exists;
- Existing best practice;
- New demands placed by mining practice;
- New possibilities offered by technological advances;
- Formal conditions placed by transboundary conventions (for example);
- And ….

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This brief presentation

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- Content in draft guideline at present
- Some big examples of the events we wish to prevent, some small examples as well ….
- Examples of extant literature:
  - I anticipate that these guidelines will extensively refer to, and cross-reference, the extensive body of work that describes best practice.
- Some of the content of existing guidelines that will be reflected in more detail
  - and that I see as the general intent

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An ethos for responsible management of the life cycle of TMFs.

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A general ethos good tailings management could be said to require that:

- *Existing and future* ***public health and safety*** *are not compromised;*
- ***Environmental resources*** *are not subject to physical and chemical deterioration;*
- *The* ***after-use*** *of the site is beneficial and sustainable in the long term;*
- *Adverse* ***socio-economic impacts are minimised****; and*
- *Socio-economic* ***benefits are maximised****.*

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A huge body of international knowledge & expertise

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- Geotechnical knowledge with engineering experience can enable safe tailings dams to be designed and constructed

- However, the rate of tailings dam failures has averaged 1.7 a year during the past 30 years – this knowledge and experience has not been applied in every case.

- In order to improve the situation the International Commission on Large Dams with the United Nations Environmental Programme published ICOLD Bulletin Number 121 – 221 examples of incidents with tailings dams and discusses causes.

- Aims to help those in charge of tailings dams to understand some of the simple mistakes that continue to occur.

ICOLD (2001). Bulletin 121. Tailings dams: Risk of dangerous occurrences. Lessons learnt from practical experience.

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Most of us have heard of the infamous sites

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Italy

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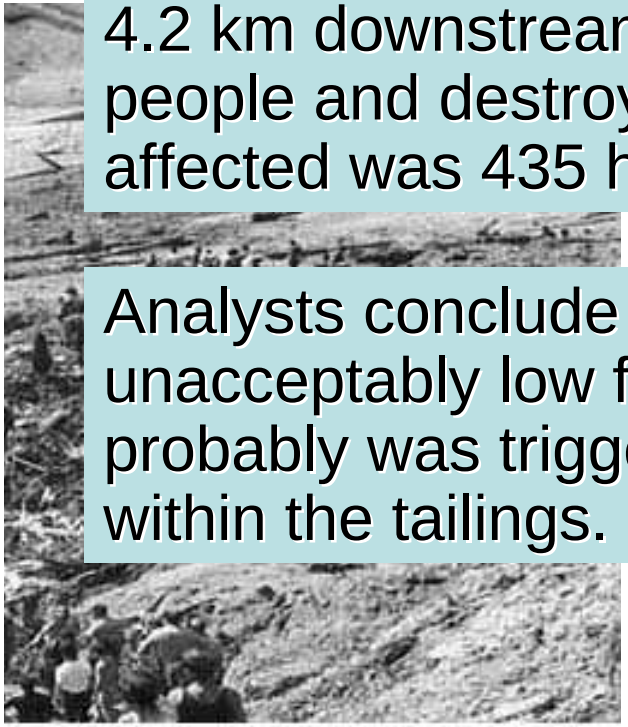
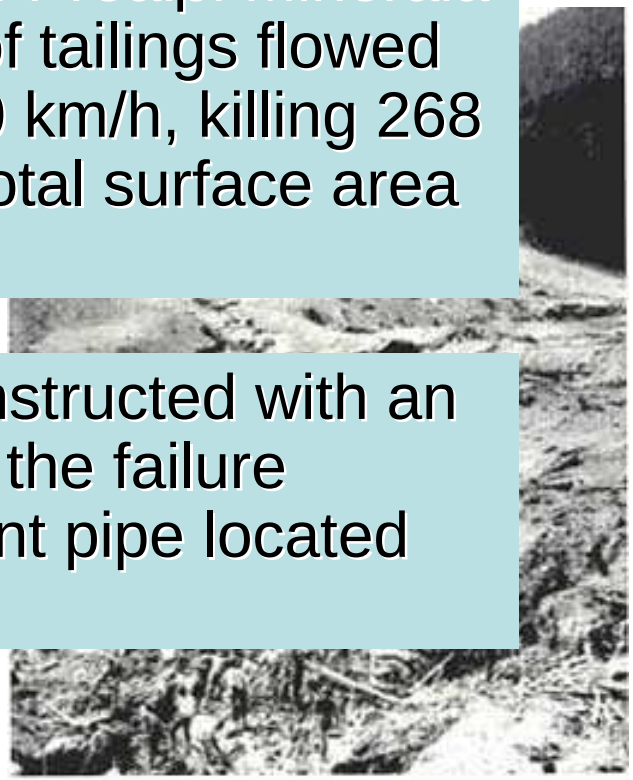
The Stava tailings dam failure (Trento, Italy)

On July 19, 1985, a fluorite tailings dam of Prealpi Mineraia failed at Stava, Trento, Italy. 200,000 m^3 of tailings flowed 4.2 km downstream at a speed of up to 90 km/h, killing 268 people and destroying 62 buildings. The total surface area affected was 435 hectares.

Analysts conclude that the dams were constructed with an unacceptably low factor of safety and that the failure probably was triggered by a blocked decant pipe located within the tailings.



La disperata opera dei soccorsi.

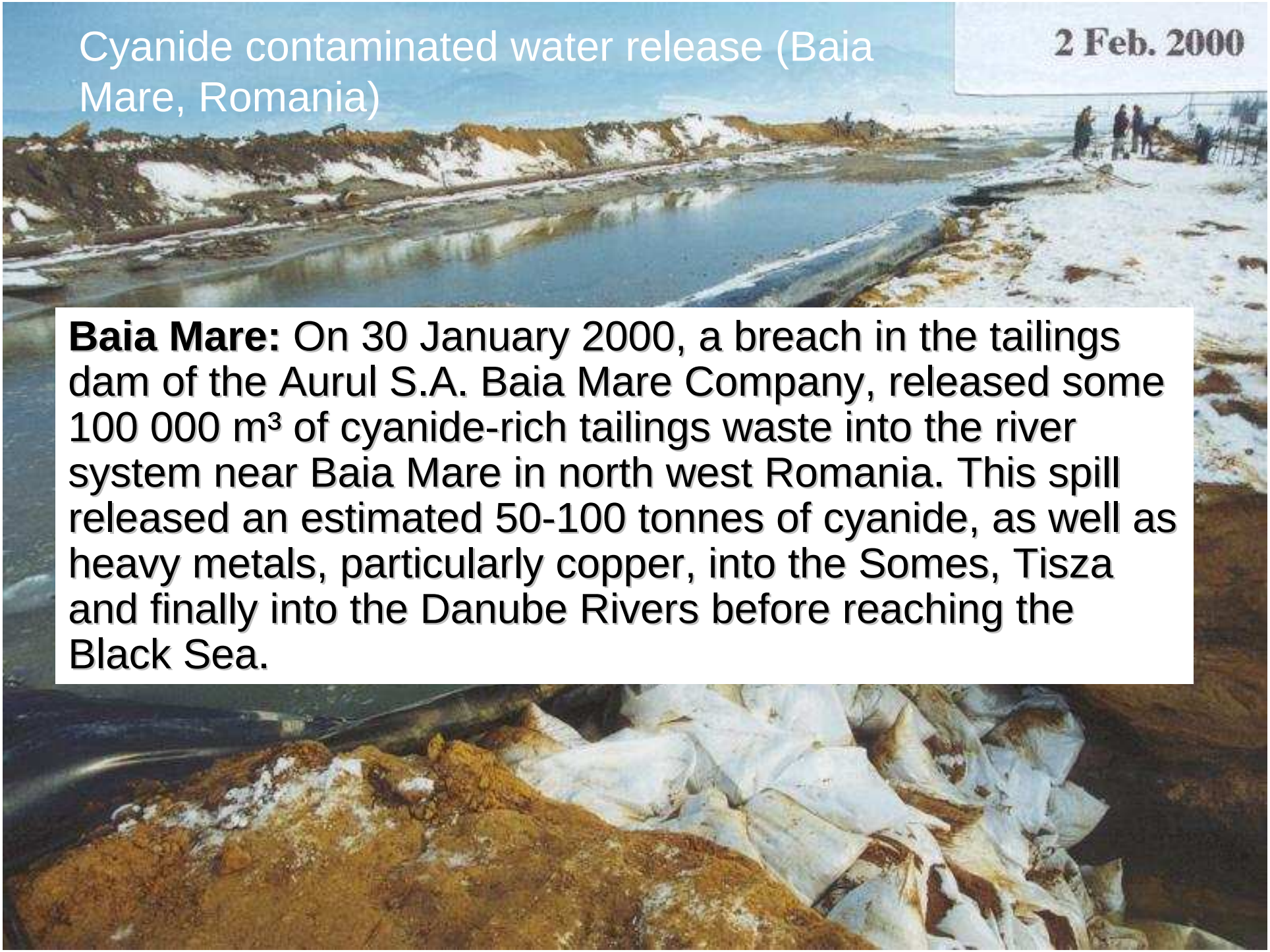


La ricerca si protrasse per tre settimane.

images from http://www.stava1985.it/

Tailings dump area Baia Mare Romania (circa 1998) – new land for the city, recovery of significant quantities of residual gold

Cyanide contaminated water release (Baia Mare, Romania)



Baia Mare: On 30 January 2000, a breach in the tailings dam of the Aurul S.A. Baia Mare Company, released some 100 000 m³ of cyanide-rich tailings waste into the river system near Baia Mare in north west Romania. This spill released an estimated 50-100 tonnes of cyanide, as well as heavy metals, particularly copper, into the Somes, Tisza and finally into the Danube Rivers before reaching the Black Sea.

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But also sites the world has not heard about … ?

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Culvert failure under Sasa Mine Tailings Dam, Macedonia

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Inappropriate design …

Lack of monitoring and maintenance ….

Circa 3Mt down the river ……

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Heavy metals contamination of soil and food
(Macedonia)

Tailings slime in riverbed downstream of Sasa Mine, Macedonia

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Circa 500 000t tailings washout, Fushe Arrez, Albania.

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Lack of inspection, maintenance and repair of water diversion channels

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Copper tailings dam (Rreshen Albania) …. Simply waiting to fail

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No monitoring

Water diversion has failed …

Evidence of structural instability ….

High phreatic surface ……

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Inappropriate tailings disposa threatens society and the environment!

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Draft UNECE safety guidelines and good practices for TMFs I

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Annex II: Operation and Management

- The TMF should be operated and managed on the basis of an operation manual, which is developed in the planning phase and progressively modified. Its aim is to effectively manage the risks/hazards at the TMF

- The operation manual should contain:
  - description of all monitoring procedures
  - mechanisms for investigations: sampling locations, sampling frequency, checklists and compliance parameters
  - procedures for reporting on non-compliance and failures
  - corrective actions to be applied in case of non-compliance
  - emergency plan
  - assessment parameters for effectiveness and suitability of the operation manual

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Draft UNECE safety guidelines and good practices for TMFs II

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Annex II: Operation and Management

- Any changes to operation manual should be subject to its performance analysis, which should be documented.
- The performance of the TMF should be assessed and described during significant seasonal events and the data gathered should be used for rehabilitation planning.
- In case of TMF acid rock drainage potential the management plans should be developed to prevent, reduce and treat acid water generation.

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But what does this mean in practice?

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Societies and prevention of TMF accidents

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In societies that care about dam safety, the normal aims with their actions are:

- To, as far as possible, ensure that dam accidents with serious consequences will not occur.
- To be prepared to mitigate the consequences in case of dam accidents.
- To make the dam safety situation transparent to the public.

How to achieve those aims probably requires different methods in different societies.

Recognise the dynamics of nature and technology **AND** society!

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Management areas in best practice mining – the Deming Cycle (Mining Association of Canada (MAC) 1998. Guide to the Management of Tailing Facilities.)

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A FRAMEWORK TO MANAGE TAILINGS

- Policy and Commitment
- PLAN
  - Roles and Responsibilities
  - Objectives
  - Managing Risk
  - Managing Change
  - Resources and Scheduling
- DO
  - Implementing the Plan
- DO & CHECK
  - Operational Control
  - Financial Control
  - Documentation
  - Competency
  - Monitoring
  - Communications
- CHECK & ACT
  - Checking
  - Corrective Action
  - **Management Review for Continual Improvement**

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Key points of departure for all this work …

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1 There are too many failures involving mine waste containment structures.
2 The reliability of mine waste containment structures is among the lowest of earth structures and risk-taking on the part of all stake-holders is excessive.
3 Design and performance requirements have changed in recent years.
"It is no longer just a question of having relevant government permits".
4 The technical requirements for design, construction and performance have never been more challenging.
5 The geotechnical engineer is capable of responding to the needs of the mining industry given the appropriate fiscal and technical management environment.
6 The role of geotechnical engineering is not restricted to the design and construction of passive containment; it has much to offer in the development of new processes for waste management.
7 Design for lease closure is geotechnically intensive.
8 Mine waste materials are complex; sometimes they behave better than expected.
9 Mine waste materials are complex; sometimes they behave worse than expected.
10 Case histories reveal that risk is not generated by technical limitations alone.
The geotechnical performance of a man-made deposit depends not only on its composition, but also on how it is
placed. The control exercised by placement method should not be underestimated.
Conclusion 11 A well-intentioned corporation employing apparently well-qualified consultants is not adequate insurance against serious incidents.

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CRITICAL OPERATION ASPECTS

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General points (after ICOLD)

The operation phase of a tailings dam often continues for several decades.

The conditions pertaining to assumptions made at the design stage may change, sometimes quite radically, during the operation phase.

Essential, both for ensuring compliance with the original design and to accommodate operating variations, that the operation be given a high level of priority from management and operators.

This DEMANDS regular internal inspections, external safety inspections and external, independent operation reviews, particularly after a significant incident(s) on a dam.

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Pre-deposition Construction (ICOLD)

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Monitoring of:

operations associated with the construction of pre-deposition works of a tailings dam for compliance with design standards

construction of perimeter starter walls, under-drainage facilities, decant facilities and other dam components.

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Operation management I (ICOLD)

UNITED NATIONS

A TMF is key factor in the overall operation of the mine or industrial process ***– it is not a side issue***.

Therefore essential to have:

- continuous support of the operation process from management
- detailed attention to the management of the tailings deposition process by trained, competent persons
- formal, detailed Operating Manual
  - updated on a regular basis to accommodate any changes in design or operation parameters according to:
    - visual inspections
    - monitoring reports

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Operation Management II – Critical factors (ICOLD)

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Constant operational control of the decant facility

Maintenance of internal beach width

Maintenance of storm freeboard

Control of beach slopes

Measurement of seepage discharge and turbidity

Measurement of the internal phreatic surface within the dam wall

Pore pressure measurement

Recording of movements in the dam wall

These factors should also be addressed in the post closure phase of the dam.

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Operation Management II – Critical factors 2 (ICOLD)

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Recording of seismic events

Recording of delivered tailings particle size distribution

Ensuring that the deposition process achieves adequate particle size segregation on the beaches

Regular monitoring of the behaviour of walls and beaches and physical properties of the deposited tailings, and the deposition procedures.

Management and maintenance of tailings delivery systems

Regular updating of monitoring response plans.

Management of all data.

These factors should also be addressed in the post closure phase of the dam.

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Tailings Dam Surveillance (ICOLD)

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The following essential aspects of surveillance are critical to success:

- What and how to measure and control
- Visual monitoring and control
- Instrumentation monitoring
- Analysis and interpretation of data
- Emergency preparedness
- Chain of responsibility.

Good surveillance includes the careful keeping of surveillance records + interpretation of these by experienced persons.

There must be a clear path for reporting of deviances and a mechanism for motivating and implementing remedial actions where necessary.

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Deposition Management (ICOLD)

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Tailings deposition requires specific attention, particularly in cases where the tailings product is being used to raise the outer wall of the tailings dam.

The deposition process, in association with the supernatant pool elevation, controls:

- Beach Length
- Beach slope
- Freeboard and flood management
- Tailings consolidation

The tailings dam wall will rise with time as deposition progresses and must be raised evenly around the dam perimeter. By managing deposition layer thickness and deposition cycle time around the perimeter, more effective drying consolidation can be achieved.

These factors are all specific to each individual dam

- must be managed daily to ensure design compliance
- must be an integral component of the surveillance process.

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Operational Water Management (ICOLD)

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Management of the supernatant pool as part of the overall deposition management process, is a key aspect of operation and all aspects of the water balance must be monitored and controlled carefully.

- size and depth should always be kept to a practical minimum

Management of the pool to a minimum size and the associated surveillance to ensure that this is always controlled will achieve:

- Reduced seepage
- Increased freeboard (larger beaches)
- Lower phreatic surfaces.

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TMFs must be built with the long long term in mind – we cannot forget closure

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- Requires a knowledge of environmental conditions, multi-objective planning, close supervision of construction, careful operational surveillance, and ongoing monitoring after closure.
- Sound engineering remains the basis of safe structures – long-term stability is ensured by a design that is intrinsically stable, self-repairing, and low-risk, and able to stand up to weather and other local influences.
- The concept is more about the design of a permanent landscape feature – NOT a short-term facility.
- In all cases a monitoring and verification procedure is needed to confirm that this goal has truly been achieved.

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An abundance of literature and work to support improvement

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IMPROVING TAILINGS DAM SAFETY :

Critical Aspects of Management, Design, Operation and Closure

ICOLD COMMITTEE ON TAILINGS DAMS – literature just on this topic of Operation & Managagement

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An abundance of literature and work to support improvement – Examples regarding water Mgt.

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United States Committee on Large Dams (USCOLD) 1994. *Tailings Dam Incidents*.

International Commission on Large Dams (ICOLD) 1992. *Selections of Design Flood* Bulletin 82 (http://www.icold-icgb.org)

Canadian Committee on Large Dams (CANCOLD) *Guidelines for Flood Design Criteria Based on Consequence and Risk*.

Australian National Committee on Large Dams (ANCOLD) 1986. *Guideline on Design Floods for Dams*

South African National Committee on Large Dams (SANCOLD). Report No. 3*. Interim Guidelines on Freeboard for Dams*.

Mining Association of Canada (MAC) 1998. *Guide to the Management of Tailing Facilities*. (http://www.mining.ca)

Kraftföretagens Riktlinjer för Dammsäkerhet (RIDAS) 2002. *Hydropower Industry Dam Safety Guidelines*. Swedenergy, Stockholm: Birger Gustafsson AB ISBN 91-7622-174-1

Reference to Operation, Surveillance and Maintenance Manual: Kraftföretagens Riktlinjer för Dammsäkerhet (RIDAS) 2002. *Hydropower Industry Dam*

Safety Guidelines. Swedenergy, Stockholm: Birger Gustafsson AB ISBN 91-7622-174-1

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An abundance of literature and work to support improvement – examples regarding deposition monitoring

UNITED NATIONS

International Commission on Large Dams (ICOLD) 1995. Tailings Dams, Transport, Placement and Decantation - Review and Recommendations. Bulletin 101

International Commission on Large Dams (ICOLD) 1996. Monitoring of Tailings Dams - Review and Recommendations. Bulletin 204

International Commission on Large Dams (ICOLD) 1996. A Guide to Tailings Dams and Impoundments - Design, Construction, Use and Rehabilitation. Bulletin 106

Minerals Council of Australia. Strategic Framework for Tailings Management

South African Bureau of Standards 1998. Code of Practice for Mine Residue Deposits. SABS 0286

Mining Association of Canada, (MAC) 1998. A Guide to the Management of Tailings Facilities.

Mining Association of Canada (MAC) 2000. Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Storage Facilities.

Government of Western Australia 1998. Guidelines on the Development of an Operating Manual for Tailings Storage.

European Commission July 2004. Draft Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities. Edificio EXPO, Seville, Spain (http://www.jrc.es/pub/english.cgi/0/733169)

ICOLD BULLETIN-Dec-06.doc

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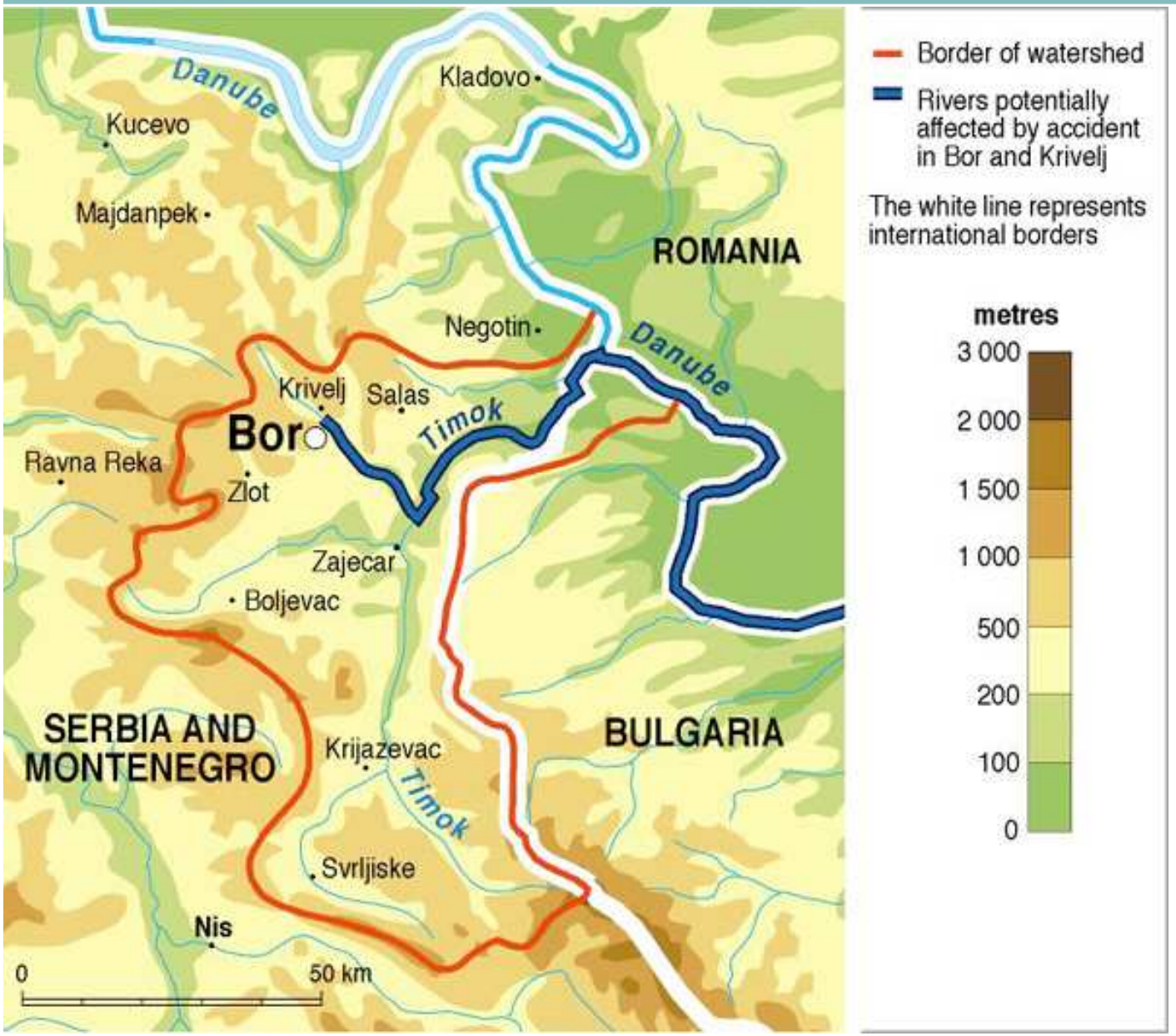
Tailings releases DO cross jurisdicational boundaries … sometimes immediately!!



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TMFs can also threaten natural or anthropogenic resources of extreme value (Mojkovac, Montenegro)

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River Tara is part of the Durmitor national park

TMF circa 15 m high at 800m asl, about 2.6Mt impounded tailings material. Tails consist of: lead 0.20%, zinc 0.30 - 0.40%, copper 0.10%, iron 4 -5% in pyrite, sulfur 10 - 12% antimony, cadmium, mercury, molybdenum, silver and gold (minor).

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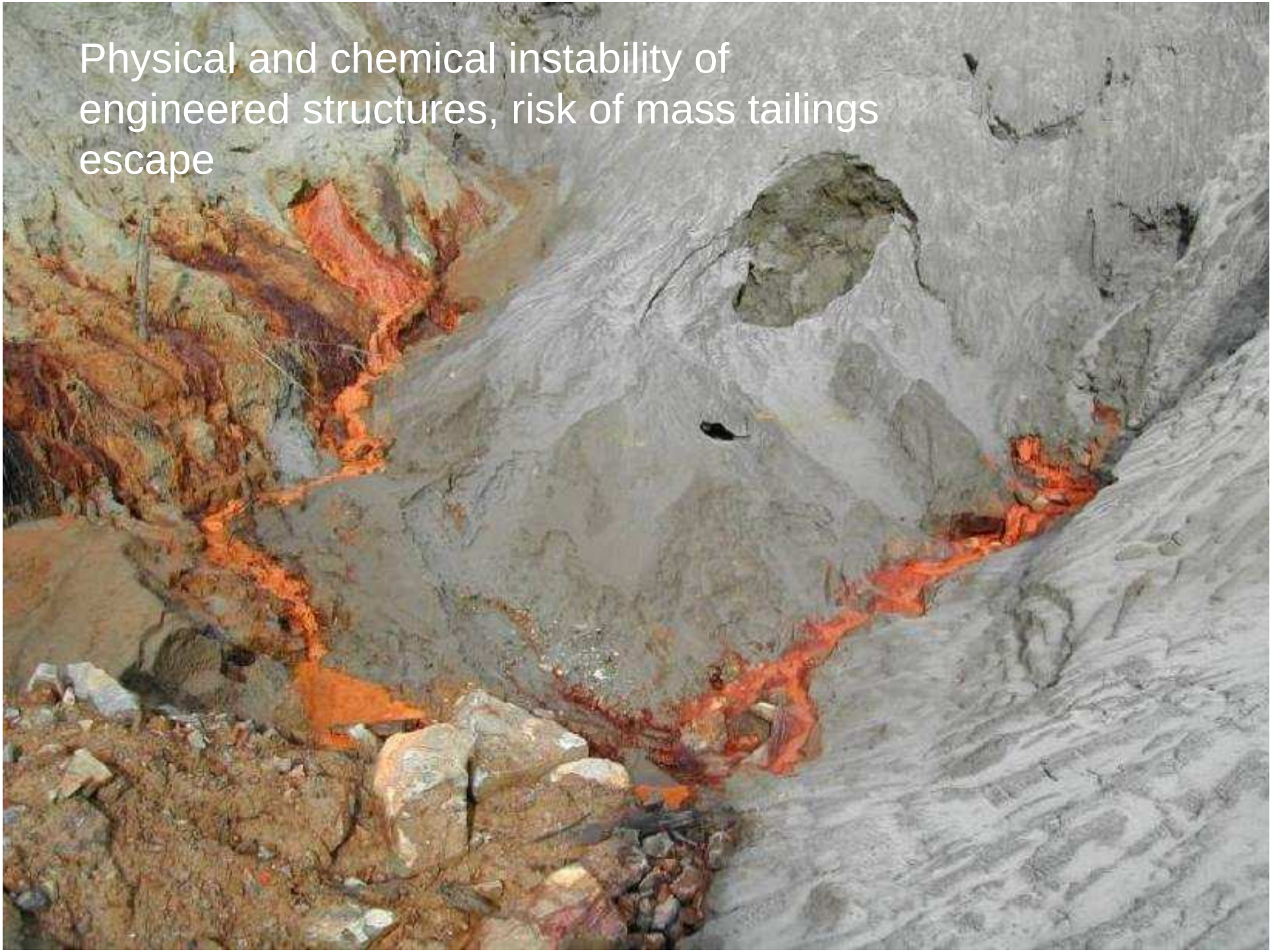
Physical and chemical instability of engineered structures, risk of mass tailings escape

Dwellings and communities ARE located below tailings dams

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Fugitive dust emissions from tailings (Macedonia)

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Tailings release to an important Danube tributary – Baia Borsa, Romania

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Thank you for your attention!

Philip Peck

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