Politecnico di Torino

Dams & Reservoirs DAY 2025

Water and Energy security for Europe

OPEN DAY ON DAMS



Dams and environment: engineering solutions for the future

TORINO , 28 maggio 2025

Ensuring dam safety: verification and design solutions

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ITCOLD – II Concorso Fotografico

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France – Italia ALCOTRA

Project "BECCA"
(ecologically sustainable and safe basins designed for climate change adaptation)

BECCA

- BECCA is a **cross-border initiative** supported by the European ALCOTRA program, fostering collaboration between **Italy and France**

- The project aims to strengthen the climate resilience of territories by improving the management of water resources through multifunctional **small and medium-sized basins**

- In the field of BECCA, the research group is developing a **guideline addressing geological, geotechnical, structural, and seismic aspects** for the design, construction and management of reservoirs

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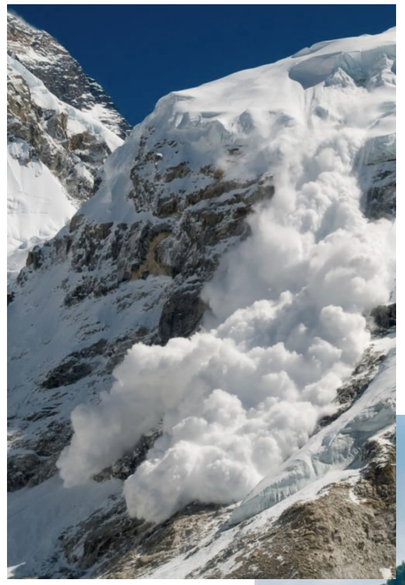
Project "BECCA": guideline

BECCA

- Objective of the guideline: providing professionals and engineers with **simple and updated procedures** for the design, construction, and management of new reservoirs, as well as the rehabilitation of existing ones

- Focus on **earth dam** (compacted and reinforced embankments) and concrete dams (in case of rehabilitation)

- Special emphasis on the **impact of natural hazards typical of mountainous regions**: rockfalls, avalanches, landslides, …





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Dam design: an interdisciplinary challenge

A dam is a complex work of engineering whose design must address:

- **Geological** conditions
- **Hydraulic** scenarios
- **Hydrological** factors
- **Structural** aspects (in particular for concrete dams)
- **Geotechnical** considerations



Dams are **strategic structures** where an interdisciplinary approach is essential to ensure a proper and safe design and long-term durability

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Dam types

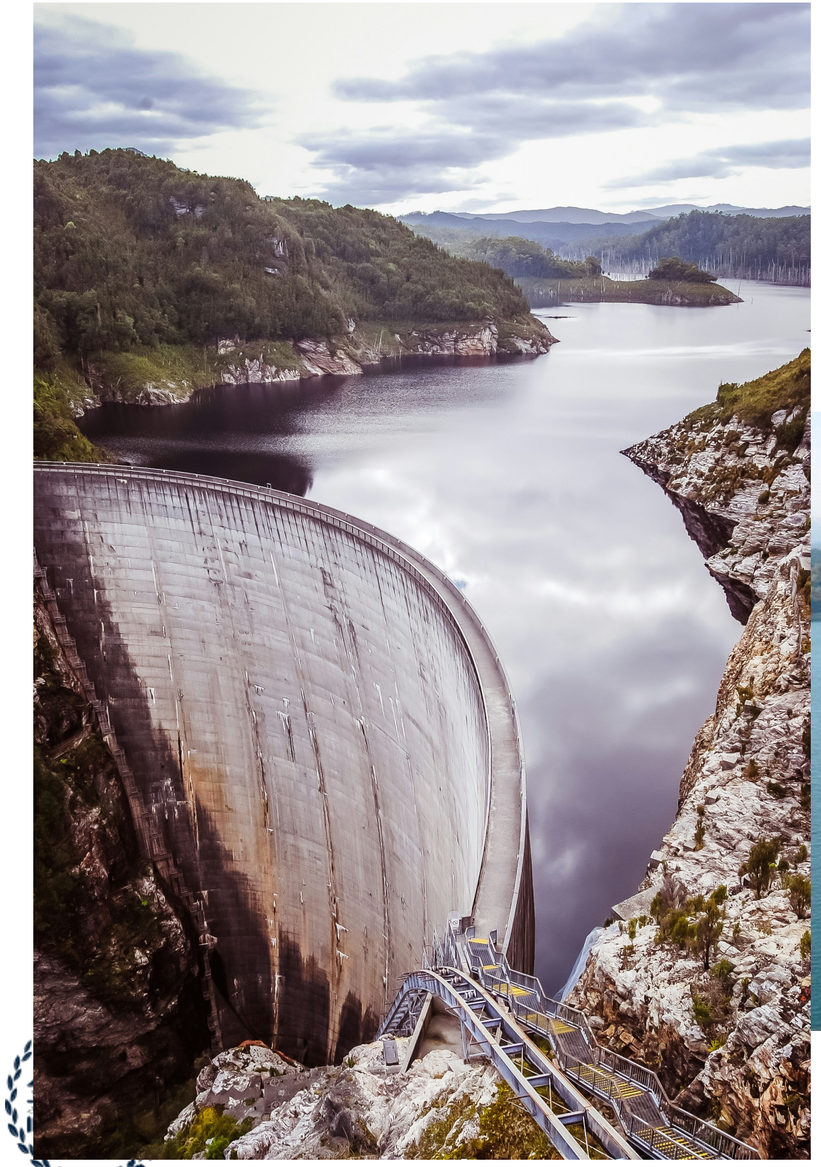
The Italian regulation «*Norme tecniche per la progettazione e la costruzione degli sbarramenti di ritenuta (dighe e traverse)», DM 26 giugno 2014* distinguishes between:

- **Concrete dams**: gravity dams, vaulted dams (arch, arch-gravity, …)
- **Embankment dams**: homogeneous embankments, soil or rockfill embankments with central (or upstream) sealing structure, …
- **Mixed-type dams**
- **River weirs**

Dams are also typically classified based on their height (H) and the basin volume (V):

- **Small dams**: $H < 15$ m or $V < 1\,000\,000$ m^3
- **Large dams**: $H \geq 15$ m or $V \geq 1\,000\,000$ m^3

Dam types



← Arch dam (credits: Unsplash)



Ordinary dam (Alpe Gera dam), credits: Direzione Dighe

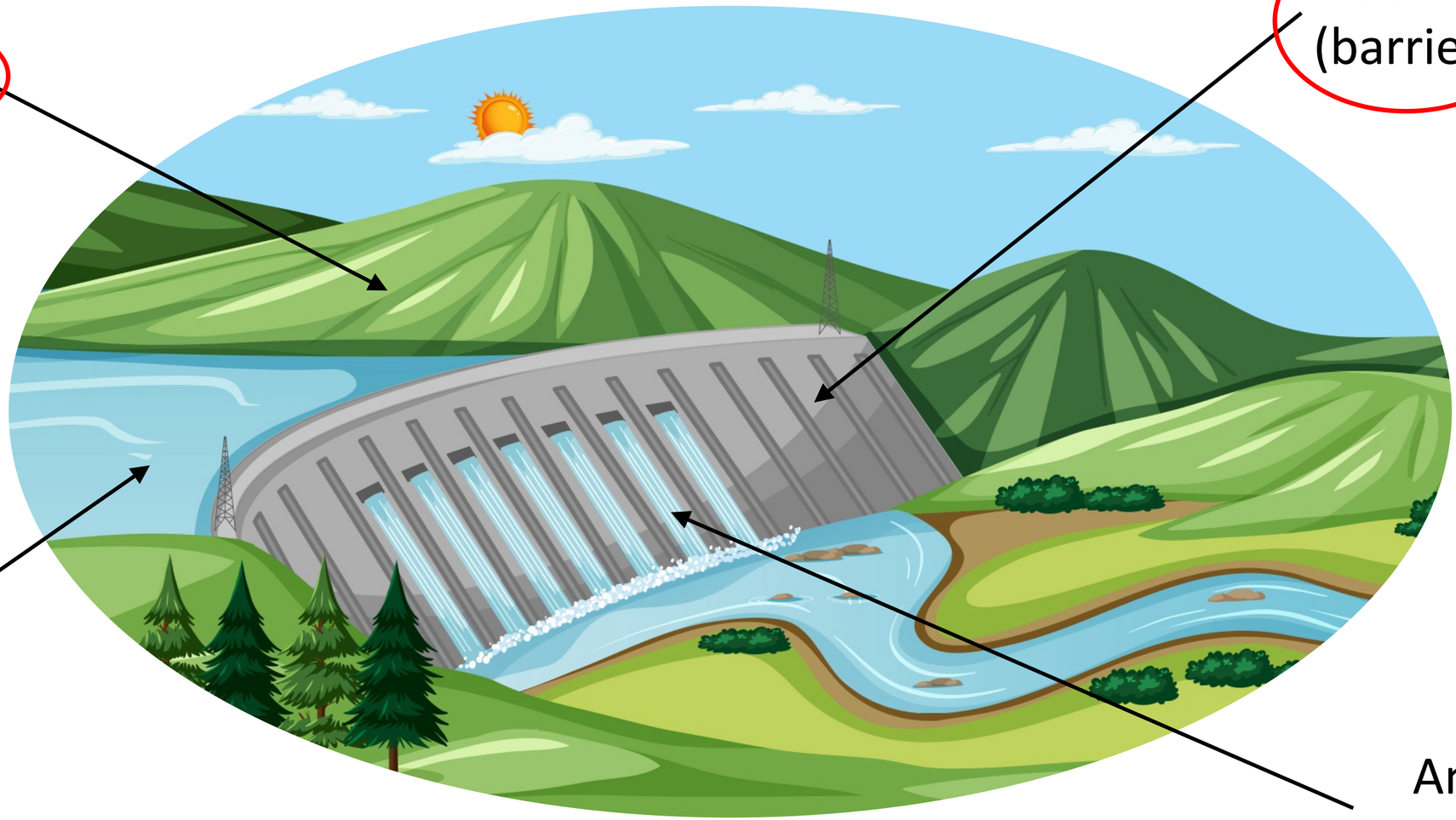


↑ Embankment dam (Bilancino dam), credits: Direzione Generale Dighe

↓ River weirs, credits: V. De Biagi



Ensuring dam safety



Key phases in dam design

- **Initial phase**: to verify the feasibility of the project with an interdisciplinary approach (water resources, hydraulic tightness of the reservoir, stability of foundations and slopes, seismic hazard, etc.)
- **Design and verifications**: to define the geometry and structural characteristics of the dam, as well as any measures needed to mitigate risks from potential failures or seismic actions
- **Construction phase**: planning and execution of all stages required to complete the work
- **Management of the dam**: periodic inspections, maintenance, etc.

Verification of the dam

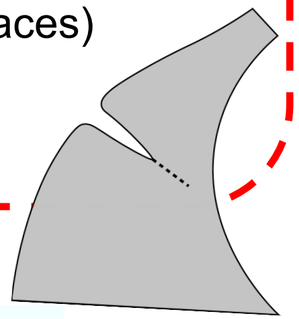
The guideline works in accordance with the Italian regulation (DM 26 June 2014):

- The dam has to be verified assuming two scenarios: **basin completely empty and completely full**;
- Both **static and dynamic conditions** have to be considered
- The **internal verifications** of the dam depend on its type
- The **external verifications** (dam/foundation soil or rock interaction) against sliding, tilting and lifting have to be performed
- **Ultimate limit states** (ULS) and **serviceability limit states** (SLS) need to be considered

Limit states

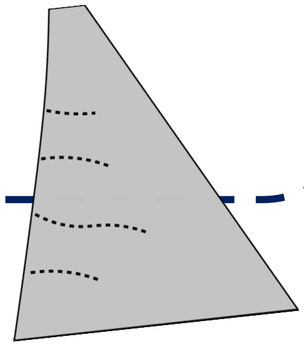
Ultimate limit state (ULS)

- **Instability** of the dam and the foundation
- Instability of the dam by sliding
- **Dam break**, fracturing, erosion, infiltration, failure of the sealing elements, siphoning
- **Permanent deformation** of the dam
- **Overflow**
- **Floods**
- **Local failures** (e.g., instability of the embankment faces)
- **Internal instability** of the dam (sliding surfaces)
- …



Serviceability limit state (SLS)

- **Stress and/or strain extreme levels** in the dam, foundation, soil/rock structures
- **Damage** of the superficial or deep exhaust systems
- Damage of the water transfer works
- Damage of the measurement and control systems
- **Nonlinear behaviour** of soil/rocks elements (for embankment dams)
- **Differential settlements**
- …

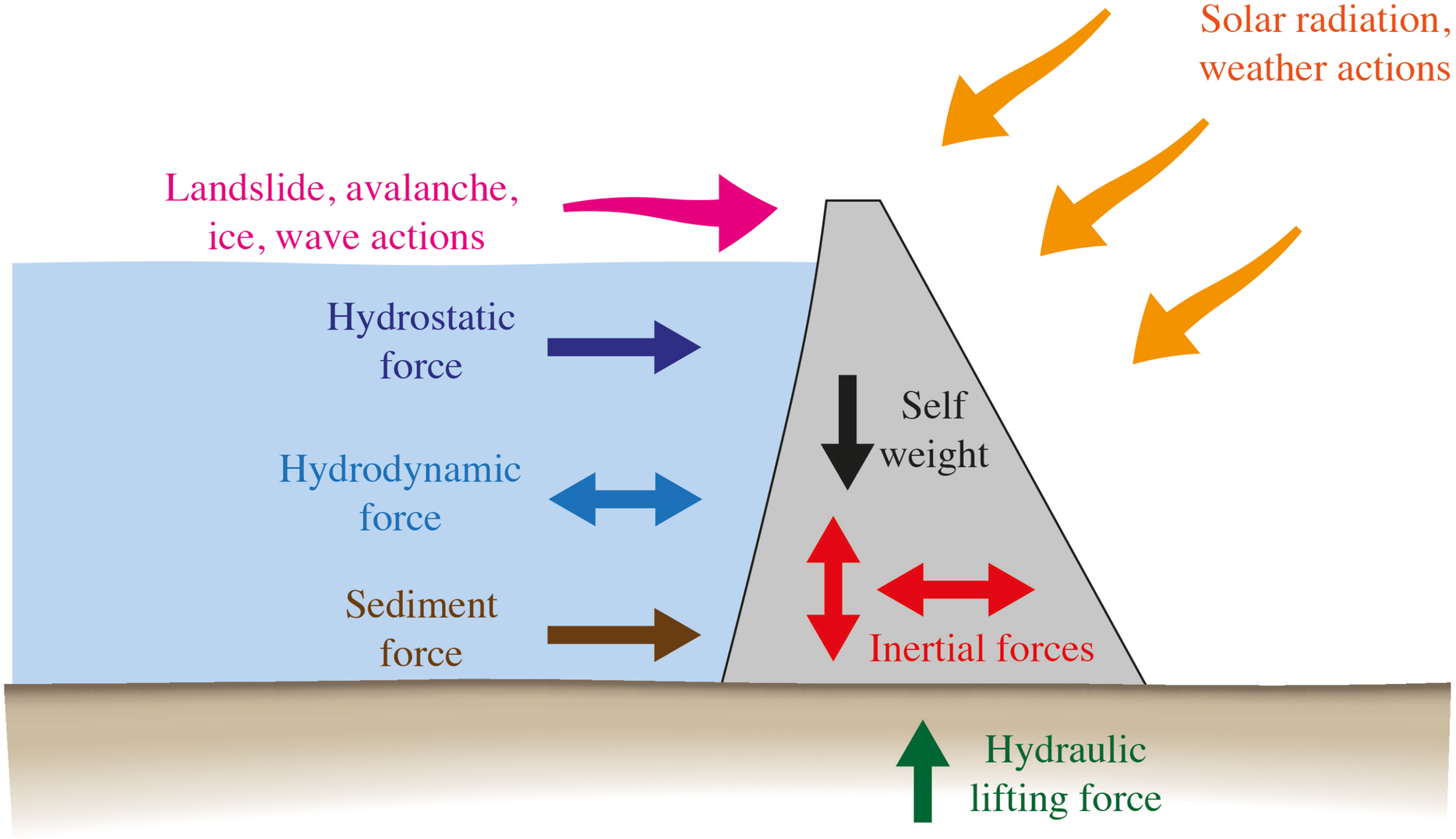


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Actions on the dam

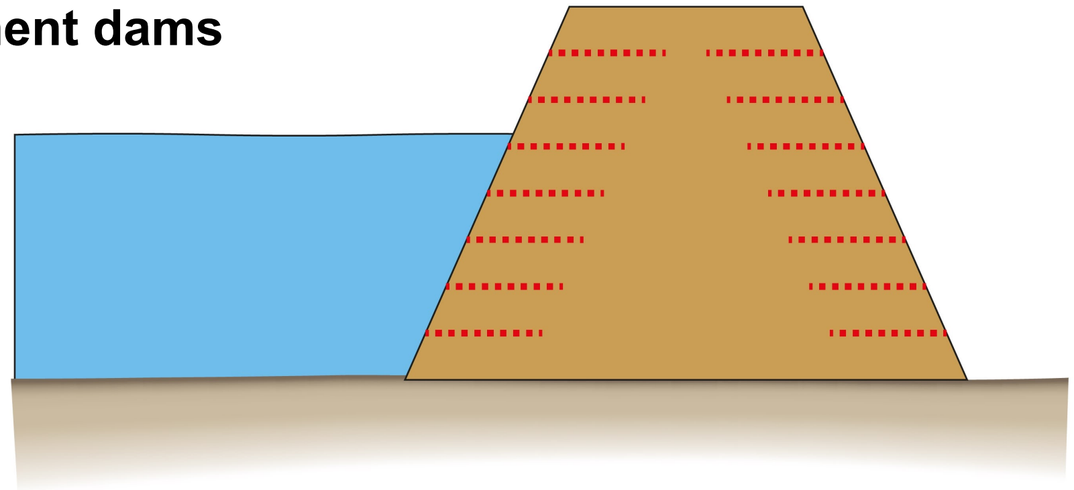


Research activities

Our research group is currently focusing on three topics related to dam studies:

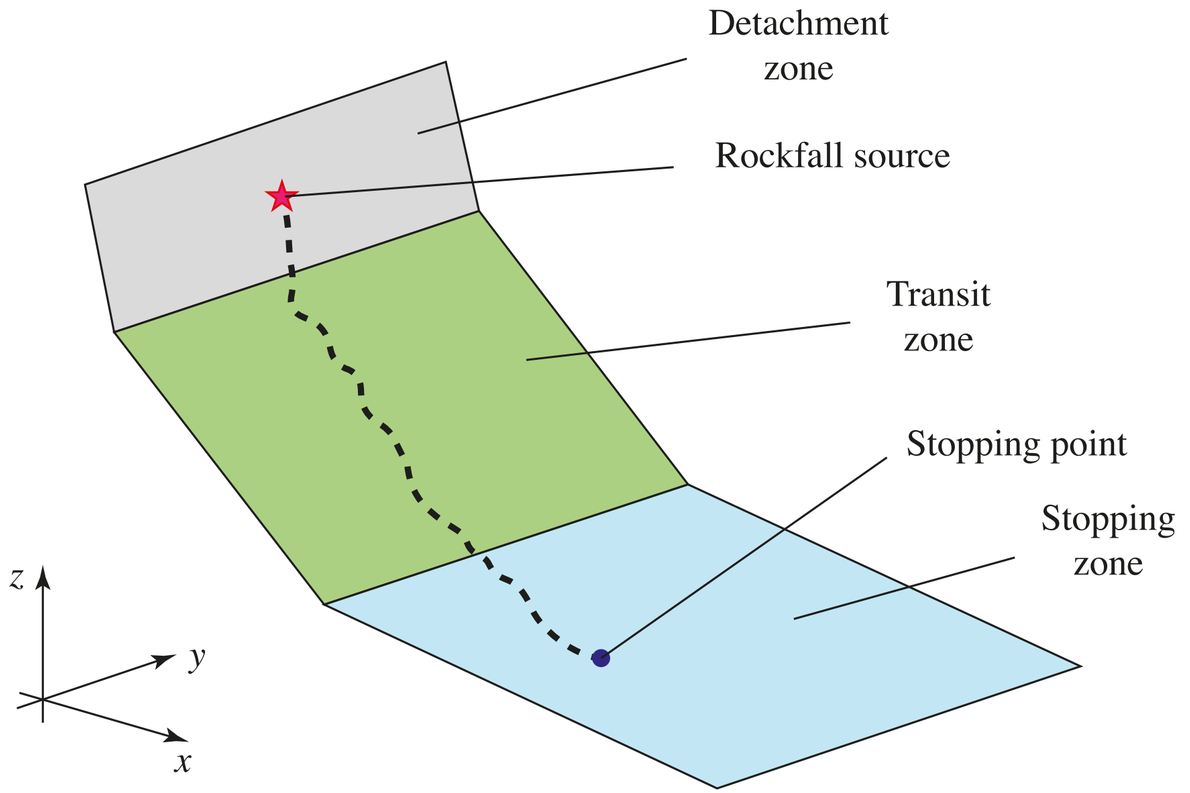
- Effect of the forest on basin slopes
- Vulnerability of dams with respect to wave induced by landslides
- Effect of vegetation on embankment dams

All the activity are performed with reference to **embankment dams**



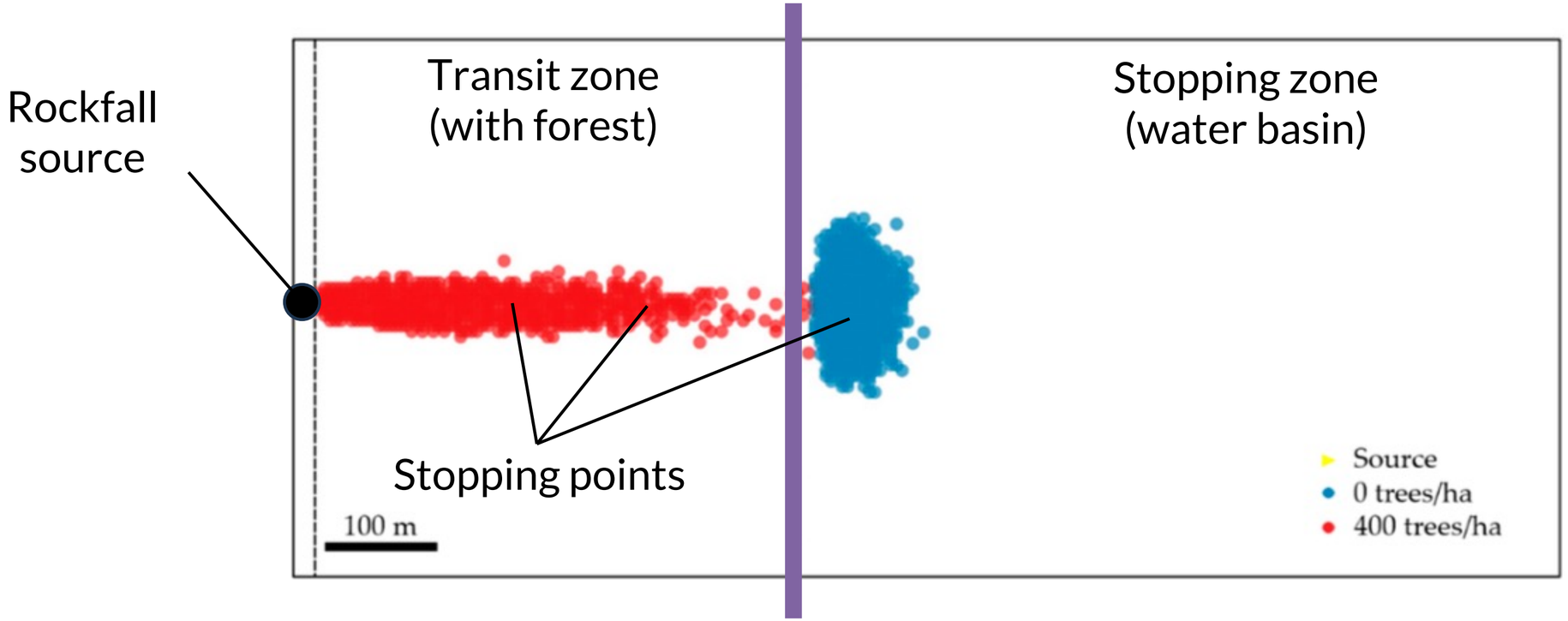
Effect of the forest on basin slopes

- The slopes surrounding the basin may be affected by various types of **mass movements**, such as: rockfalls, shallow landslides, snow avalanches, debris flows, etc.
- Landslides can generate effects on dams (**wave**)
- **Forests can mitigate landslide hazard and risk** by reducing the runout distance and dissipating the energy of the moving mass
- To assess the effect of the forest in case of **rockfall**, numerical simulations have carried out on **simplified slopes** with the software **Rockyfor3D**



Effect of the forest on basin slopes

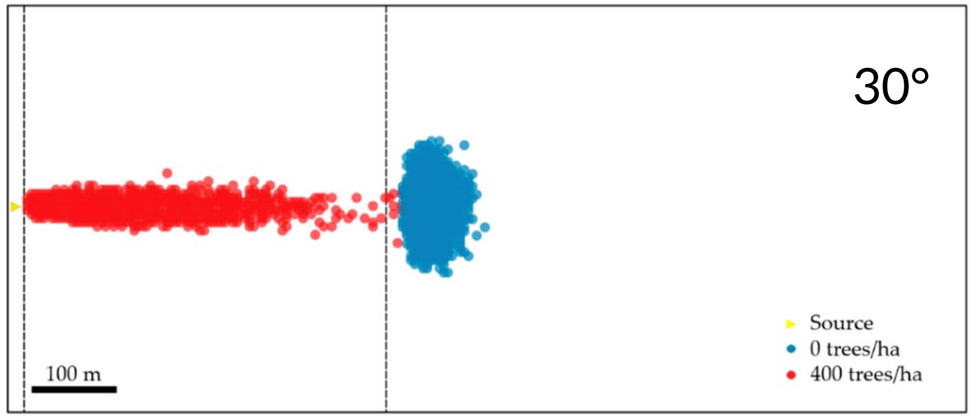
Top view of the simplified slope: first results

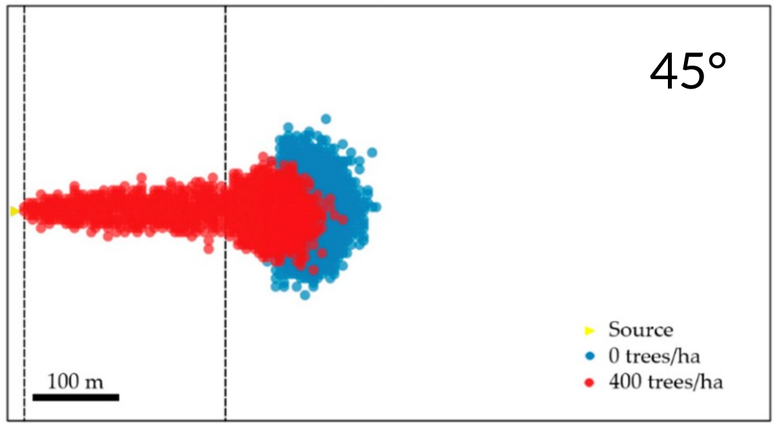


Measure of the kinetic energy at the base of the slope

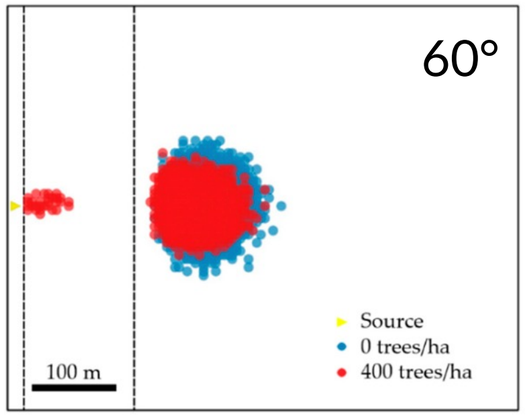
Effect of the forest on basin slopes

Effect of the slope steepness





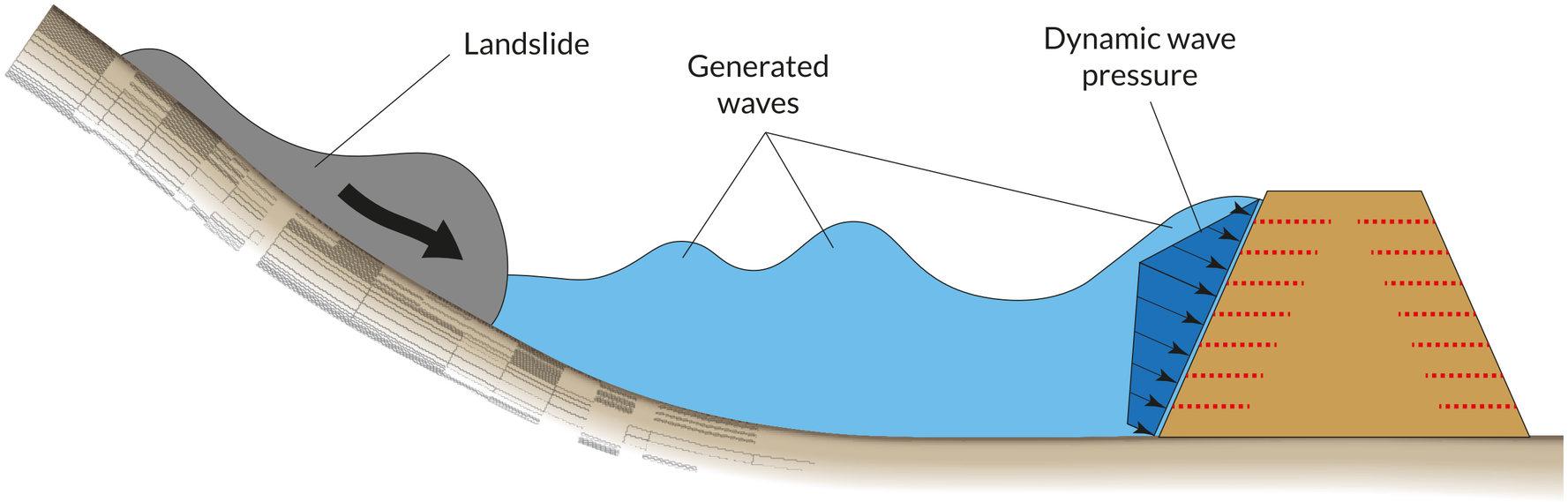
(**b**)

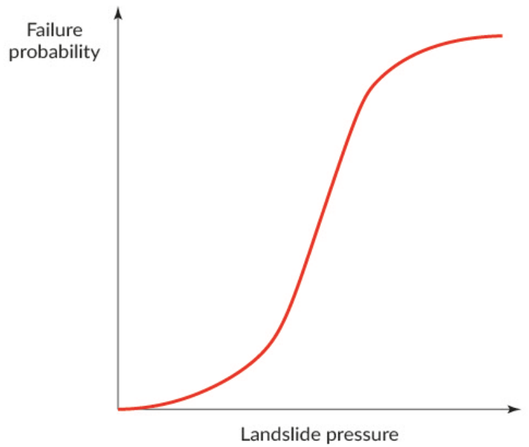


(**c**)

Vulnerability wrt to landslide-induced waves

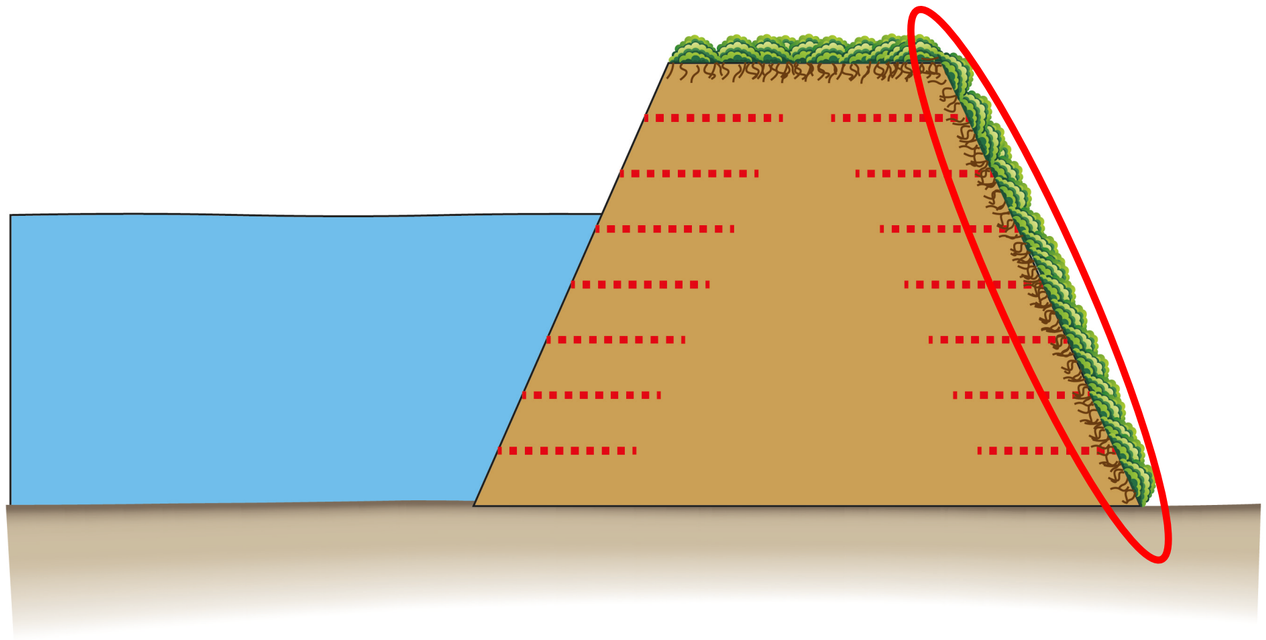
- The second activity focuses on developing fragility curves for embankment dams subjected to landslide-induced waves.
- We are performing **Finite Element Method (FEM) analyses** using the RS2 software





Effect of vegetation on the embankment

- Study on the effect of vegetation growth (roots) on the stability of the embankment
- 2D analyses with limit equilibrium method (Slide2D) and FEM (RS3)



- The growth of roots may **reduce the effective anchorage length of geogrids** and compromise their connection to the faces of the embankment.
- How does this phenomenon impact the stability of the structure?

Thank you for the kind attention

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