Centre d'Ingénierie Hydraulique

OVERFLOWING EROSION OF EMBANKMENT DAMS AND DIKES: EDF PERSPECTIVE

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International Workshop on Overflowing Erosion of Dams and Dikes.
Aussois – France

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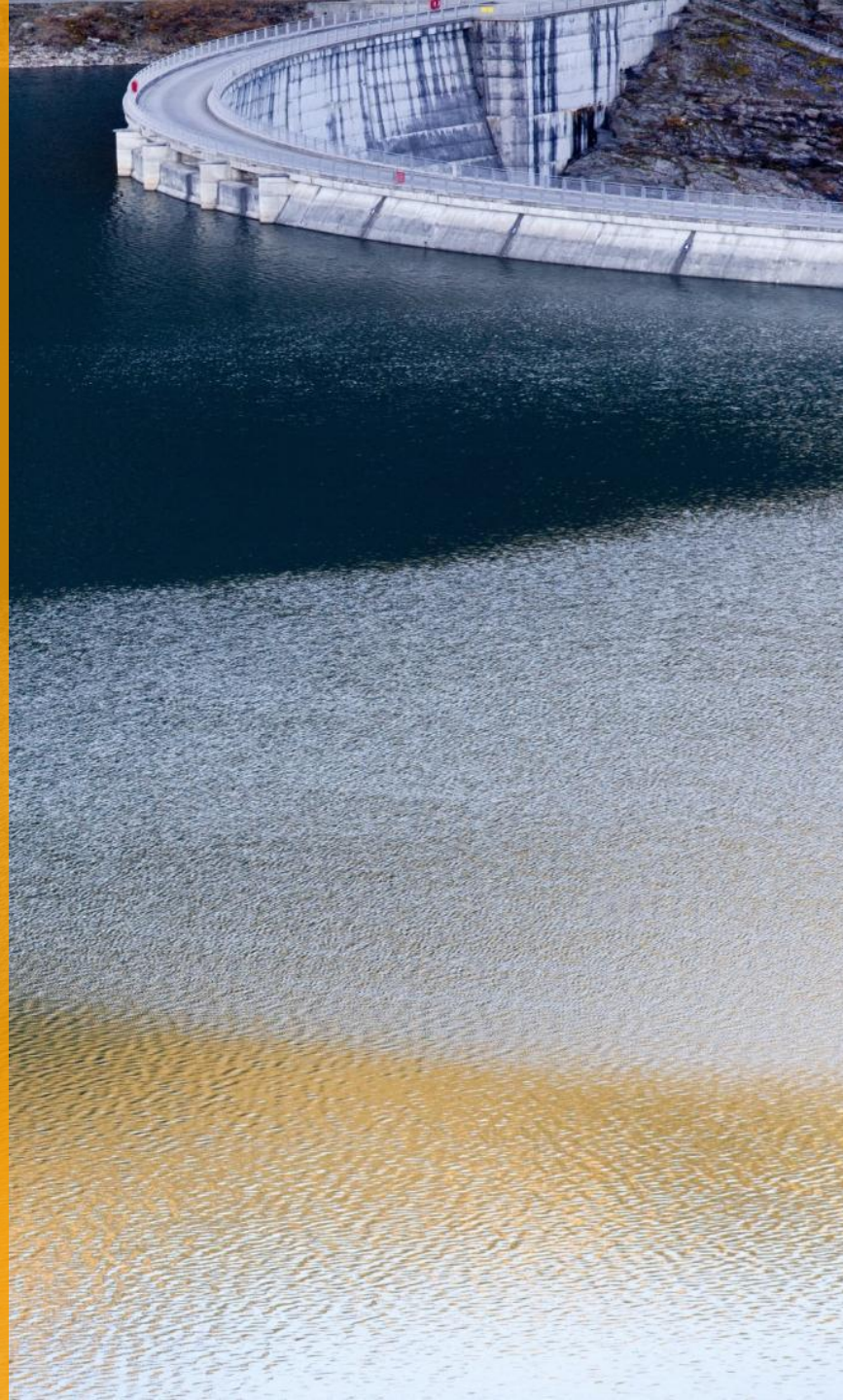


OUTLINE

1. EMBANKMENT DAMS AND DIKES OPERATED BY EDF
2. SAFETY ISSUES ASSOCIATED WITH OVERFLOWING EROSION
3. WHAT ARE THE ENGINEERING TOOLS AVAILABLE? WHAT ARE THE GAPS WHICH NEED TO BE FILLED?

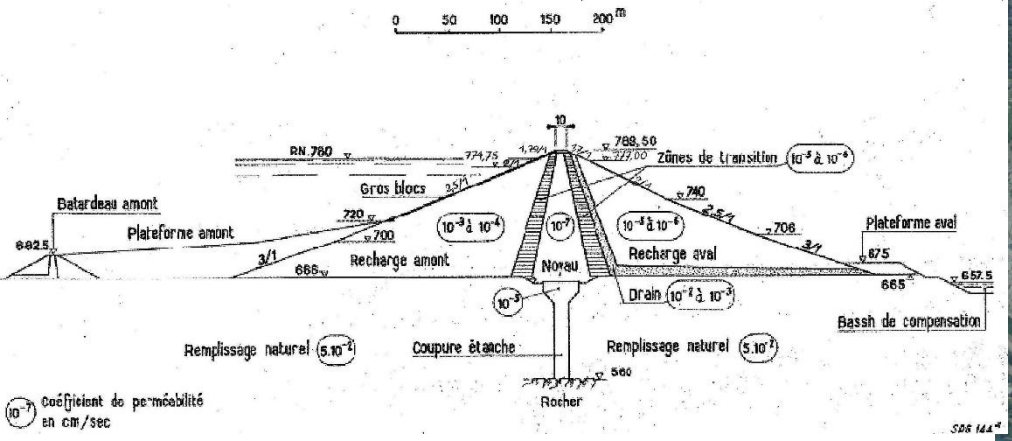
EMBANKMENT DAMS AND DIKES OPERATED BY EDF

- **Around 50 large embankment dams**
- **500 km of canal embankments and dikes**
- **Average age: more than 70 years.**

EMBANKMENT DAMS AND DIKES OPERATED BY EDF

Various types of embankments

Large dams with a zoned embankment.
Example: Serre-Ponçon Dam.

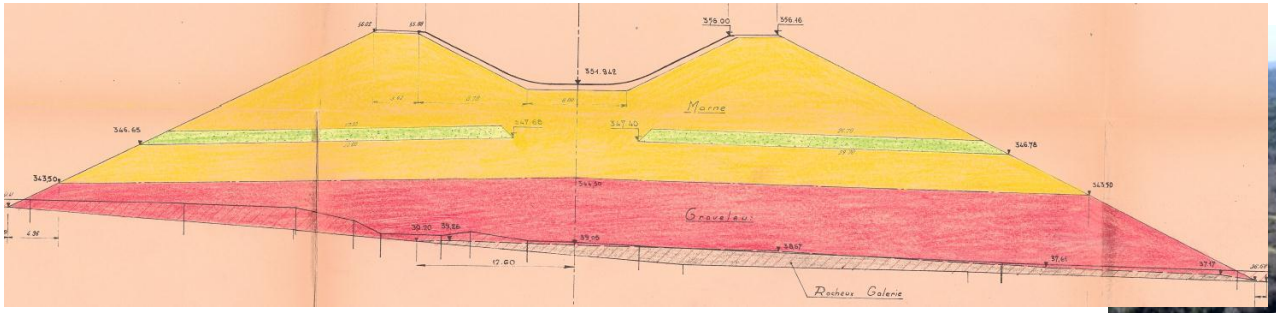


Dam height: 120m, reservoir volume: 1.2 billion of m^3

EMBANKMENT DAMS AND DIKES OPERATED BY EDF

Various types of embankments

Canal embankments
Example: Malaurie canal (Durance – Verdon scheme)



Dam height: 35m,
Reservoir volume: 130,000 m^3

EMBANKMENT DAMS AND DIKES OPERATED BY EDF

Various types of embankments

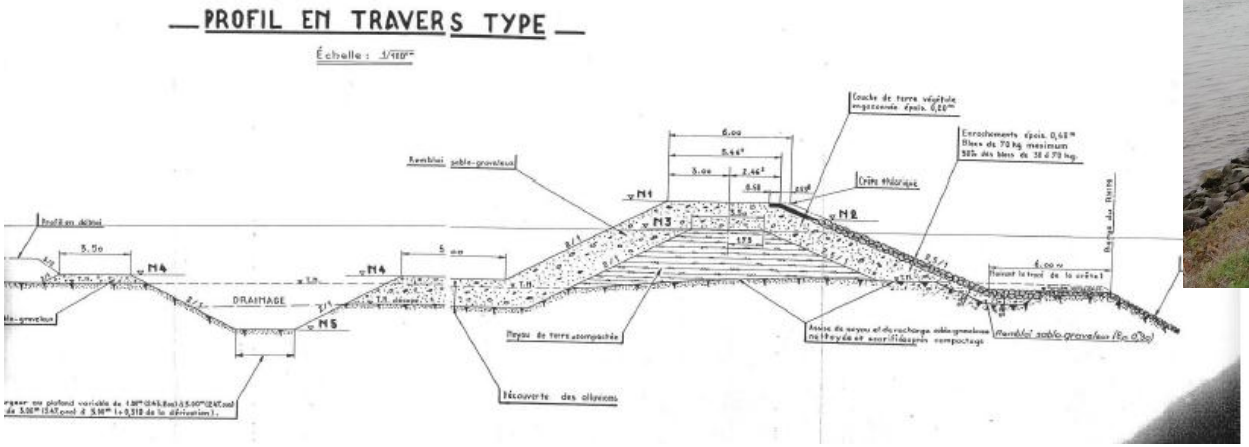
Canal embankments

- Lengths ranging from 3km to 30km
- Heights above ground level ranging from 0 to 35m.
- Hydraulic load around 10m
- Watertightness performed by the upstream face (concrete, bituminous concrete, geomembrane)

EMBANKMENT DAMS AND DIKES OPERATED BY EDF

Various types of embankments

Dikes
Example: Rhine dikes



Embankment heights above downstream ground level ranging from 0 to 10m
Central or inclined core made of sandy silts
Highly permeable foundation
Drainage channel downstream the dikes

SAFETY ISSUES ASSOCIATED WITH OVERFLOWING EROSION

General context

- All embankment dams and dikes operated by EDF were primarily designed to have satisfactory safety margins for a given project flood or a given maximum water level of operation (according to the state of the art at the time of their design).

- The maximum water level for which the dam can be operated must be lower than the top of the watertightness (taking into account a safety margin).

- Since the new dam safety regulations promulgated in France in 2007, dam and dike owners must perform Risk Analysis studies for dams higher than 10m. These studies must characterize the risk induced by the dam or the dike to the population and property located downstream. In these studies, the risk of failure is estimated following a semi-quantitative probabilistic scale (levels of occurrence A, B, C, D, E).

- The French regulations defining the project floods and/or the maximum water levels for dams and dikes are being updated soon (in 2018).

SAFETY ISSUES ASSOCIATED WITH OVERFLOWING EROSION

Present issues

- In the Risk Analysis studies, estimating downstream consequences of an embankment overflow can be necessary.
- Based on the results of the DSIG project “Erosion”, the only type of embankments for which a deterministic approach to model overtopping erosion considered by EDF as sufficiently validated is the type of embankments constituted in homogeneous fine cohesive materials => approach developed by USDA/ARS/HERU relying on determining erodibility and geotechnical parameters (K_d, τ_c, Cu) and running Windam or HRBreach model.

SAFETY ISSUES ASSOCIATED WITH OVERFLOWING EROSION

Present issues (continued)

- For other types of embankments (homogeneous coarse materials, zoned embankments, i.e. the large majority of embankment dams and dikes operated by EDF!), no deterministic approach to model overtopping erosion has been validated up to now.

  => overflowing erosion (criterion of erosion initiation, breach dimensions) is estimated by rules of thumb…

This situation needs to be improved: a lot of uncertainties and potentially inappropriate diagnosis result from this lack of a proper physical representation of overflowing erosion.

SAFETY ISSUES ASSOCIATED WITH OVERFLOWING EROSION

Potential issues

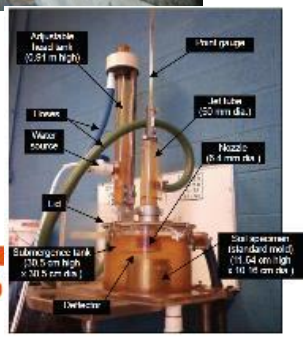
- Updates of hydrologic studies and/or modifications of safety regulations could lead in a near future to consider a risk of overflow for existing embankment dams /canals / dikes with the new project flood conditions.
- The ability to predict properly the erosion mechanisms in these cases would be very helpful in the definition of strategies of remediation.

Presently available engineering tools do not allow to make these predictions of overflowing erosion for the embankments constituted of coarse materials and the zoned embankments.

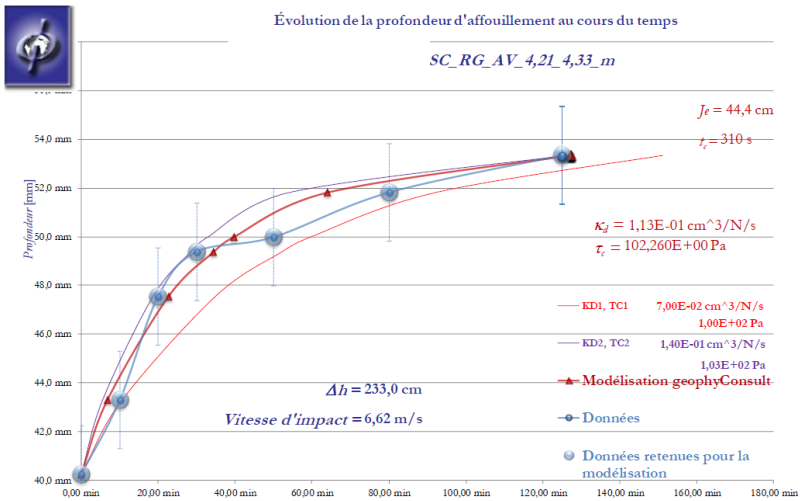
WHAT ARE THE ENGINEERING TOOLS AVAILABLE? WHAT GAPS NEED TO BE FILLED?

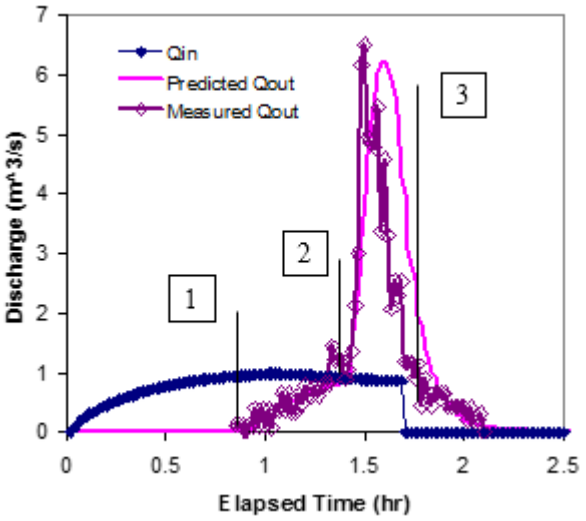
Engineering tools available

For homogeneous embankments made of cohesive fine soils… approach resulting from the USDA/ARS/HERU research and validated through the DSIG project.



$$\dot{\varepsilon} = \frac{dJ}{dt} = \begin{cases} 0 \ \ if \ \ \tau \le \tau_c \\ K_D(\tau - \tau_c) \ if \ \ \tau > \tau_c \end{cases}$$





WHAT ARE THE ENGINEERING TOOLS AVAILABLE? WHAT GAPS NEED TO BE FILLED?

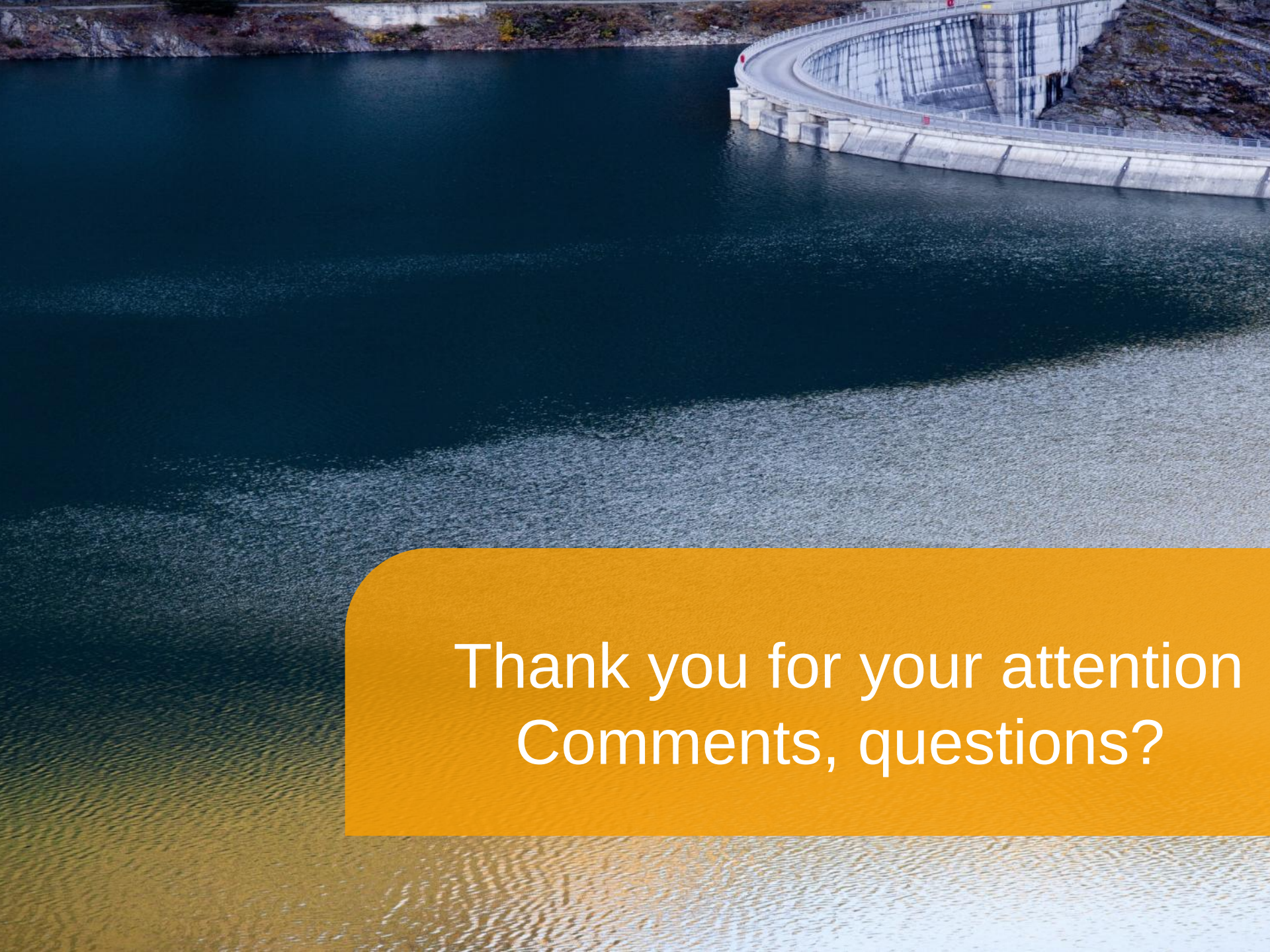
What gaps need to be filled?

Validated engineering numerical modelling able to represent:

- The overflowing erosion of zoned embankments (clay core, silt core, sandy-silt core with coarse downstream and upstream fills.

- The overflowing erosion of homogeneous embankments constituted in coarse materials (mixtures of fines, sands, gravels, cobbles), with an upstream face watertightness.

3 steps are crucial:
- Understanding the physics through experimental tests (including scale 1 tests)
- Development of an engineering numerical model (simple to use)
- Validation using scale 1 test results and (if possible) real case studies


Thank you for your attention
Comments, questions?