DR. D.N.D Hartford

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An owner's view of assessing and managing internal erosion risk

Concerning internal erosion risk, dam owners have three fundamental questions that can be answered to varying degrees of satisfaction by engineers using best available practices. These questions are:

1. Is there a problem with internal erosion?
2. Where is it (in the dam)?
3. How much time is there to resolve the problem?

Not much else matters as the issue of "Tolerability of Risk of Failure by Internal Erosion" is debatable. It is debatable because the tolerability of the consequences of any dam failure is dependent on the context of the failure. If the failure occurs within the design envelope of the dam the owner can expect a different social and political response than would be the case if the dam were overwhelmed by an unprecedented natural event such as a flood or earthquake of magnitude that were to exceed the best practice design criteria.

This presentation will provide a basis for a complete re-set of the approach to Tolerability of Internal Erosion Risk and provide a rationale as to why research on internal erosion needs to advance from empirically based answers to Question 1 above and move to a physically-based approach to addressing Questions 2 and 3.

An Owner's Perspective on a physical problem of uncertainty

3 Questions and a need for actionable answers

1. Do I have a problem with internal erosion?
2. Where in the body of the dam is the problem?
3. How long do I have to fix it?
   - Answers like:
     - maybe,
     - possibly here or maybe there, and,
     - it depends

   Are not much use

- So how well does B164 help me (the owner) with my questions?

Antonym's – to help in interpretation

High	→	Low
Possible	→	Impossible
Can happen		Cannot happen
Probable	→	Improbable
Can happen		Can happen
Likely	→	Unlikely
Can happen		Can happen

How well do people “judge” chance

- We should not think that an individual’s (even an expert) natural tendencies concerning probability are well-calibrated to the physical world.
- People behave as if games of chance even out,
  - or as if pulling the slot machine handle oneself improves the chance of winning, or,
  - as if small numbers of observations are highly representative of a random process.
- These things are all false
  - In particular, people tend to overconfidence in their assessments, and mis-calibration seems to vary systematically with the difficulty of the assessment

How does B164 help me answer my questions?

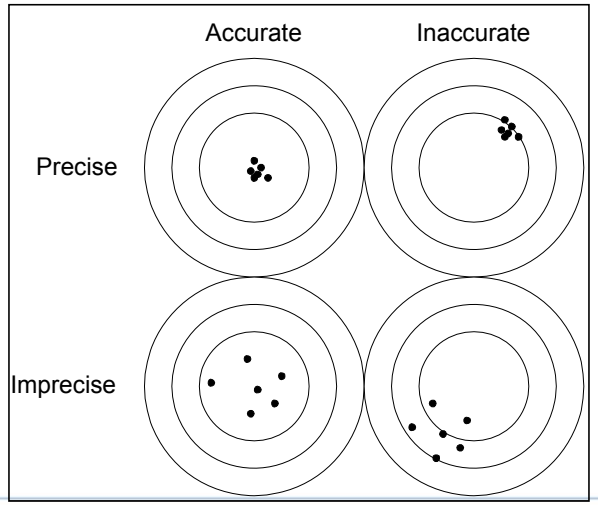
Table 4
Classification of likelihood of internal erosion associated with the dam zoning

Likelihood of Internal Erosion	Control for internal erosion	Dam zoning and category number
A Large	Little or no control	Homogeneous earth fill (category 0); Earth fill with rock toe (category 2).
B Moderate	Some control of internal erosion depending on detail of zoning and filter capability.	Zoned earth fill (3); Zoned earth and rock fill (4); Puddle core(8); Hydraulic fill (11).
C Low	Moderate control of internal erosion depending on the filter capacity and details of the core wall or face slab.	Concrete face earth fill (6); Concrete face rock fill (7); Concrete core earth fill (9); Concrete core rock fill (10).
D Very Low	Good control of internal erosion subject to good details of zoning and filter design.	Earth fill with filters (1); Central core earth and rock fill (5).

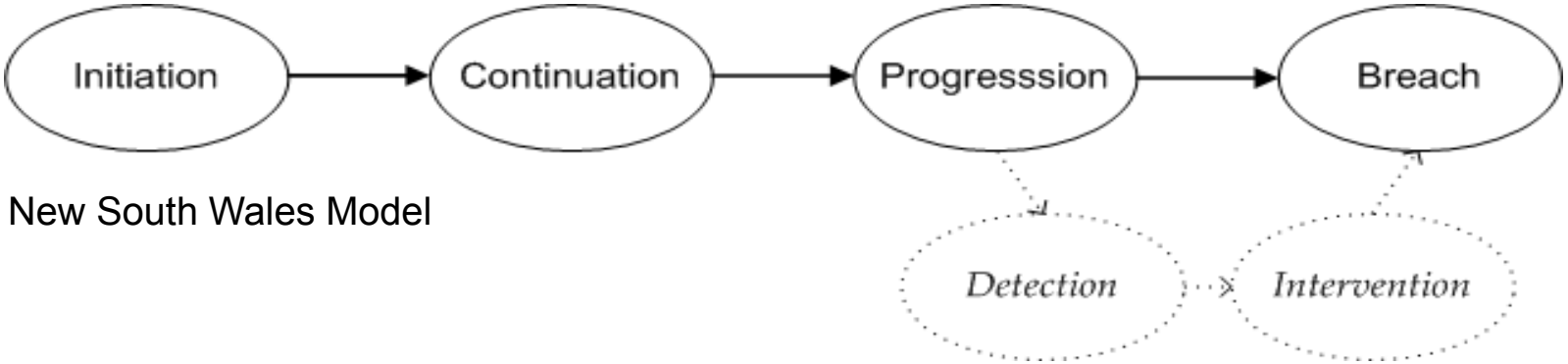
Answer to Q1: Under all circumstances, internal erosion ***is*** possible
Action:- Be prepared

Model Uncertainty and Parameter Uncertainty

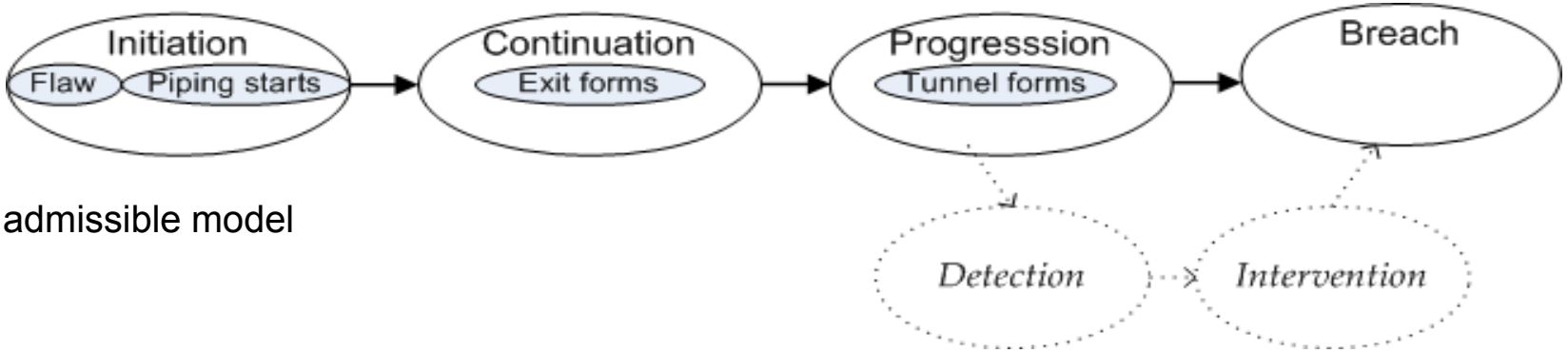
- Model uncertainty has to do with the degree to which a chosen mathematical model accurately mimics reality;
- Parameter uncertainty has to do with the precision with which model parameters can be estimated.



Generic degradation (internal erosion) models



University of New South Wales Model



Equally admissible model

Need for stable advice

- The essence of Bayesian probability is that the probability changes when the information changes
  - The problem with subjective probability in risk analysis is that:
    - The probability changes when the “expert” changes!
- So, how can we control this problem of expert probabilities?
  - But it is much more widespread than probabilistic risk analysis
- It is a problem with expert opinion in general

Mafeteng Dam, Lesotho (*failed: 21-02-1988*)

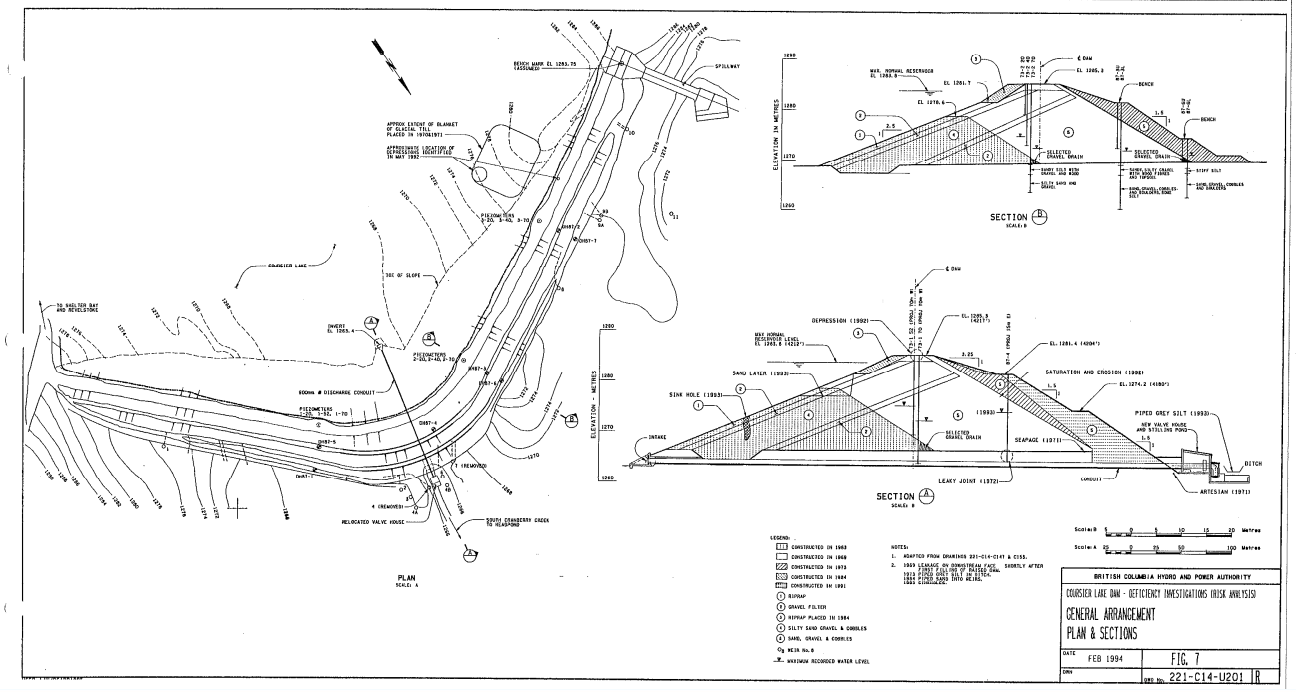
Failure was caused by piping along the spillway wall and embankment interface in which about 10 m wide of the embankment material and the left inclined spillway retaining wall slab were breached. (African Development Fund, 1999)
ADF-BD-IF-99-175-EN-LESOTHO-PCR-FOUR-TOWNS-WATER-SUPPLY-PROJECT

But what about uplift underneath the very thin, lightly reinforced spillway chute slab?

It was established that both design and construction errors had caused the failure, and consequently the Government initiated legal actions against both the Consultant and the Contractor. (ADF, P.10)

Dam and reservoir

Design detail



Sinkhole

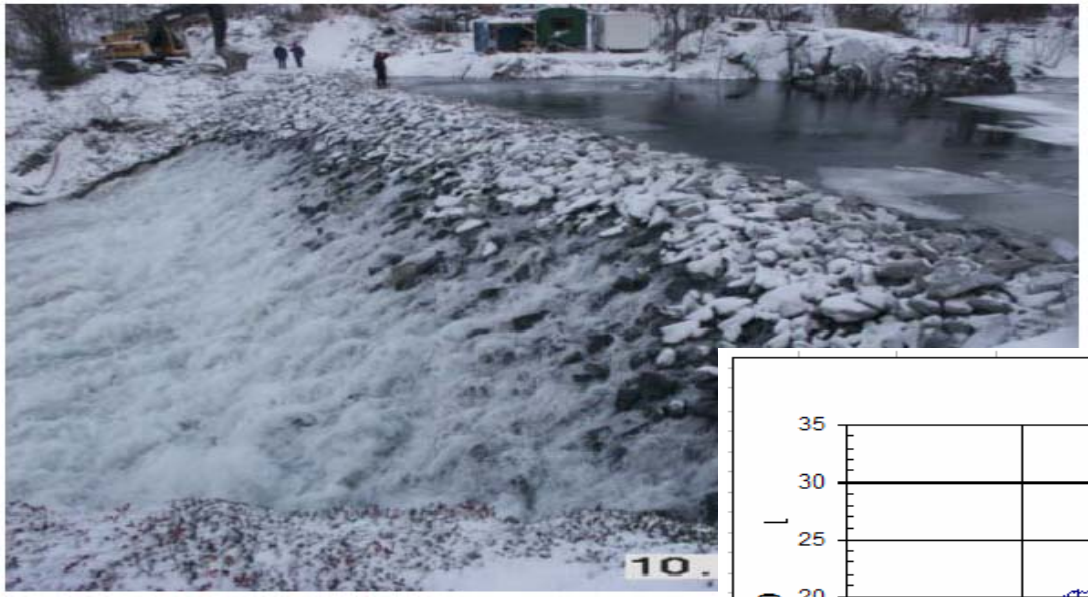
Construction material!

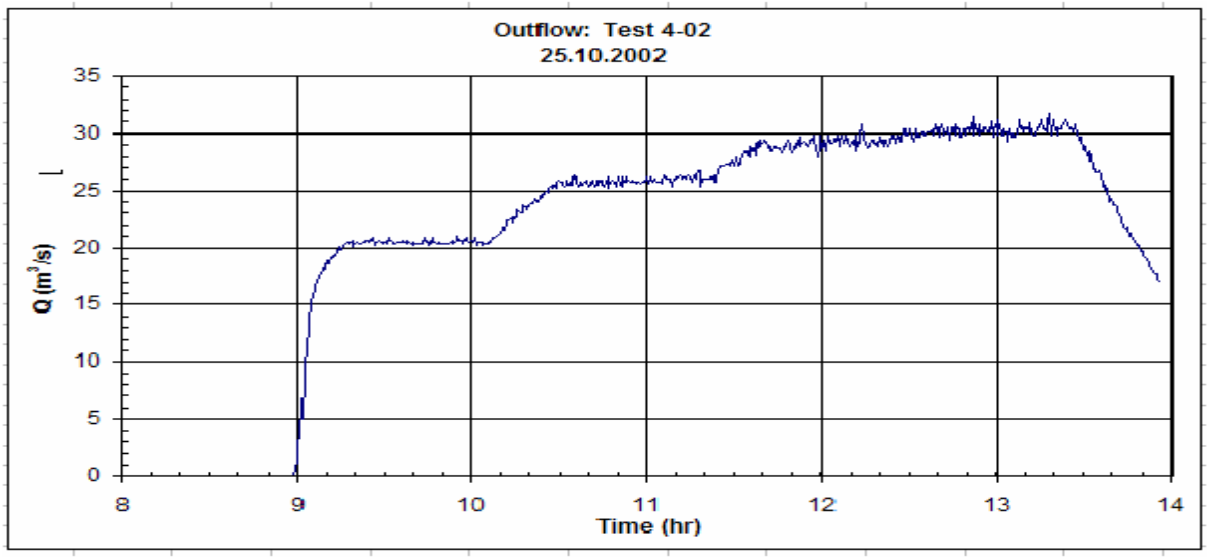
How much evidence do we have?

Arching during internal erosion!

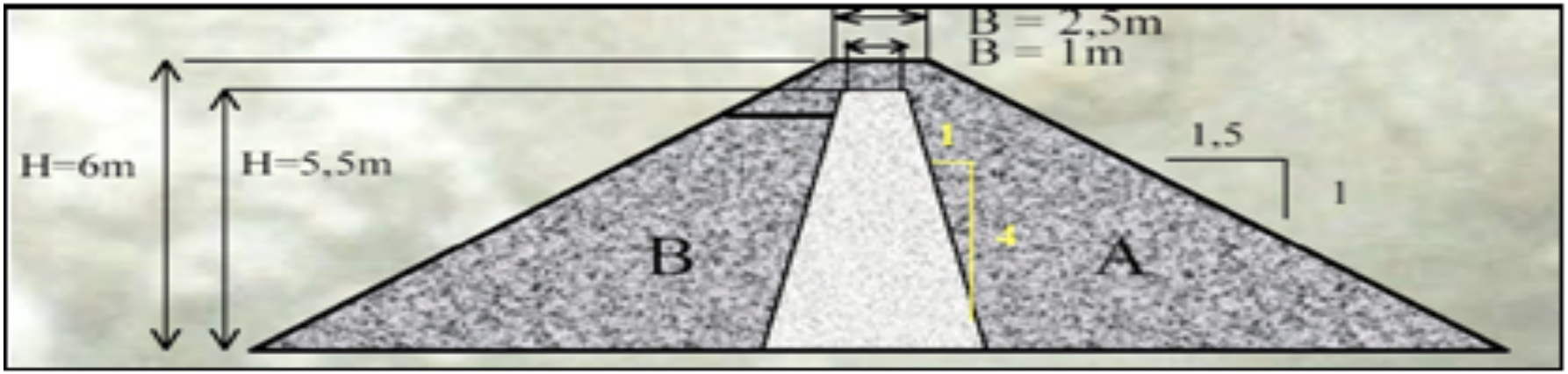
Failure of Norwegian Test Dam

Rock fill dam seepage tests (Norway)





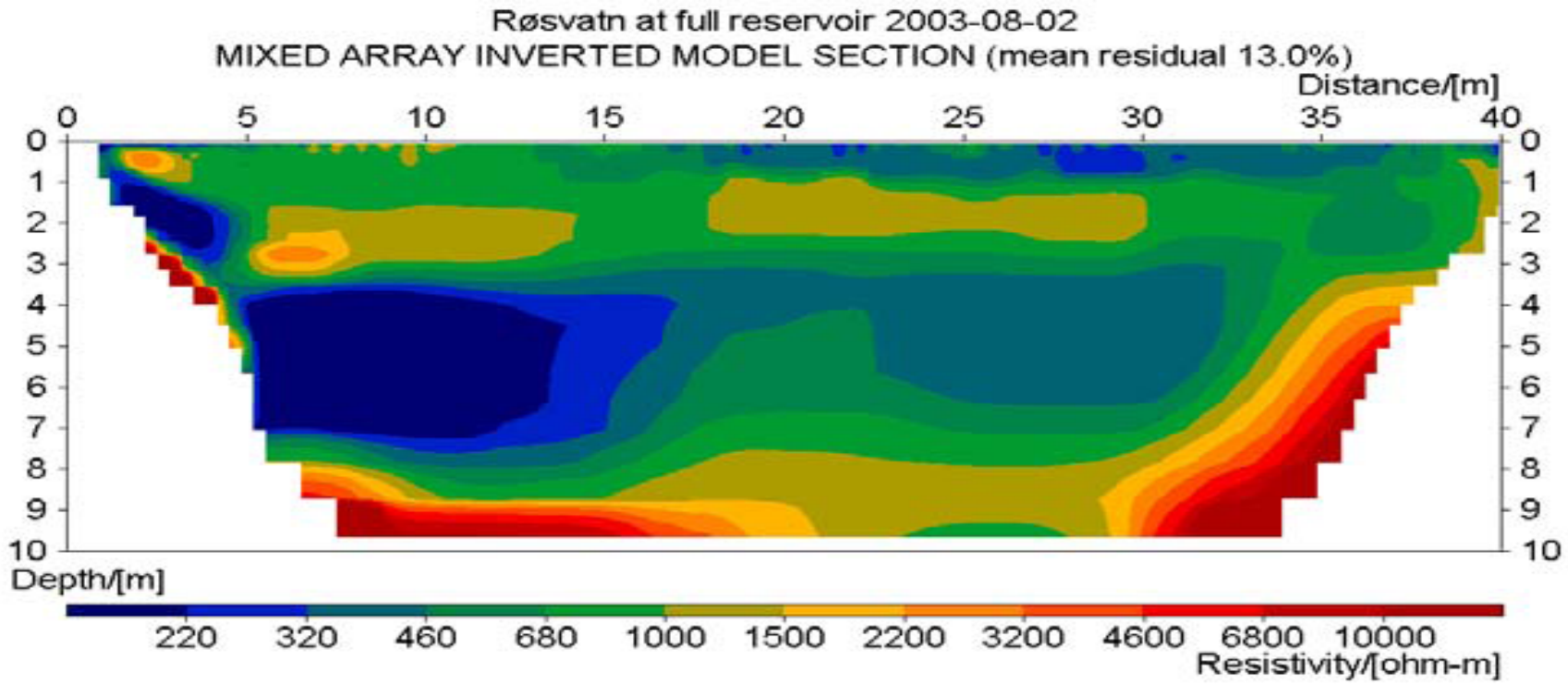
Blind test



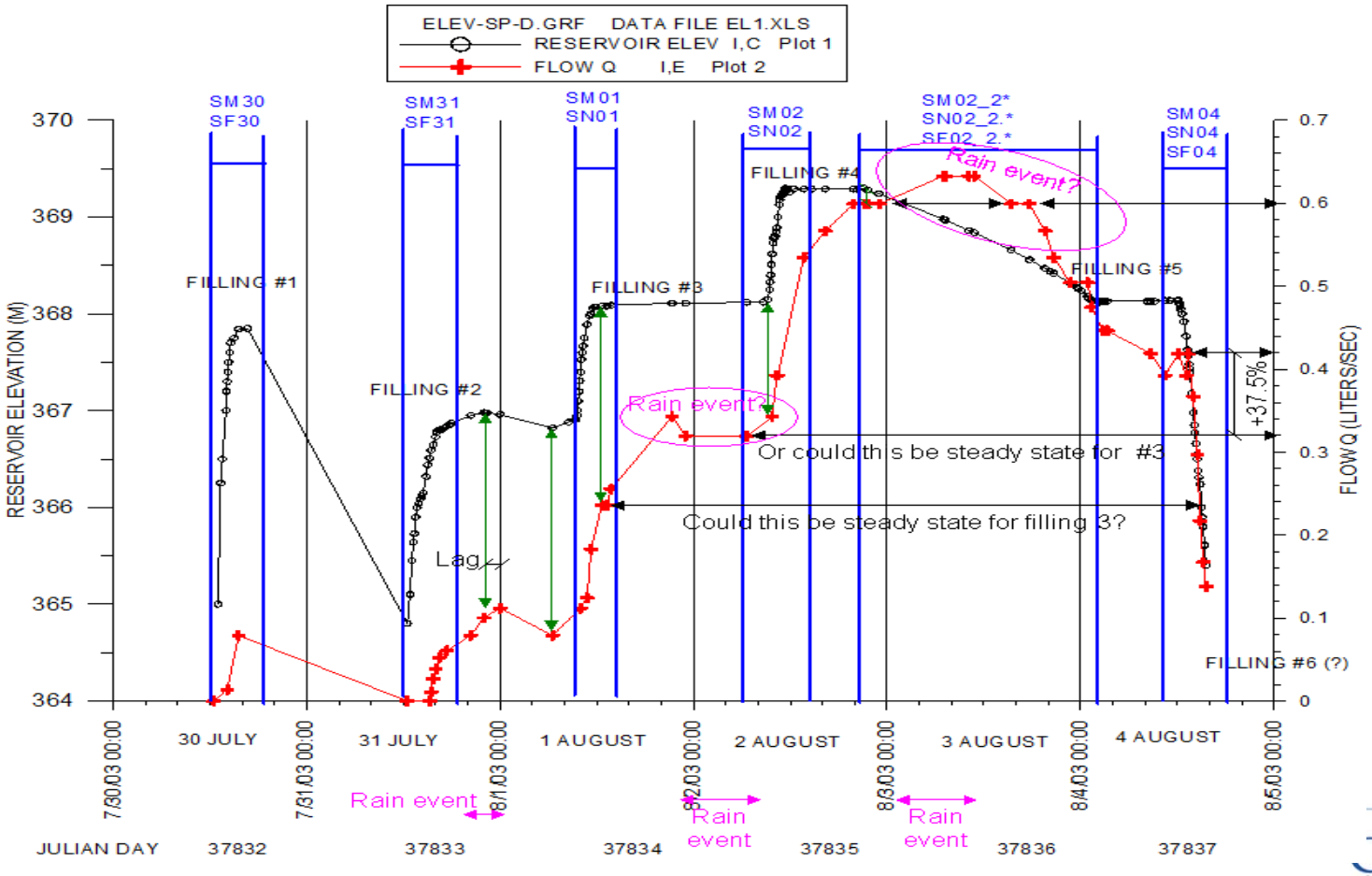
Building a “leaky dam”

Electrical sensors

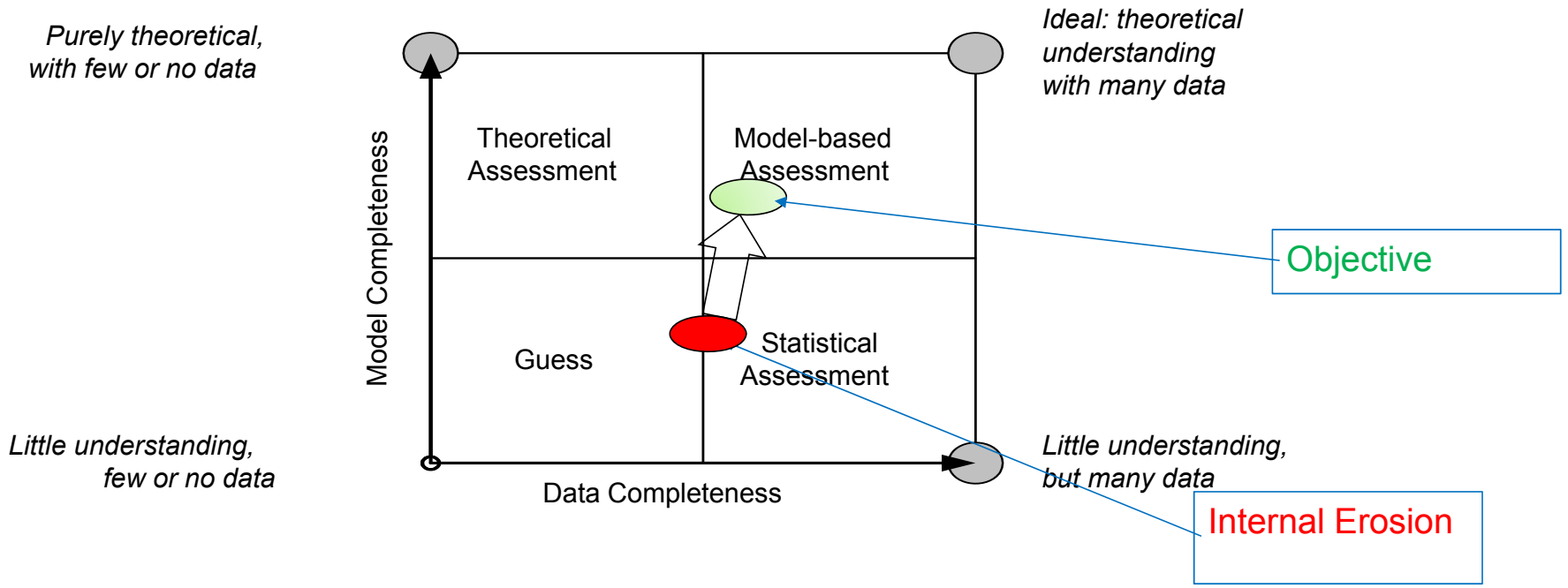
Resistivity profile during filling



Dam leaked perfectly



Dimensions of internal erosion analytics



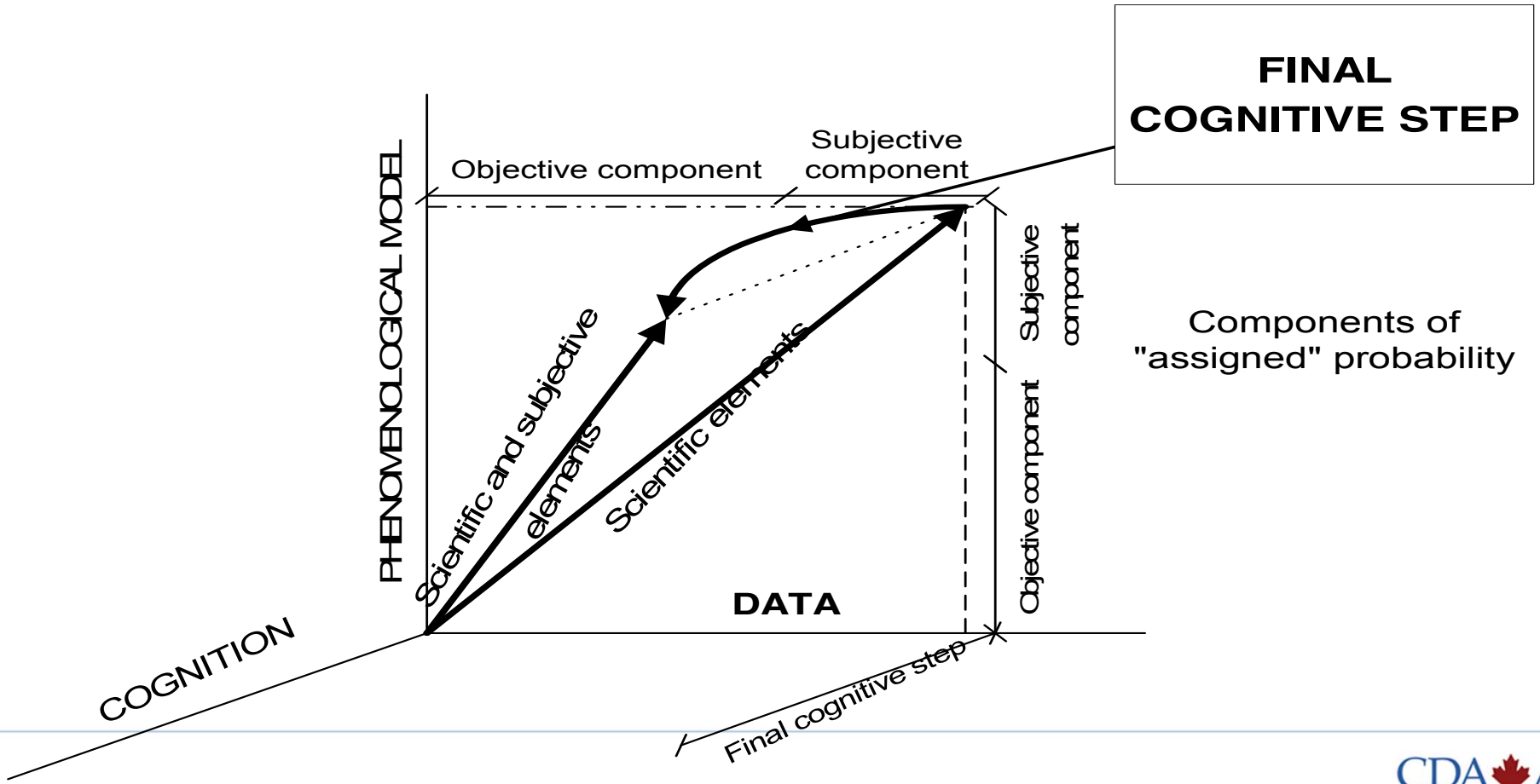
Predictive models (Lambe, 1973)

Prediction type	When prediction made	Results at time prediction made
A	Before event	-
B	During event	Not known
B1	During event	Known
C	After event	Not known
C1	After event	Known

What we need!

What we have!

Subjectivity cannot be eliminated



Role of judgement

- Judgement has an important role to play in performance assessment of dams and levees
  - But it must be used appropriately
    - To control the effects of uncertainty

- Essence of *risk-informed* performance assessments are:
  - Predictive analysis models that reflect the physics of the failure mechanisms
  - Quality, scientifically qualified data
  - Experts selected on the basis of qualities and expertise
  - Systems analysis methods