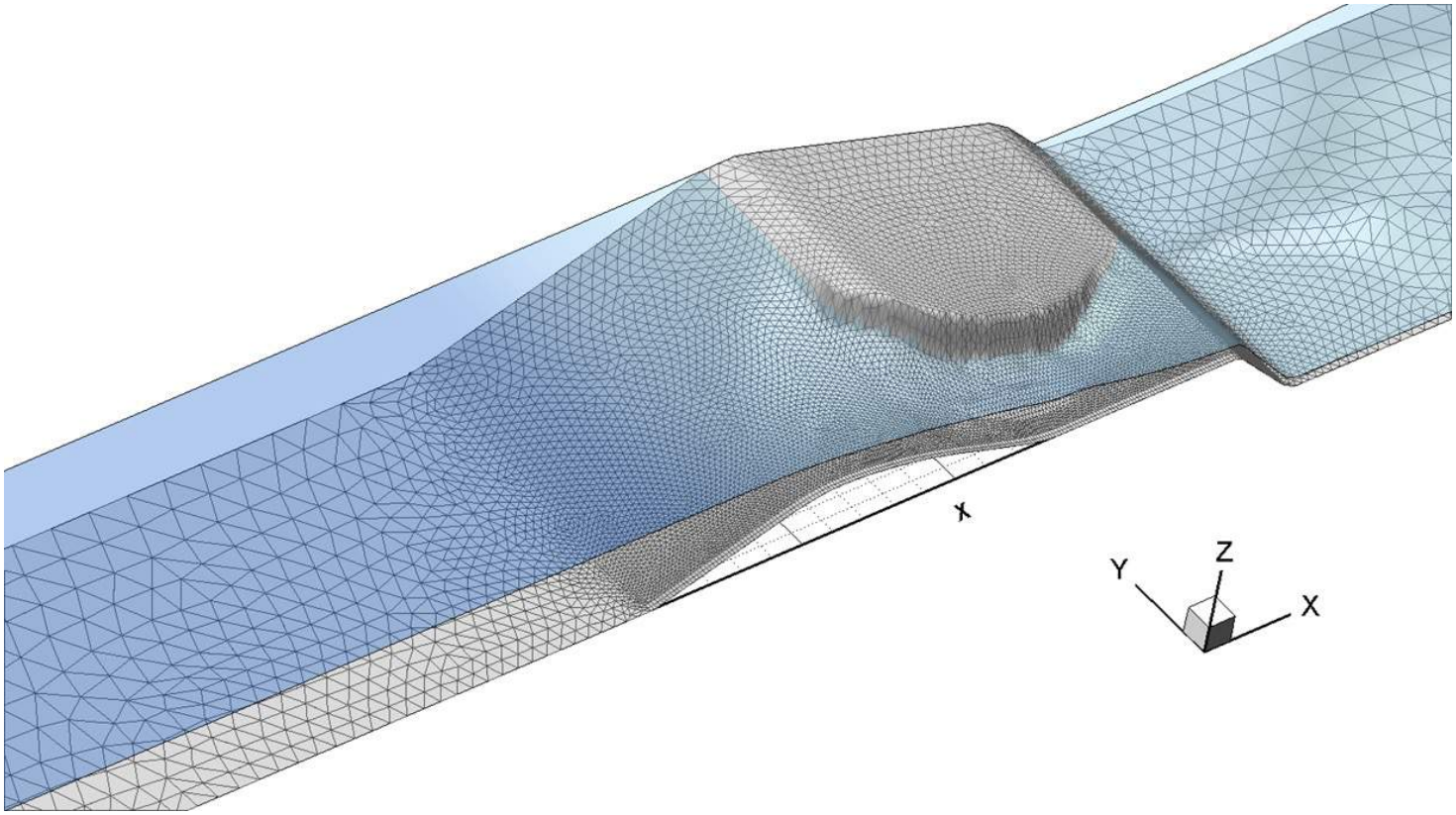
# Surrogate modelling for complex dike failure mechanims

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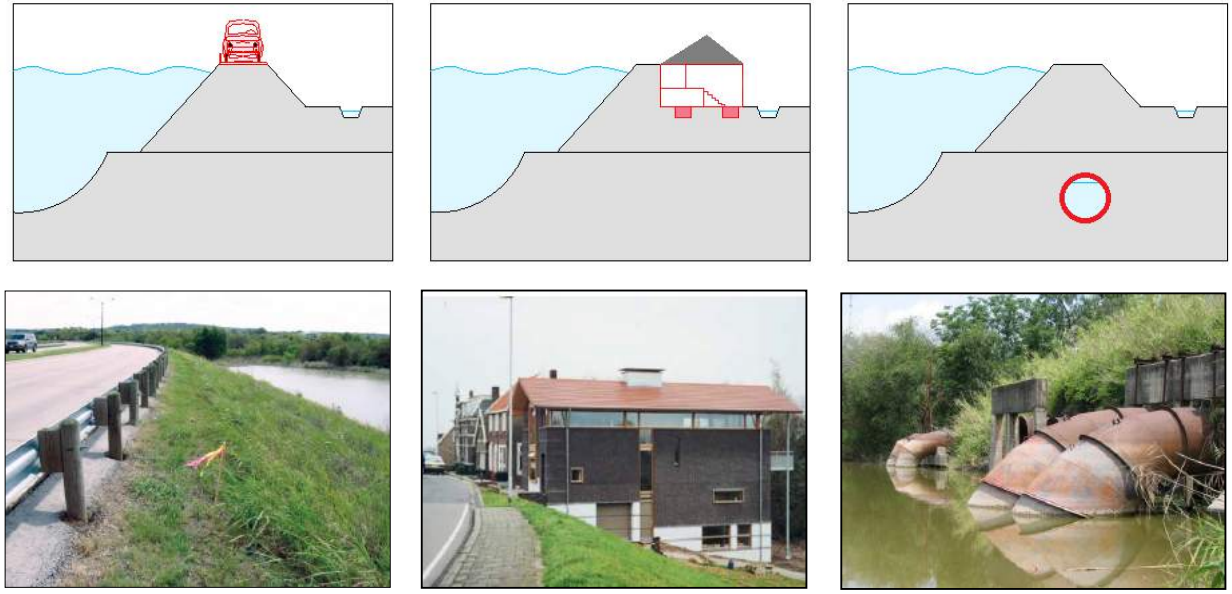
*Hydraulic Structures and Flood Risk - Hydrualic Engineering Department (TU Delft)*

TU Delft

# *What is a complex flood defence ?*

A flood defence for which the conventional modeling aproach cannot be easilly implemented in an stochastic framework due to the presence of hetereogenities such as houses, roads, pipes, or any other type of discontinuity.



# *Emulator/ Surrogate model / Meta-model / Responce-surface / Digital twin ?*

**"A Model built to imitate a more complex capable of reducing its computation time."**

**Pros:**

- Reduction of calculation time
- Dimension reduction

**Cons:**

- Course of dimensionality (Sampling)
- Extrapolation capacity
- Probabilistic sampling bias
- Induced errors due to fitting

**Methods (Data Driven):**

- Principal component analysis
- Kriging/Gaussian Process
- Artificial Neural Netwrok
- Support vector machines
- Deep learning
- Bayesian Networks
- Bla, bla, bla, bla .....

# Paper 1: Where to put a sewer pipe under dike ?

*European Journal of Environmental and Civil Engineering*, 2018
Vol. 22, No. 6, 707–735, https://doi.org/10.1080/19648189.2016.1217793

Taylor & Francis
Taylor & Francis

Check for updates

**Piping erosion safety assessment of flood defences founded over sewer pipes**

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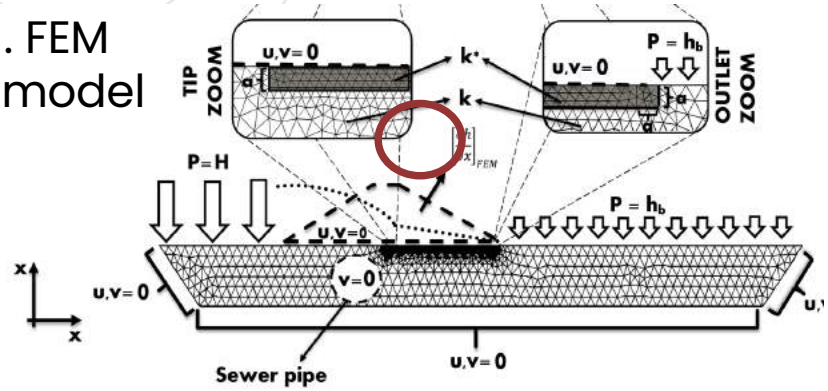
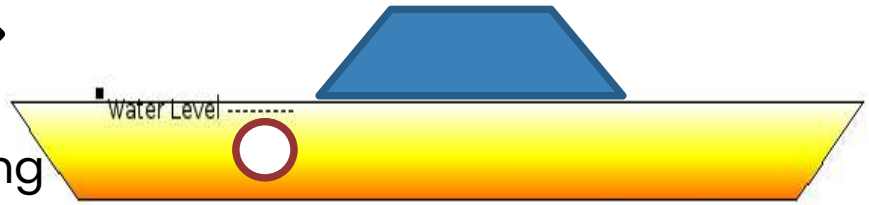
(*Received 27 January 2016; accepted 18 July 2016*)

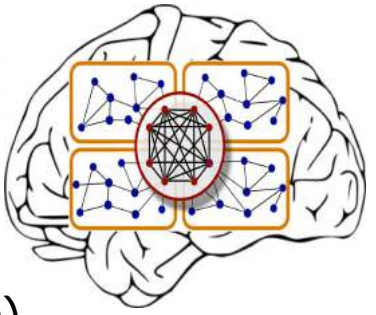
1. FEM model




2. Training Data (10k simulations)

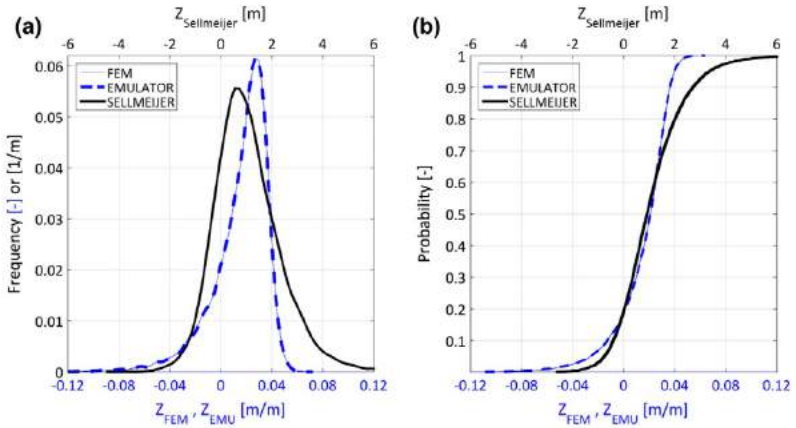



3. Surrogate model (ANN-MLP)



5. Missing samples

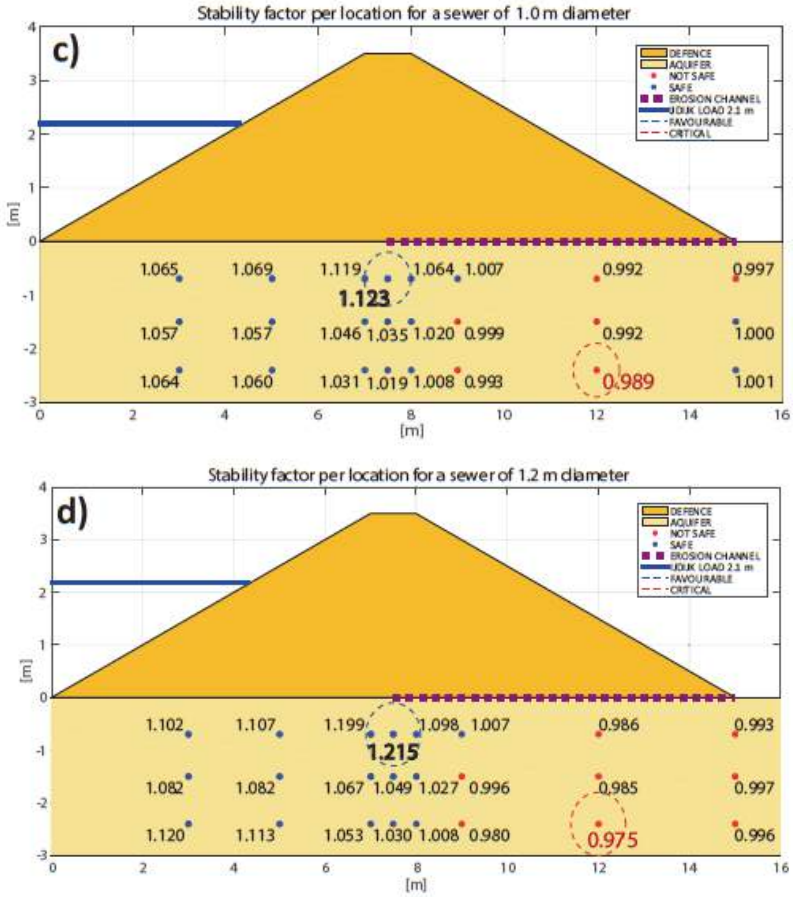
4. Validation vs Sellmeijer



# Paper 1: Where to put a sewer pipe under dike ?

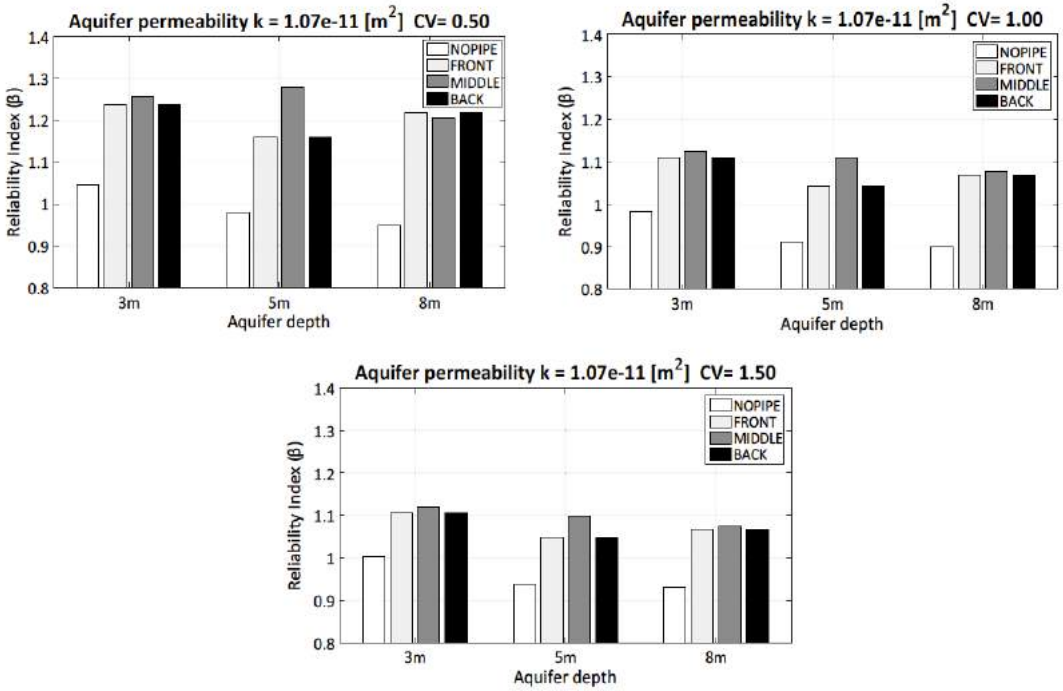
TU Delft

## Deterministic as Safety Factor (SF)




Conclusion 1: Pipe as deep as possible and after midpoint.

## Probabilistic as Beta Factor ($\beta$)




Conclusion 2: Midpoint location is always best, but safety is reduced with heterogeneity.

# Paper 2: Is a dike with a road less or more safe against wave overtopping ?

1. Wave overtopping simulator experiment with road (Millingen)


Journal of Marine Science and Engineering

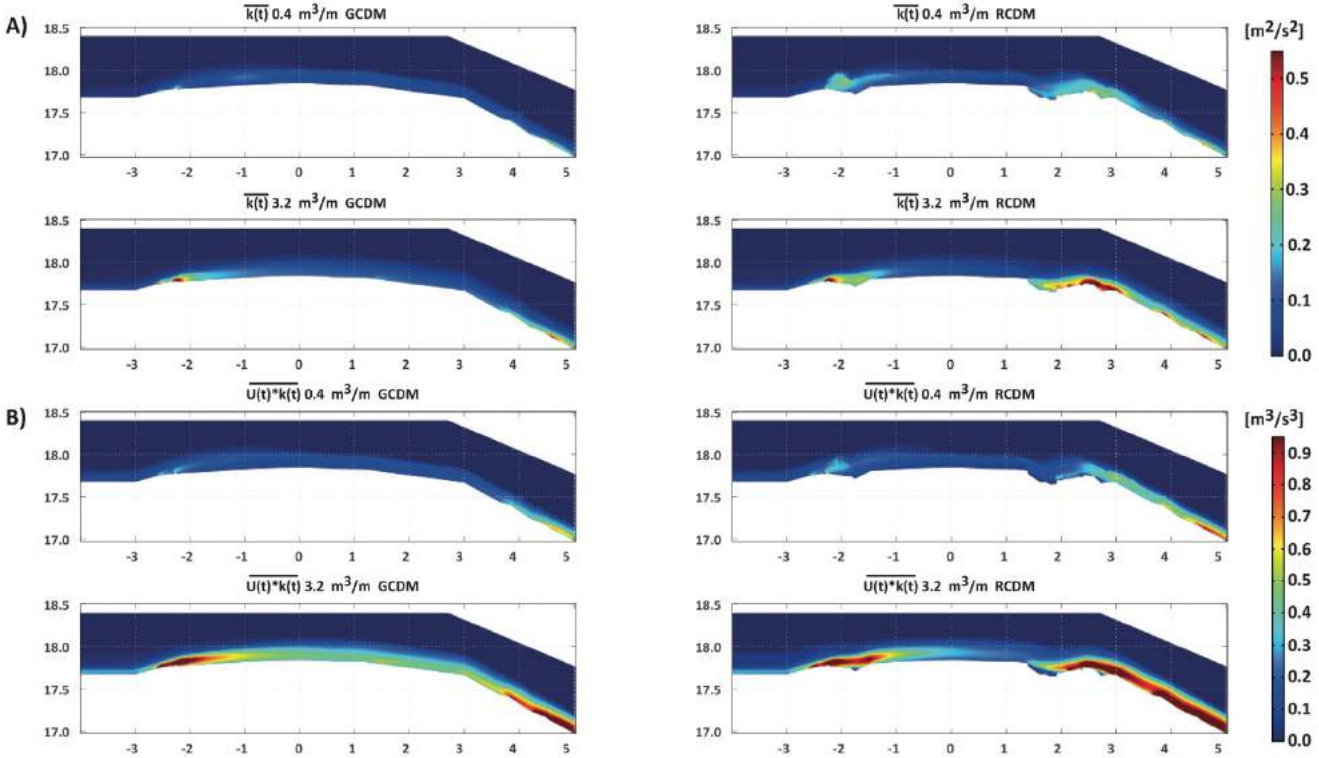
MDPI

*Article*

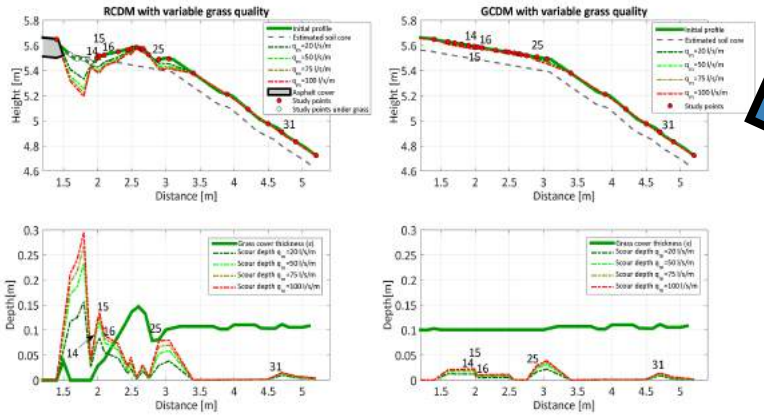
**Failure of Grass Covered Flood Defences with Roads on Top Due to Wave Overtopping: A Probabilistic Assessment Method**

Juan P. Aguilar-López [1,2,*], Jord J. Warmink [2], Anouk Bomers [2], Ralph M. J. Schielen [2,3] and Suzanne J. M. H. Hulscher [2]

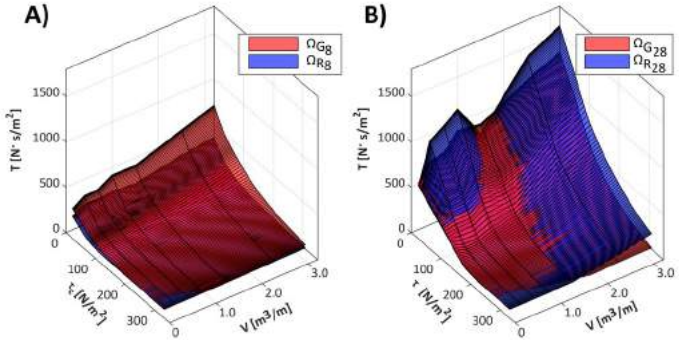
2. CFD Model calibrated for different wave volumes



# Paper 2: Is a dike with a road lees or more safe ?

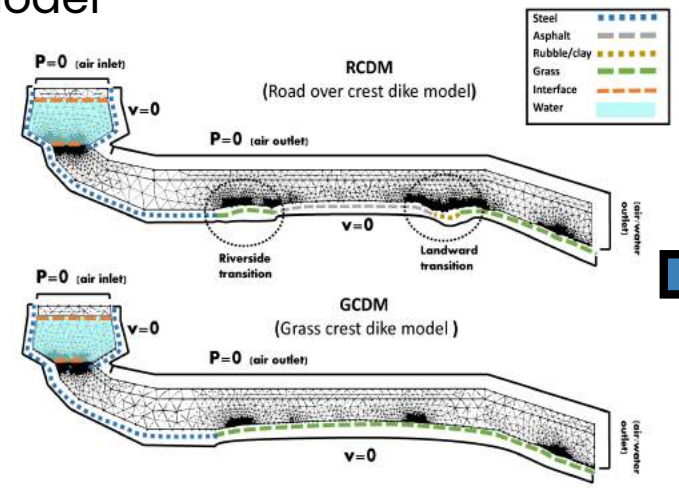


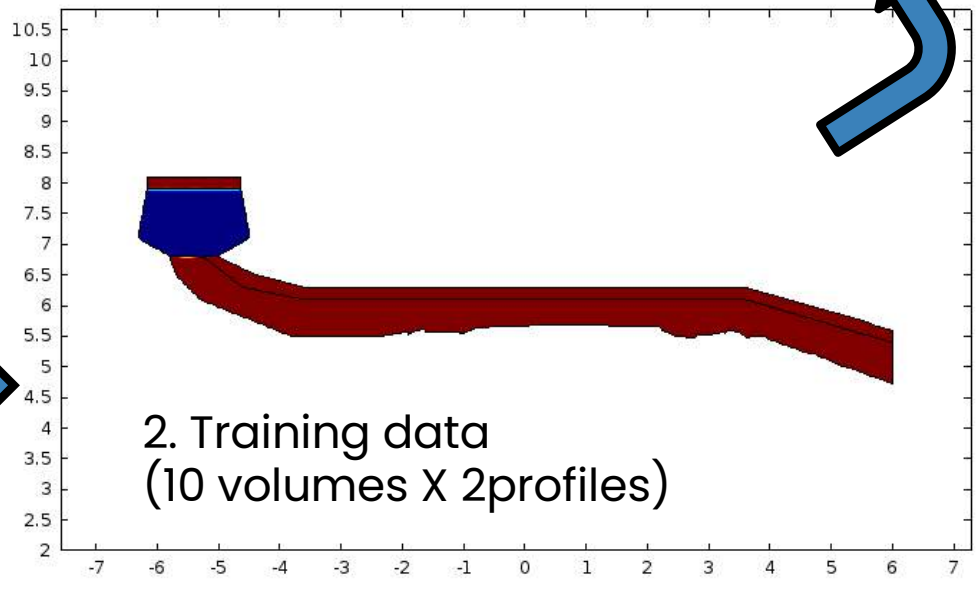

3. Surrogate model –
3D Response surface
(10 volumes X 2profiles)




4. Storm based stochastic temporal cumulative scoured profiles.

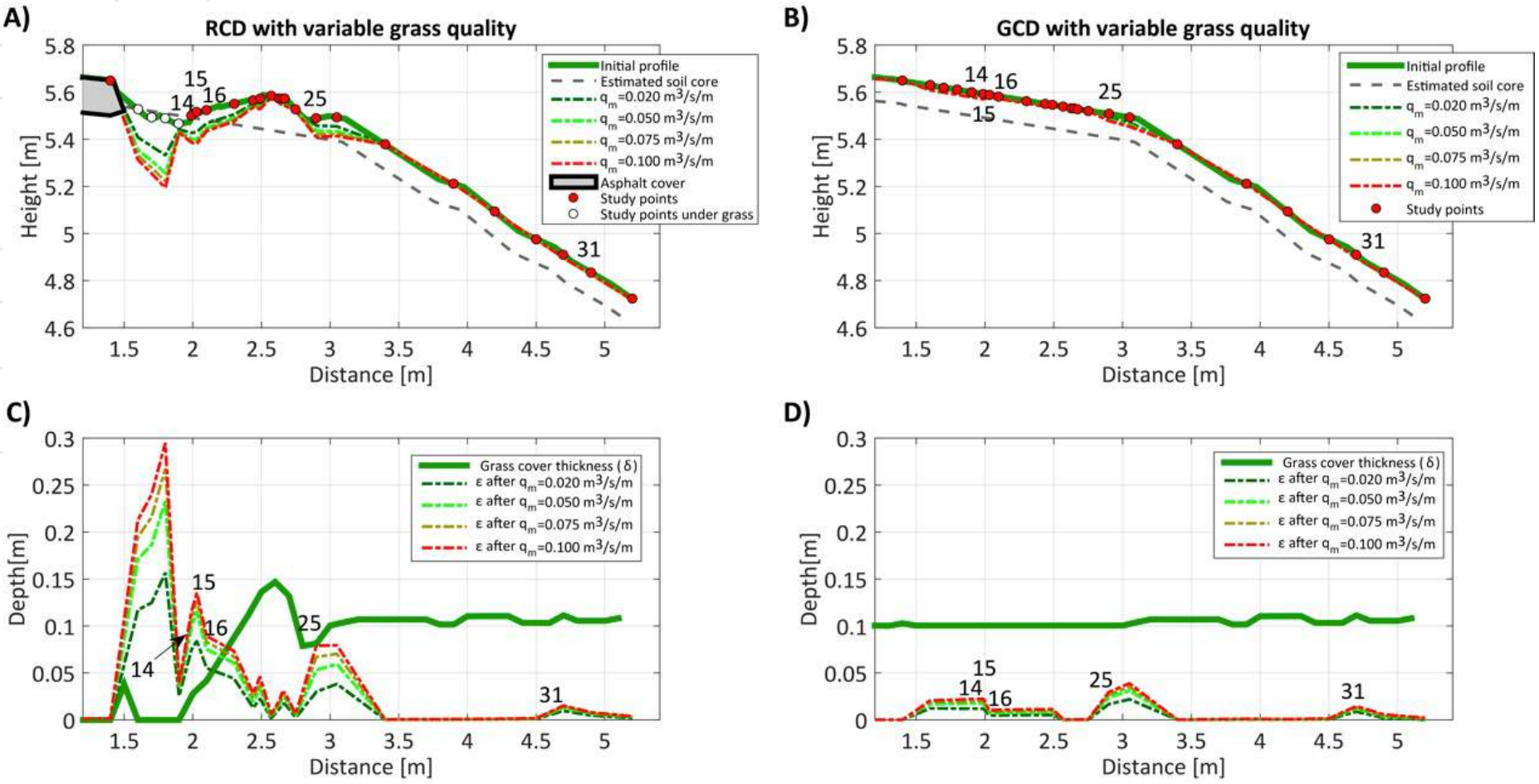
1. FEM model



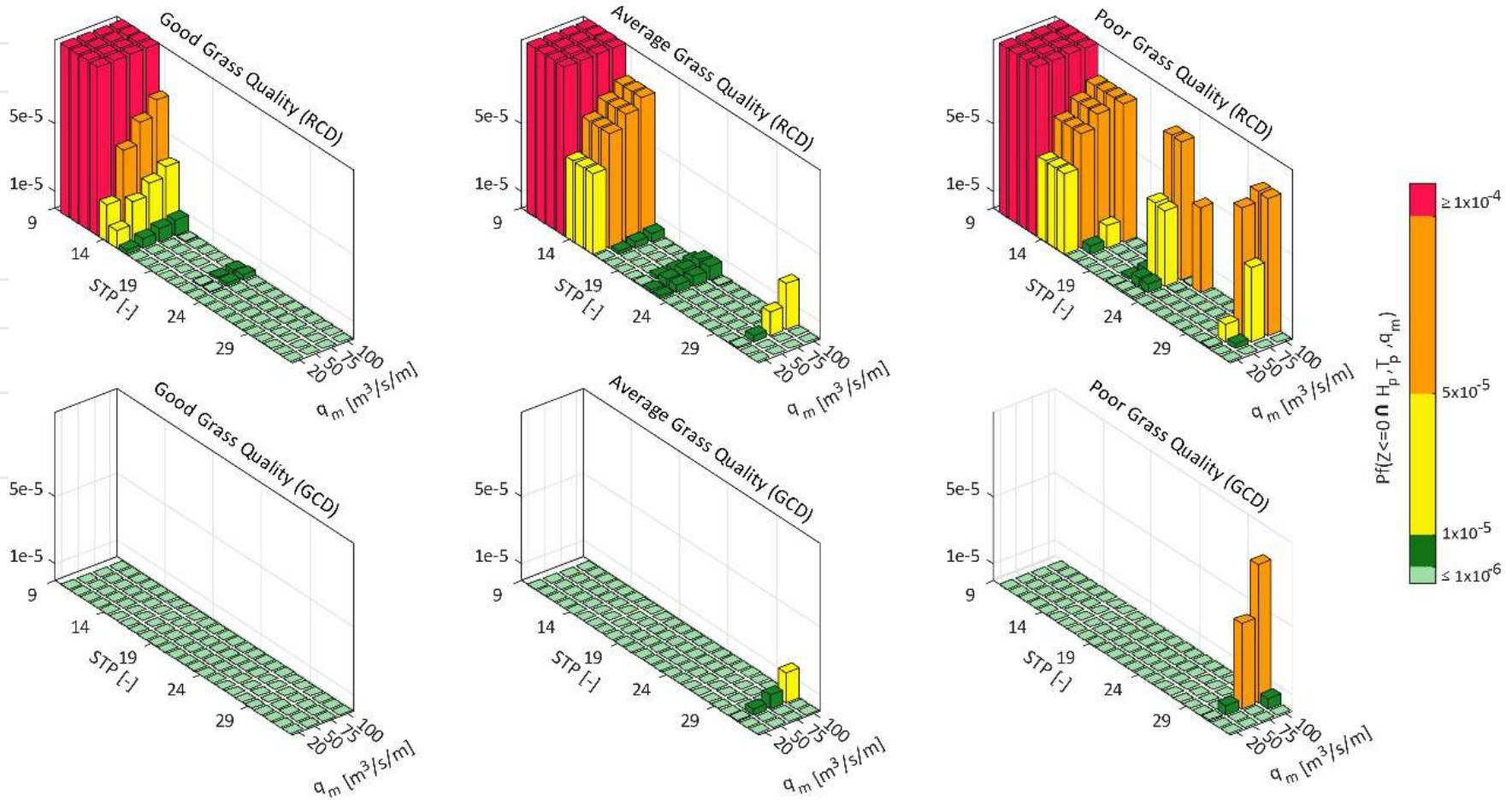
2. Training data
(10 volumes X 2profiles)

# Paper 2: Is a dike with a road lees or more safe ?



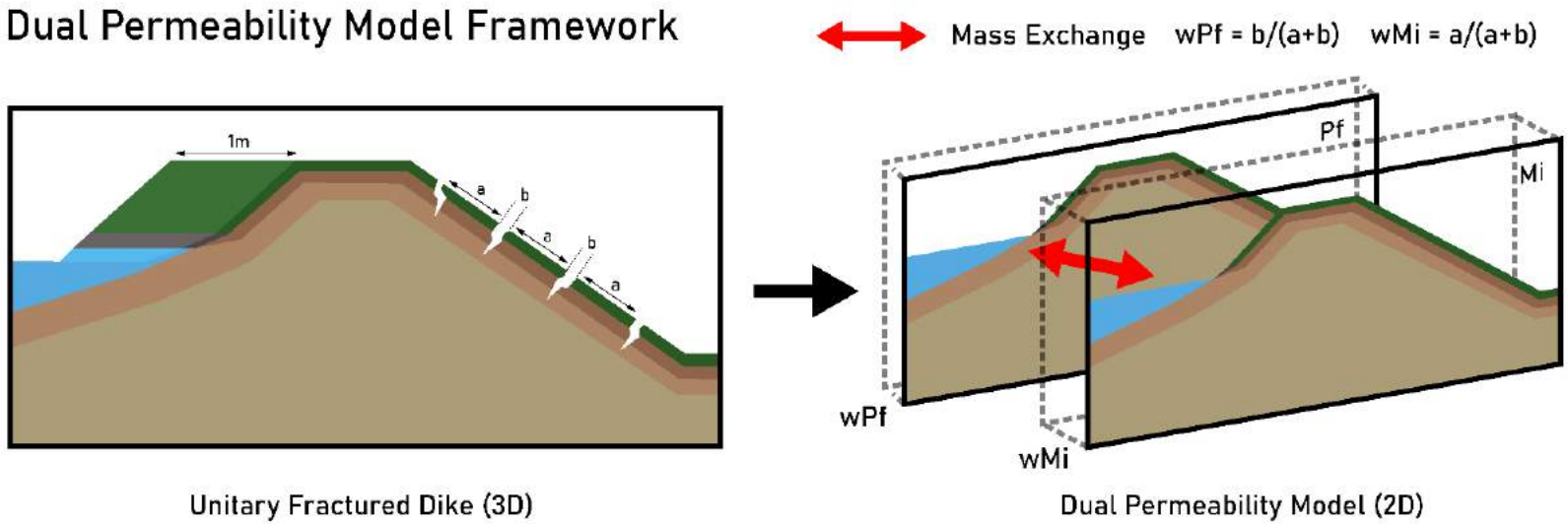

Conclusion 1: Dikes with roads are significantly less safe than dikes without roads. Scouring in healthy covers failed for storm of q = 100 l/s/m. Dike without a road failed for 150 l/s/m.

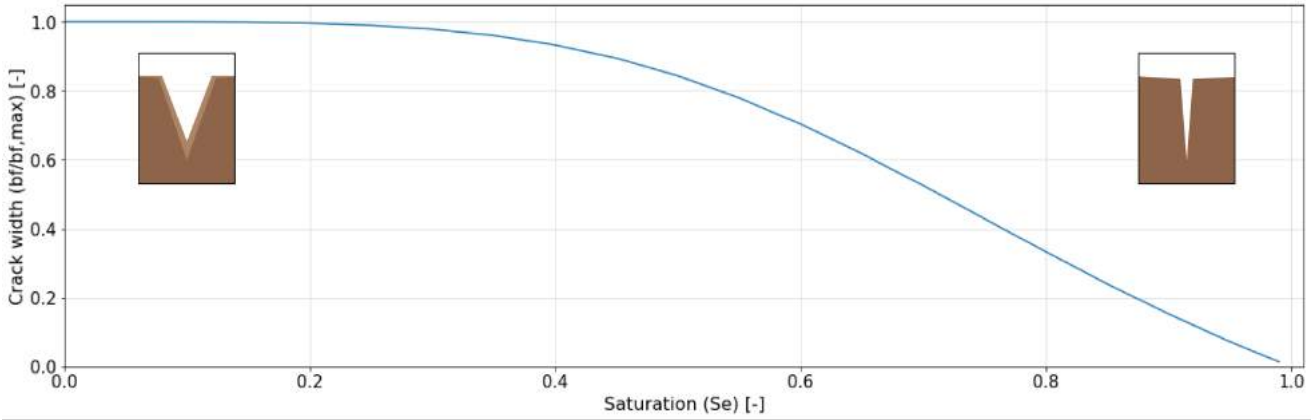
# Paper 2: Is a dike with a road lees or more safe ?




Conclusion 2: Loss of safety from poor grass quality is more important than the effects of turbulence due to road and transitions in terms of failure probability.

# Paper 3: What is the (hydrological) effect in the macro-stability of canal dikes derived from presence of cracks ?

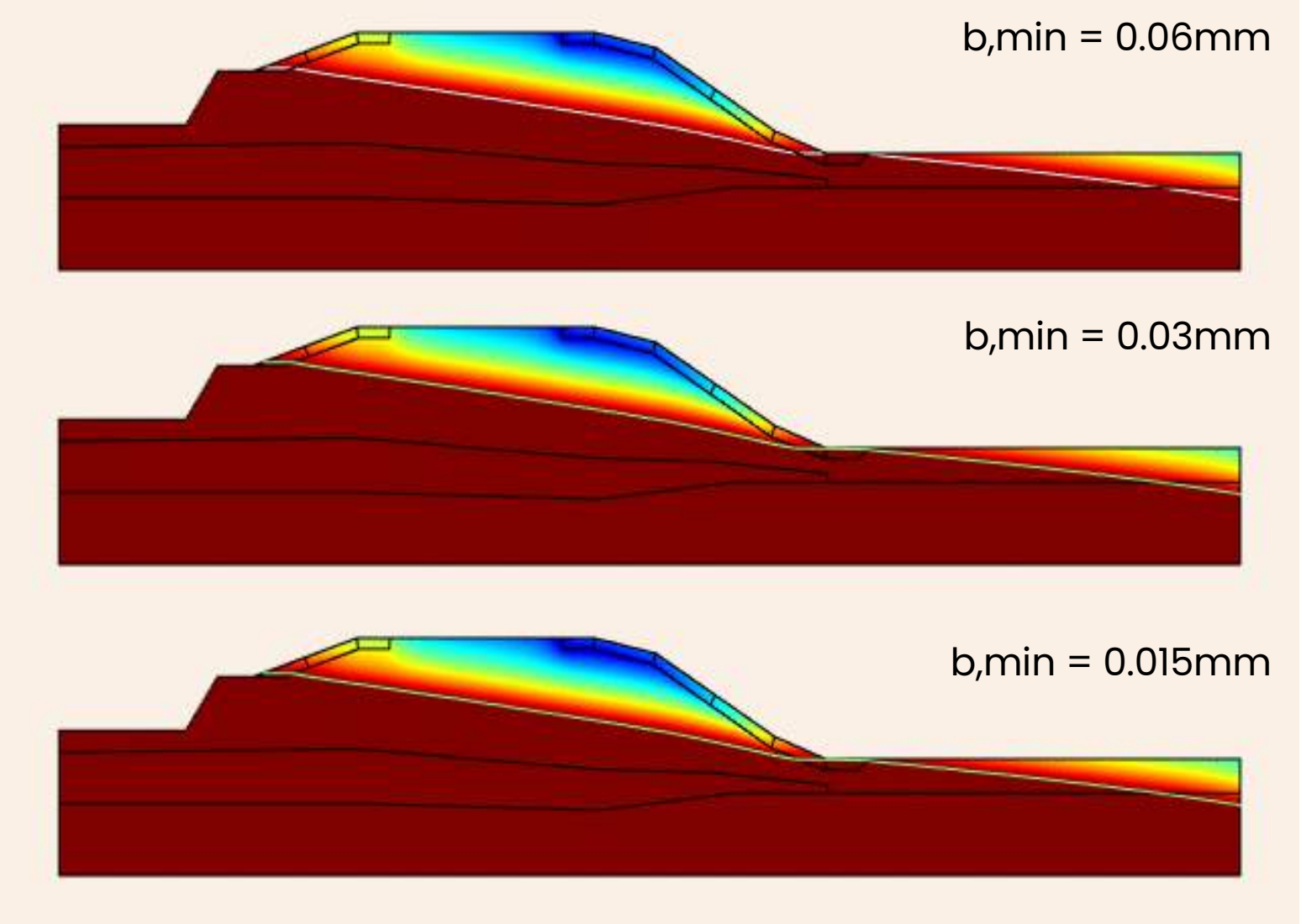



MSc thesis by Jorijn Holstvoogd (2022).

# Paper 3: What is the (hydrological) effect in the macro-stability of canal dikes derived from presence of cracks ?

Same rainfall event with different crack aperture



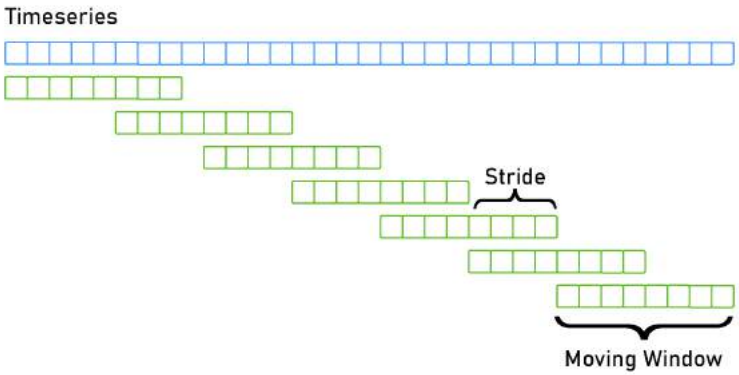
# Paper 3: What is the (hydrological) effect in the macro-stability of canal dikes derived from presence of cracks ?

1000 Simulations **only**
(double Richard's equation is
3.5 Hours per rainfall event)

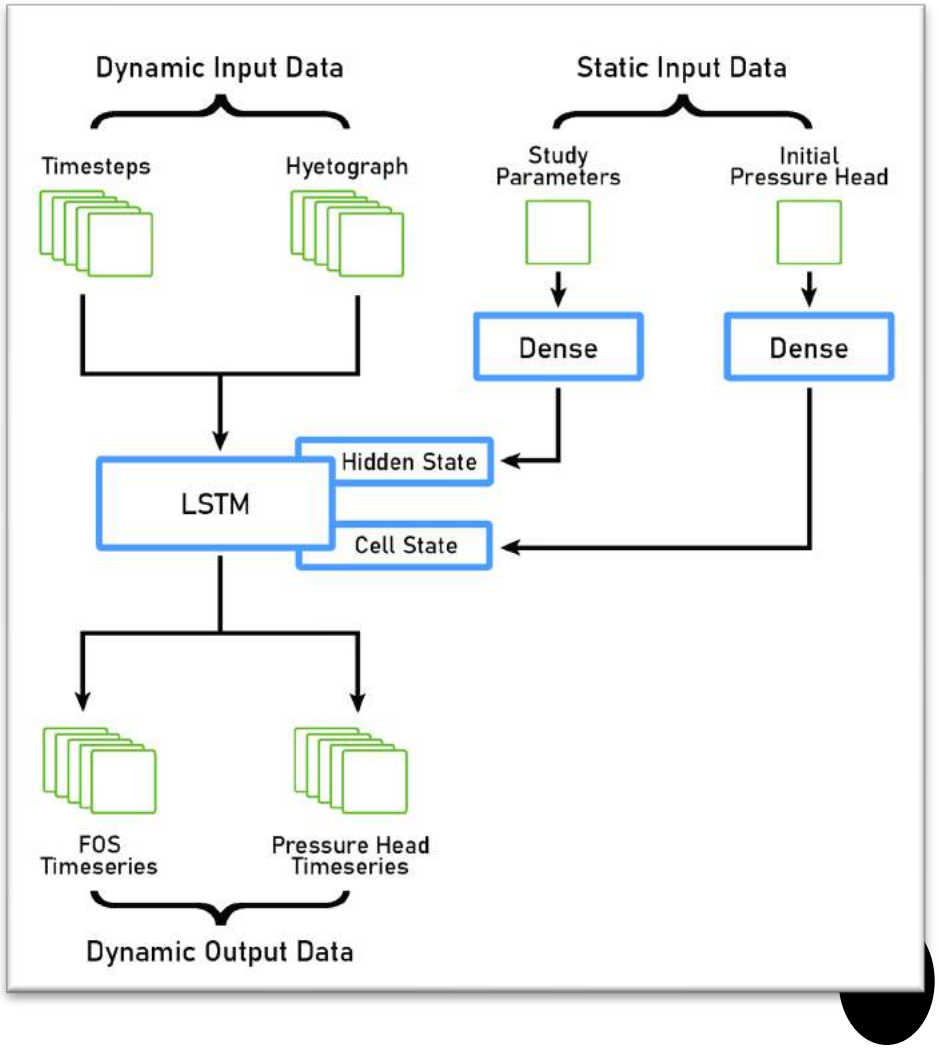
Information theory for static data:

| # LHS Parameter Sets | Augmented Dataset |
|---|---|
| 10 | 206 |
| 100 | 1958 |
| 200 | 4358 |
| 1000 | 21875 |

Lagging block for dynamic data:




Surrogate Architecture (LSTM-ANN)



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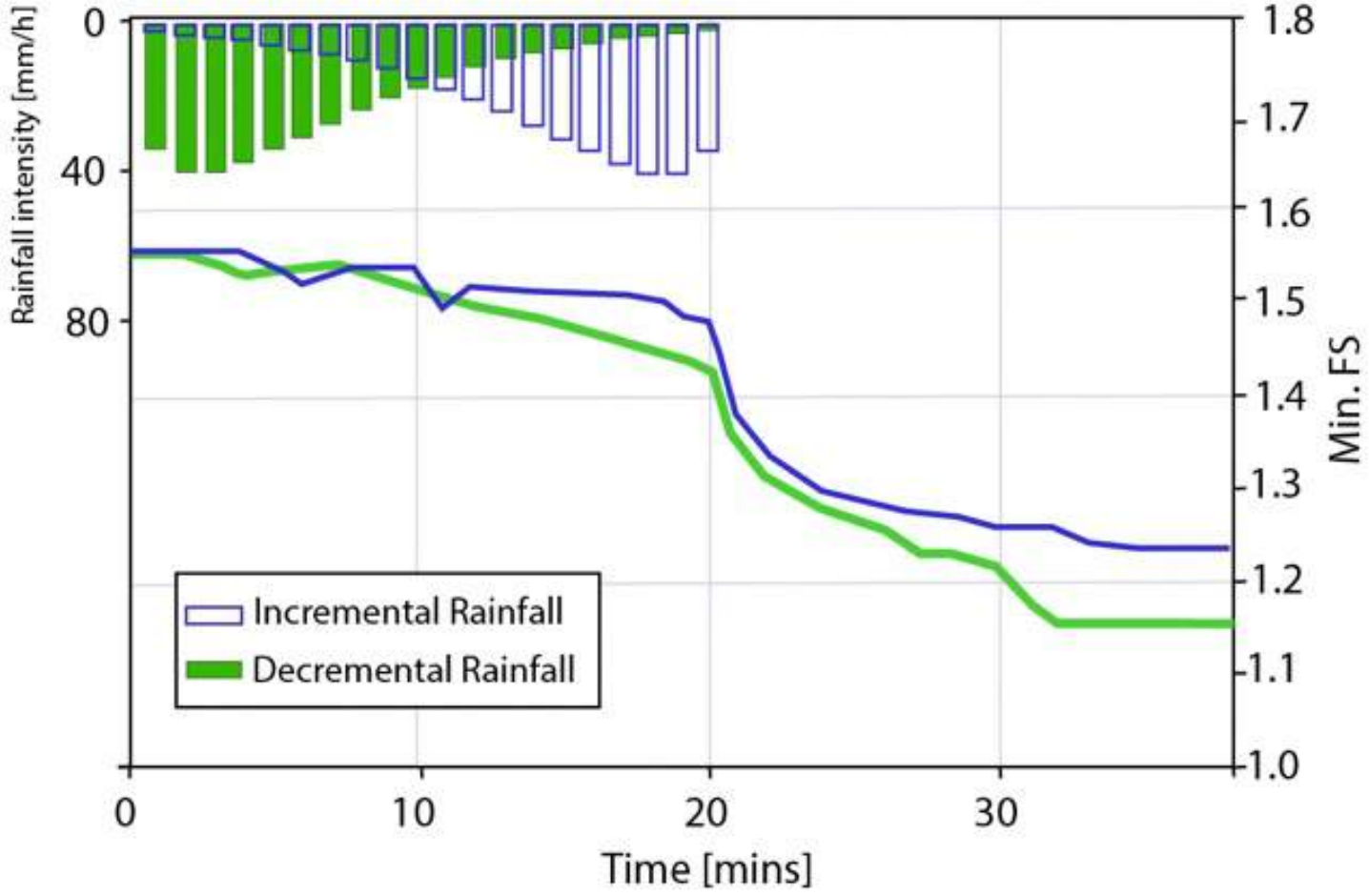
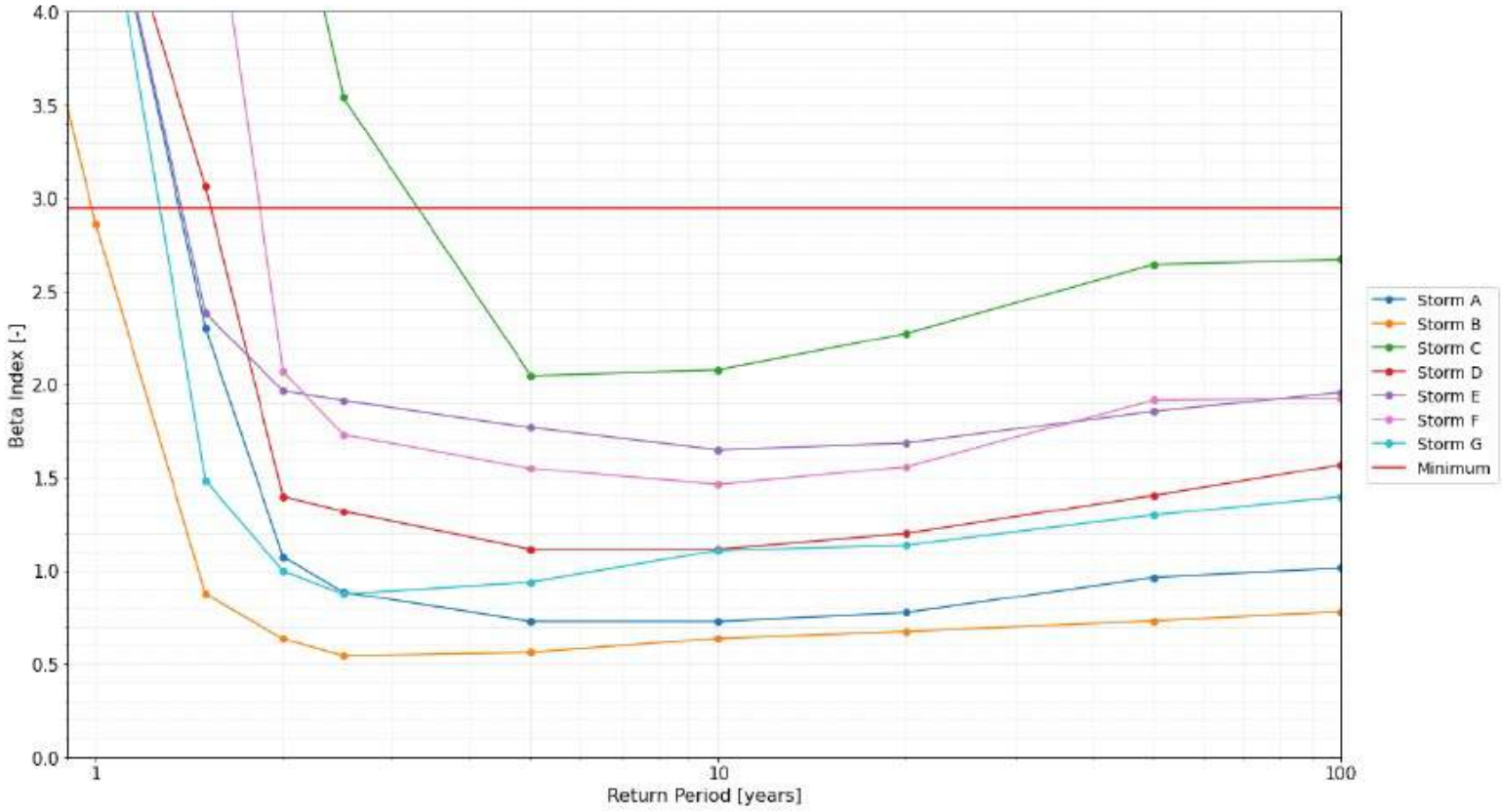



Conclusion 1: The same dike under the same return period event with the same rainfall volume but with different order in the hyetograph will result in a significantly different minimum safety factor.

# Paper 3: What is the (hydrological) effect in the macro-stability of canal dikes derived from presence of cracks ?




Conclusion 2: The competition between moisture front and saturation makes low return periods less safe than larger one.

# Thanks