

Understanding levee failure patterns to complement flood risk assessments

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Background

- Low Probability ↔ High Impact
- Levee failures can lead to enormous damages and loss of life
 - ∅ *New Orleans (2015)* *Germany (2013)*



- Demand on detailed risk analysis & management of levee systems
- Large uncertainties in modelling and predicting the failures
- No systematic analysis of multiple failure events

SAFElevee Project

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

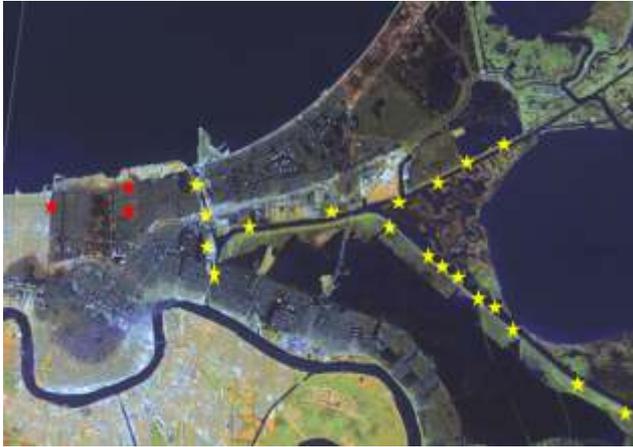
- Conclusions

- To improve the understanding of failure mechanisms and breaching of flood defence systems
- To enhance failure models, reliability analyses and designs of flood defences
- To provide systematically collected datasets for future scientific research

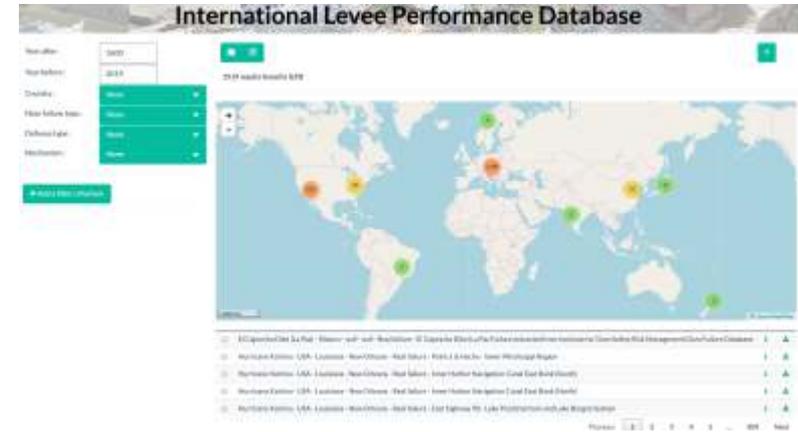


SAFElevee Project - WP's

1. Levee failure patterns



2. International Levee Performance Database



3. Breach initiation and development



4. Hindcasting of failures



International Levee Performance Database (ILPD)

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

- Full-scale testing is challenging and costly
- Historical failures provide insights into the real failure processes and conditions
 - No systematically gathered large-scale datasets
 - Several databases for levee breaches – only generic information
 - Limiting the scientific analyses

ILPD:

ü **Structured**

ü **Open-access**

ü **Regularly updated global database**

ILPD - content

- Background

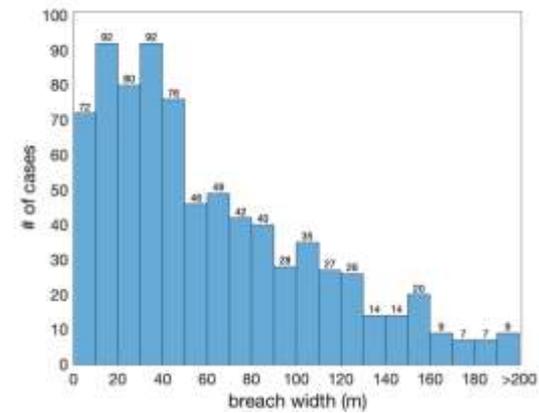
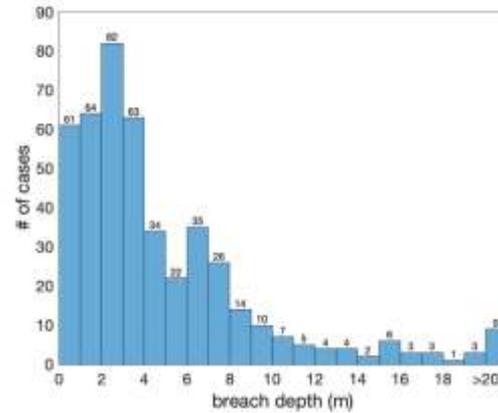
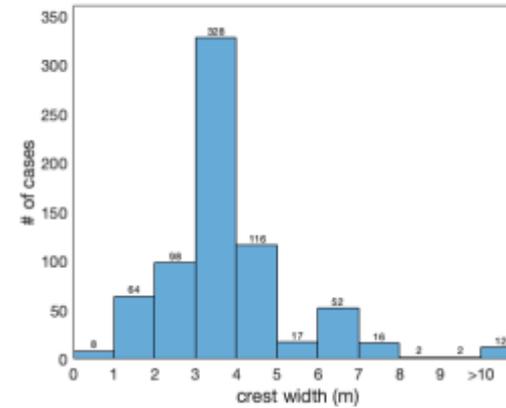
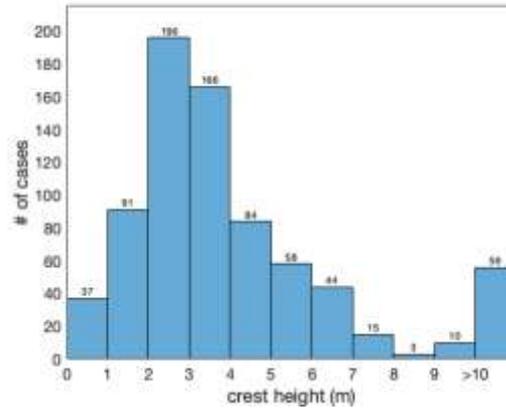
- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

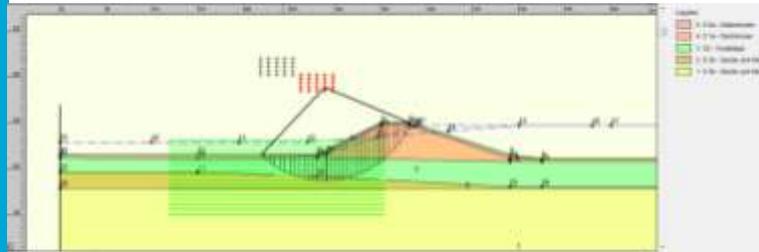
- *Level-1: Metadata* - **General** information on individual failures



ILPD - content

- Background
- SAFElevee Project
- ILPD
- Macro-scale analysis
- Conclusions

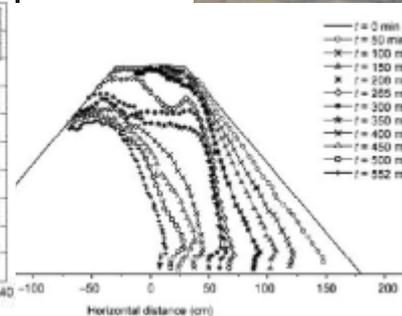
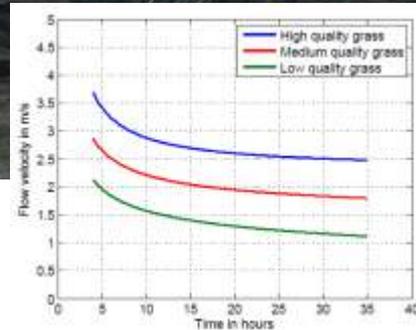
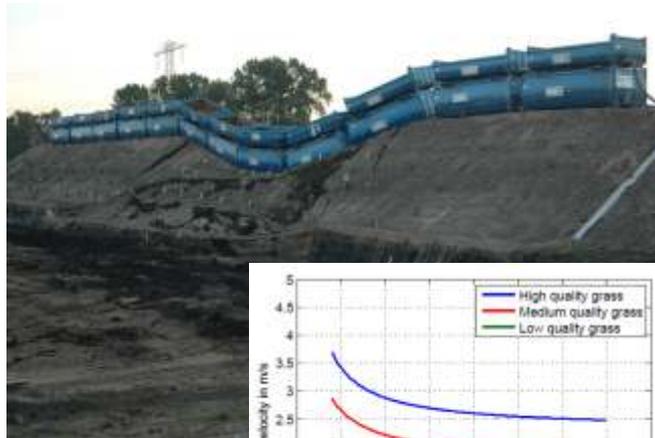
- *Level-1: Metadata* - **General** information on individual failures
- *Level-2: Intermediate* - **Detailed** geotechnical **investigations** and breach processes of historical levee failures and earthen dams



ILPD - content

- Background
- SAFElevee Project
- ILPD
- Macro-scale analysis
- Conclusions

- *Level-1: Metadata* - **General** information on individual failures
- *Level-2: Intermediate* - **Detailed** geotechnical **investigations** and breach processes of historical levee failures and earthen dams
- *Level-3: In-depth* - **Detailed** datasets of small- and large-scale **experiments**



ILPD

- leveefailures.tudelft.nl

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

The screenshot shows the ILPD website interface. A modal window titled "Welcome @ ILPD" is open, displaying the following text:

Welcome @ ILPD

International Levee Performance Database
version: ILPD 0,2.0

The database was developed under the research project **SAFElevee**, made possible by the Dutch Technology Foundation **STW**.

SAFElevee Partners:

The modal lists the following partners with their logos: NWO Applied and Engineering Sciences, TU Delft, Technische Universiteit Dresden, HKV, Deltares, Stowa, HKUST, and Colorado School of Mines. An "OK" button is located at the bottom right of the modal.

In the background, the website header reads "International Levee Performance Database". On the left, there are filter options for "Year after:" (1900), "Year before:" (2019), "Country:" (None), "Near failure type:" (None), "Defence type:" (None), and "Mechanism:" (None). A button "Add a filter criterium" is also visible. On the right, a world map shows several locations marked with green and yellow dots. At the bottom, a table lists dam failure events, including "Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Point a la Hache - lower Mississippi Region".

ILPD

- Interactive map with failure events

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

Year after: 1600
Year before: 2019
Country: None
Near failure type: None
Defence type: None
Mechanism: None

+ Add a filter criterium

1519 results found in ILPD

3000 km

El Cajoncito Dike (La Paz) - Mexico - null - null - Real failure - El Cajoncito Dike (La Paz Failure extracted from Institute for Dam Safety Risk Management Dam Failure Database

Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Point a la Hache - lower Mississippi Region

Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (South)

Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (North)

Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - East Highway 90 - Lake Pontchartrain and Lake Borgne System

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The map showing the failure locations present in the database

ILPD

- Interactive map with failure events

International Levee Performance Database

Year after: 1600
Year before: 2019
Country: None
Near failure type: None
Defence type: None
Mechanism: None

1519 results found in ILPD

3000 km

Table contains the datasets on the map by event, failure name and description

El Cajoncito Dike (La Paz) - Mexico - null - null - Real failure - El Cajoncito Dike (La Paz Failure extracted from Institute for Dam Safety Risk Management Dam Failure Database
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Point a la Hache - lower Mississippi Region
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (South)
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (North)
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - East Highway 90 - Lake Pontchartrain and Lake Borgne System

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ILPD

- Dataset containers

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

Clicking a dataset point automatically zooms the map to the extent of these datasets, showing in more detail on the map

International Levee Performance Database

Year after: 1600
Year before: 2019
Country: None
Near failure type: None
Defence type: None
Mechanism: None

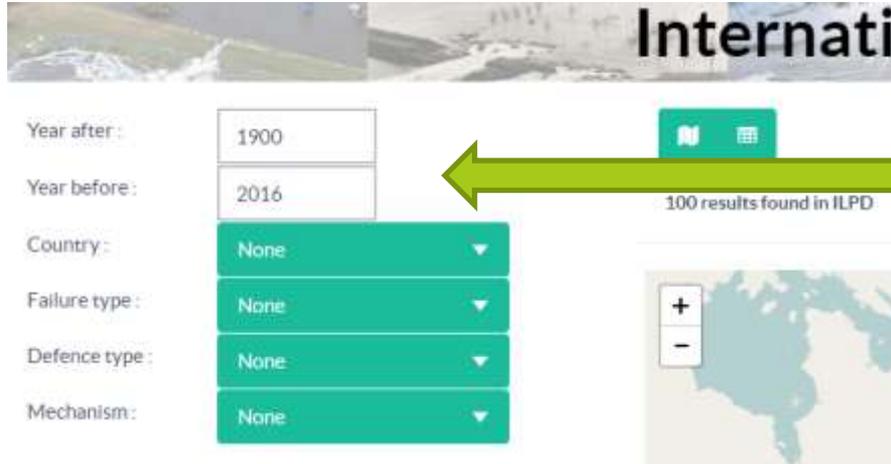
+ Add a filter criterion

1519 results found in ILPD

Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Point a la Hache - Lower Mississippi Region
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (South)
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (North)
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - East Highway 90 - Lake Pontchartrain and Lake Borgne System
Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - East Back Levee - Lake Pontchartrain and Lake Borgne System

ILPD

- Easy filter options



The screenshot shows the ILPD search interface. At the top, there are two satellite images and the word "Internati". Below this, there are several filter options:

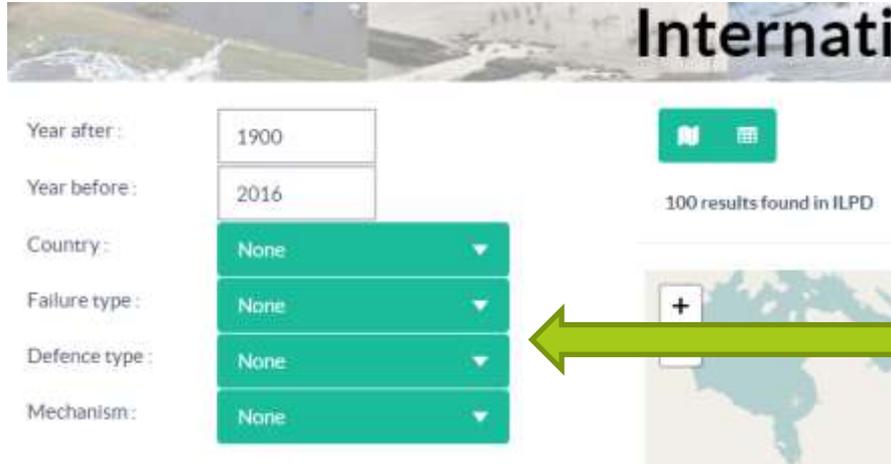
- Year after : 1900
- Year before : 2016
- Country : None
- Failure type : None
- Defence type : None
- Mechanism : None

To the right of the filters, there is a green arrow pointing left towards the "Year after" and "Year before" fields. Above the arrow, there is a green button with a grid icon and the text "100 results found in ILPD". Below the filters, there is a map of Europe with a zoom-in (+) and zoom-out (-) button.

filter the datasets for specific failures dates and for a specific country

ILPD

- Easy filter options



The screenshot shows the ILPD search interface. At the top, there is a header with the word "Internati" and a background image of a coastal area. Below the header, there are several filter options: "Year after:" with a value of "1900", "Year before:" with a value of "2016", "Country:" with a dropdown menu set to "None", "Failure type:" with a dropdown menu set to "None", "Defence type:" with a dropdown menu set to "None", and "Mechanism:" with a dropdown menu set to "None". To the right of these filters, there is a green button with a magnifying glass icon and a grid icon, and a text label that says "100 results found in ILPD". Below the filters, there is a map of the world with a green arrow pointing to it from the right. The map has a "+" sign in the top left corner.

Other easy filter options are:

- failure type (e.g. a real failure or a experiment)
- defence type (e.g. a levee or a floodwall)
- failure mechanism (e.g. overtopping or instability)

ILPD

- Advanced filter options

- Background

- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

International Levee Performance Database

Year after: 1600
Year before: 2019
Country: None
Near failure type: None
Defence type: None
Mechanism: None

+ Add a filter criterium

1519 results found in ILPD

World map showing results distribution: North America (287), South America (4), Europe (118), Asia (12), Australia (2).

Search results list:

- El Cajoncito Dike (La Paz) - Mexico - null - null - Real failure - El Cajoncito Dike (La Paz Failure extracted from Institute for Dam Safety Risk Management Dam Failure Database
- Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Point a la Hache - lower Mississippi Region
- Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (South)
- Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - Inner Harbor Navigation Canal East Bank (North)
- Hurricane Katrina - USA - Louisiana - New Orleans - Real failure - East Highway 90 - Lake Pontchartrain and Lake Borgne System

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ILPD

- Select what to extract from the database

Export settings ILPD

Only references

Only metadata

All data

Custom selection

references

metadata

documents

photos

videos

data files

OK Cancel

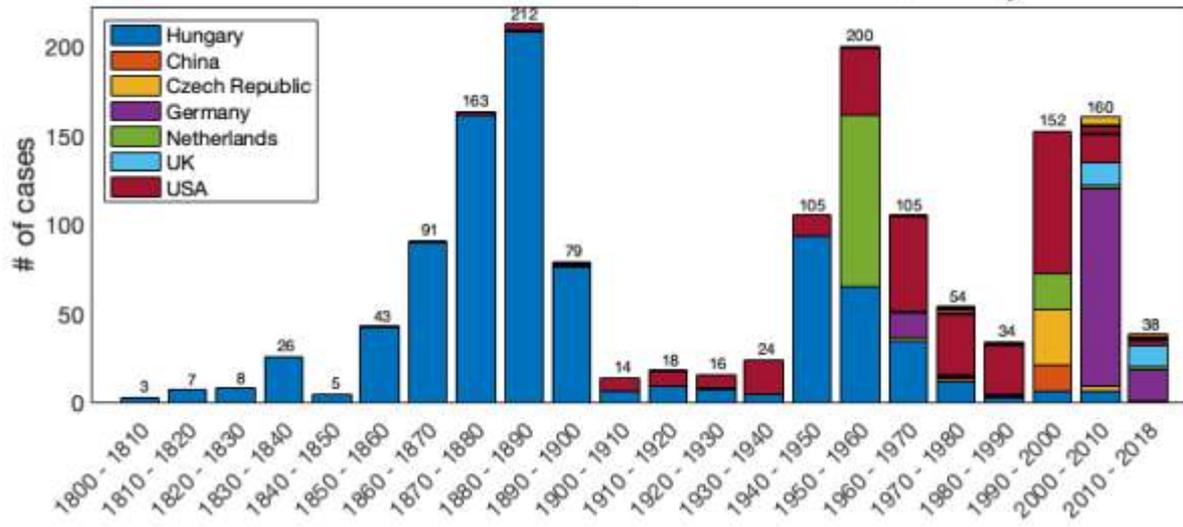
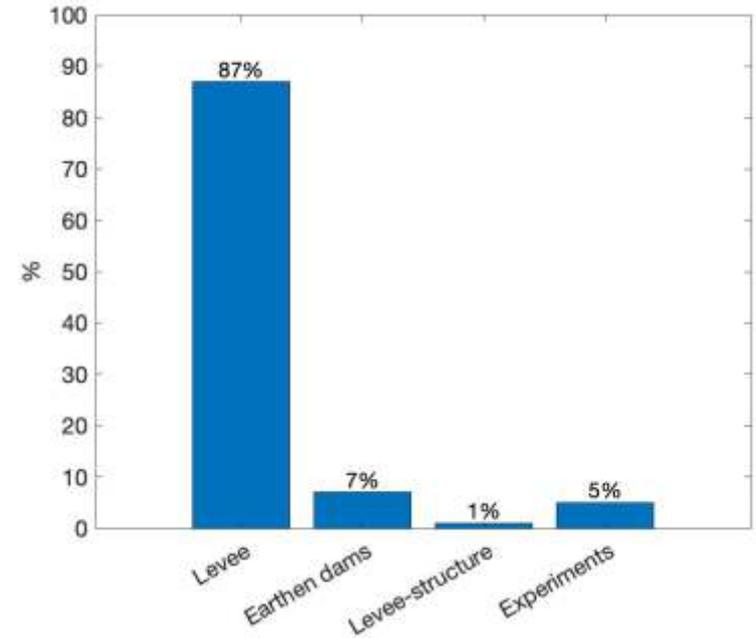


Make a custom selection of data to extract from the database

ILPD - overview

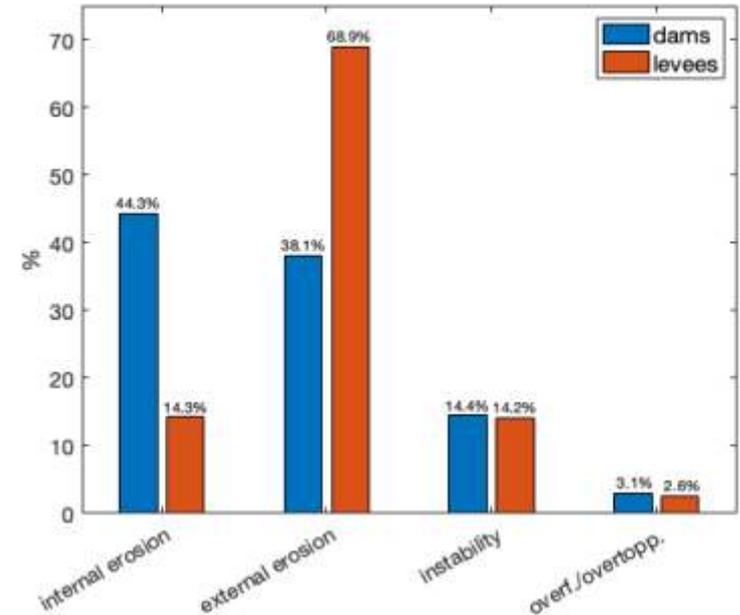
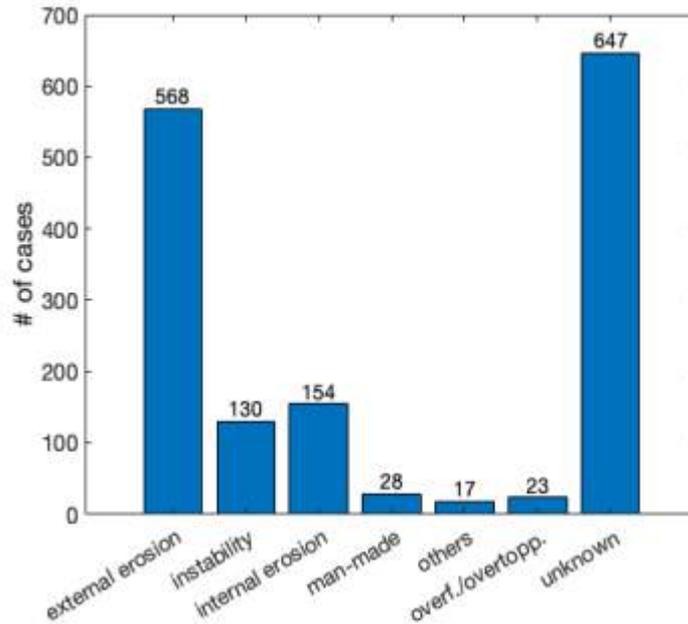
- ~ 1600 failure cases of which;

- Background
- SAFElevee Project
- ILPD
- Macro-scale analysis
- Conclusions



ILPD - Failure mechanisms

- Background
- SAFElevee Project
- ILPD
- Macro-scale analysis
- Conclusions



ILPD – Events

- Background

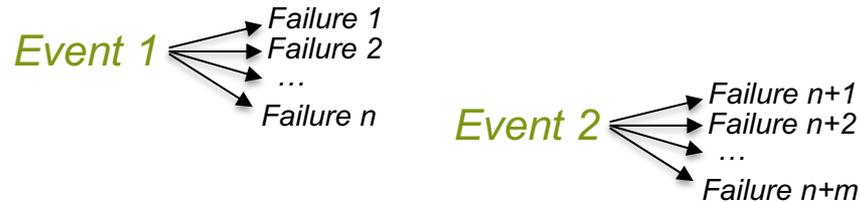
- SAFElevee Project

- ILPD

- Macro-scale analysis

- Conclusions

- Some extreme events caused multiple failures at different locations



- ~40% of the failures occurred in the events with more than one failure
 - Germany (2002) with 111 failures
 - Netherlands (1953) with 101 failures
- Information can be used to inform and improve (local) flood risk assessment

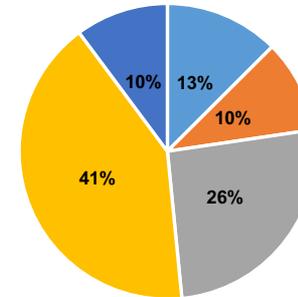
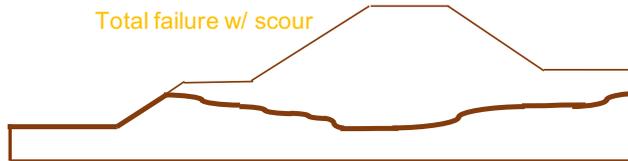
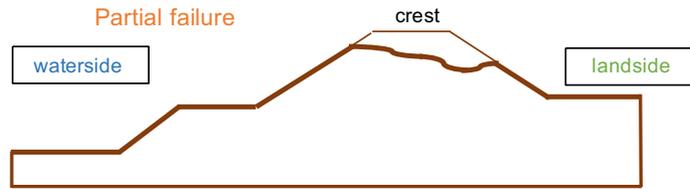
Germany 2002, 2013

- Elbe tributaries
- Extreme meteorological conditions
- Two catastrophic flooding events
 - 2002: 111 levee failures
 - 2013: 17 levee failures



Damages on levees

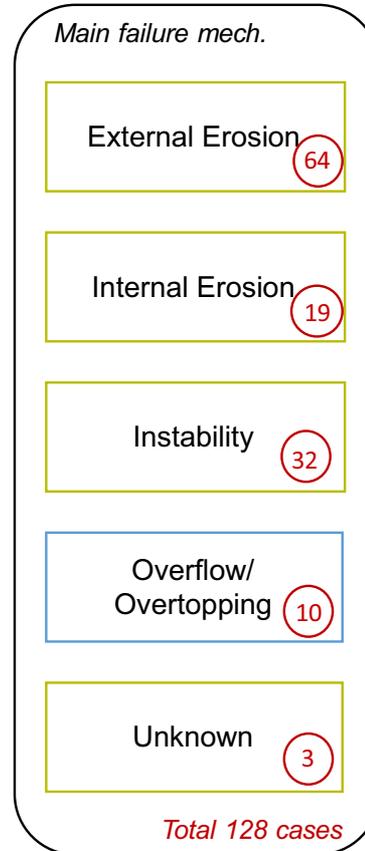
- Degree of damage on the levee cross section



- No breach
- Partial failure
- Total failure
- Total failure w/ scour
- Breach but no info. available

Germany 2002, 2013

- Main failure mechanisms



- Background

- SAFElevee Project

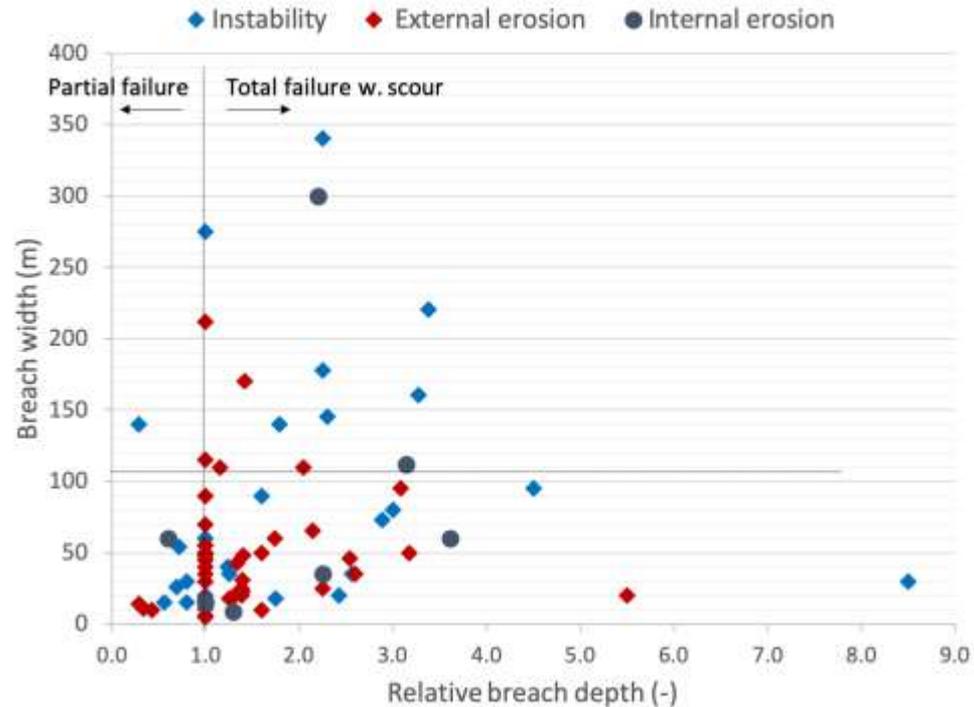
- ILPD

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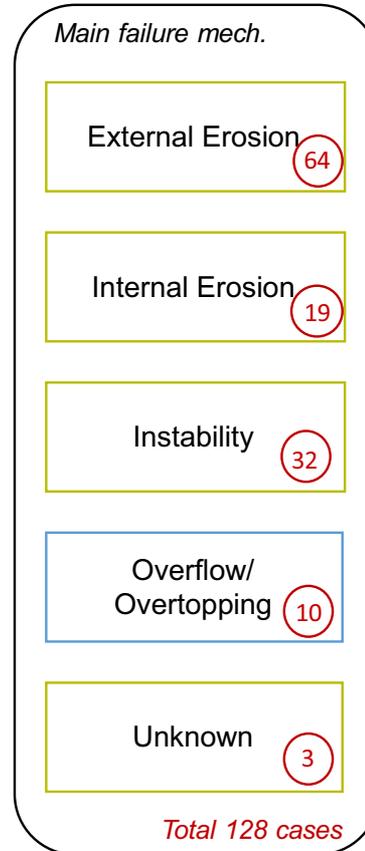
Germany 2002, 2013

- Breach characteristics per main failure mechanism



Germany 2002, 2013

- Initial and main failure mechanisms



- Background

- SAFElevee Project

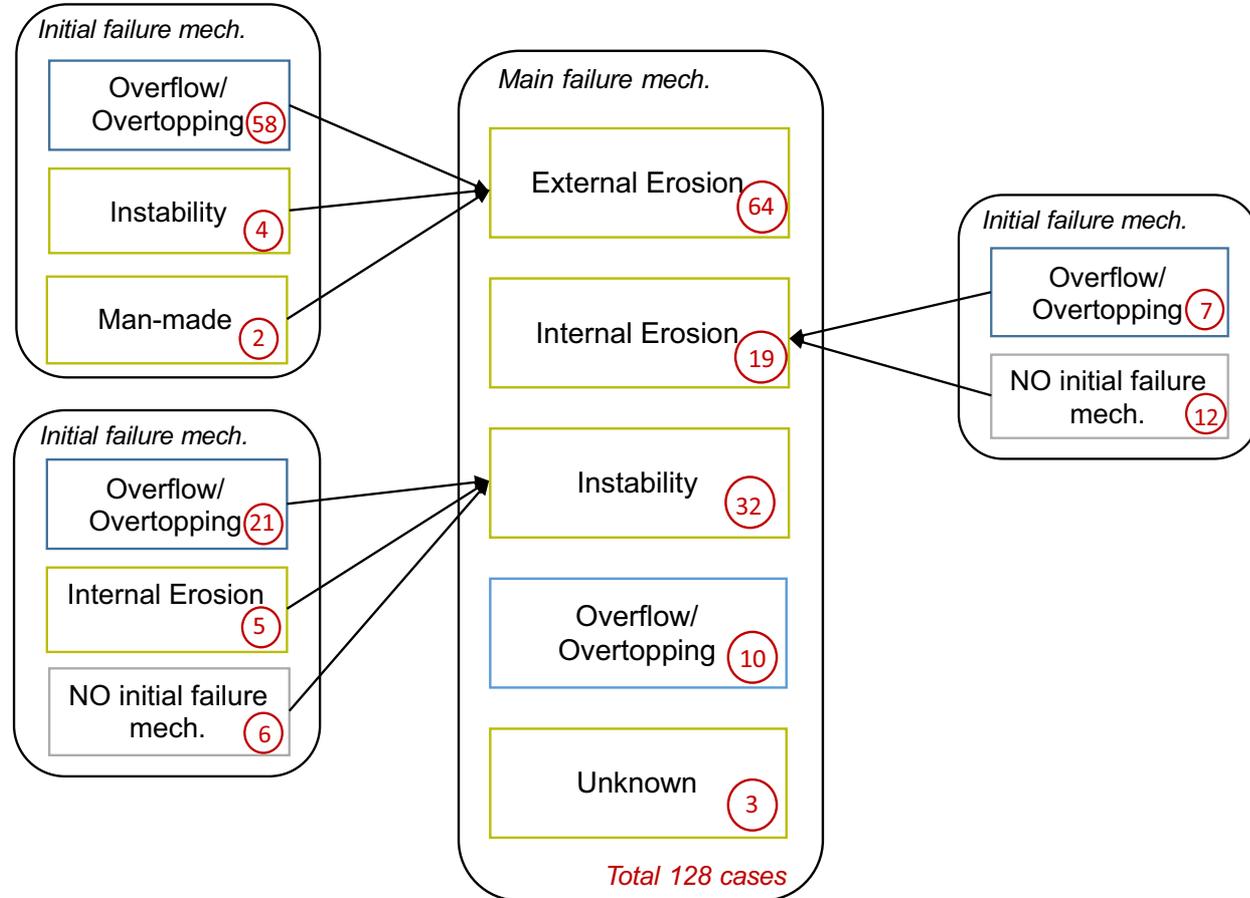
- ILPD

- Macro-scale analysis

- Conclusions

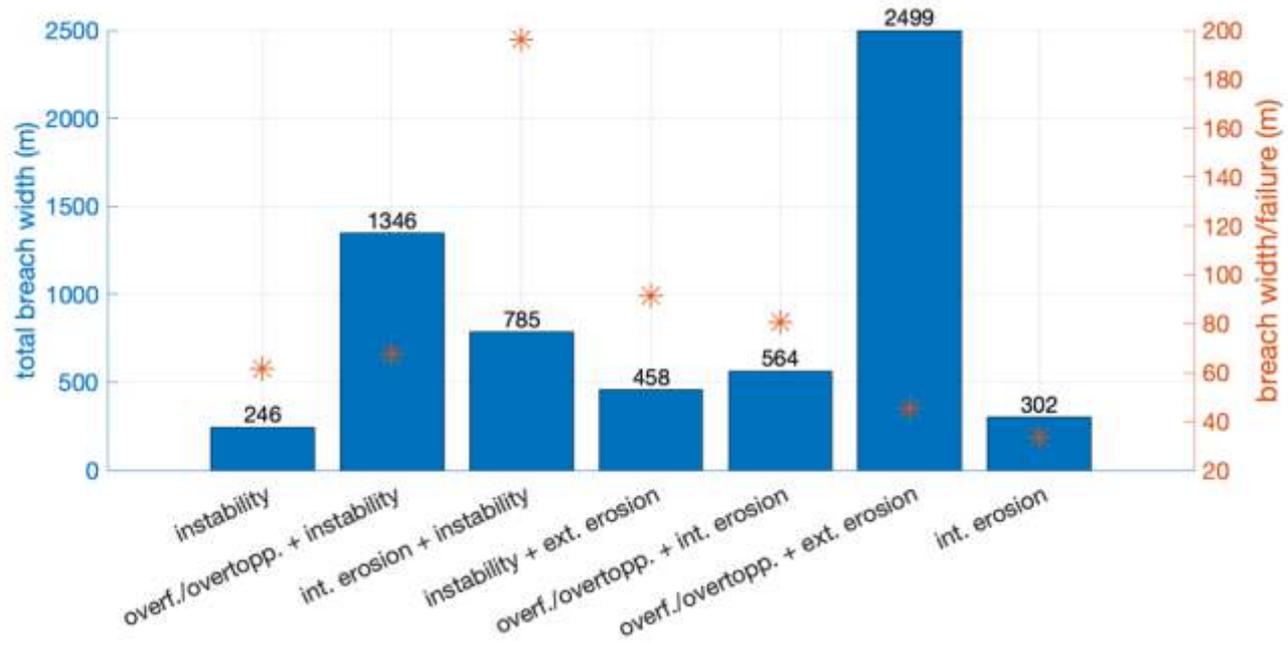
Germany 2002, 2013

- Initial and main failure mechanisms



Germany 2002, 2013

- Total and average breach width per failure



Conclusions and Future Work

ILPD

- Fully public, international data sharing platform
- supporting detailed analyses, (1) geotechnical analysis of individual failures or (2) detailed breach analysis
- Most common levee failure mech. à external erosion triggered by overtopping/overflow (62%)
 - Internal erosion is more common in earthen dams

Macro-scale analysis

- Main failure mech. of the large breaches à instability or internal erosion
- Initial failure mechanisms play important role in defining the breach characteristics

Conclusions and Future Work (2)

- The investigation of historical levee failures is of critical importance in both risk assessments and proper design methods
- Further analysis of data from the ILPD at the event level can provide critical insights in identifying
 - (1) typical vulnerabilities and common failure mechanisms,
 - (2) breach characteristics, and
 - (3) density of breach occurrence

- Background

- SAFElevee Project

- ILPD

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Ministerie van Infrastructuur en Milieu



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