



International Levee Handbook

Overview of the handbook

Chapter 3

Functions, Forms and Failure of Levees



Content and aims

3 Functions, forms and failures of levees

- 3.1 Functions of levees
- 3.2 Functions & forms of levee components
- 3.3 Forms of levees
- 3.4 Structures associated with levees
- 3.5 Understanding failures of levees

2 Understanding levees: basic concepts

Fundamentals

4 Operation & Maintenance

6 Emergency Preparedness & Management

5 Levee Assessment & Risk Attribution

Managing levees

7 Site Characterization & Data Requirements

8 Physical Processes & Tools for Levee Design

Toolbox

9 Design

10 Construction

Making changes

Chapter 3 introduces the form and function of levees and provides an understanding of failure mechanisms. Explanations of these concepts will be useful to all users for both assessment and design.

Key input from other chapters.

- Chapter 2 ⇒ **flood risk management context**

Key output for other chapters.

- **forms, functions and failure mechanisms** ⇒ Chapters 4 to 10

Note: The reader should revisit **Chapters 2 and 3** throughout the levee life cycle for a reminder of important issues.

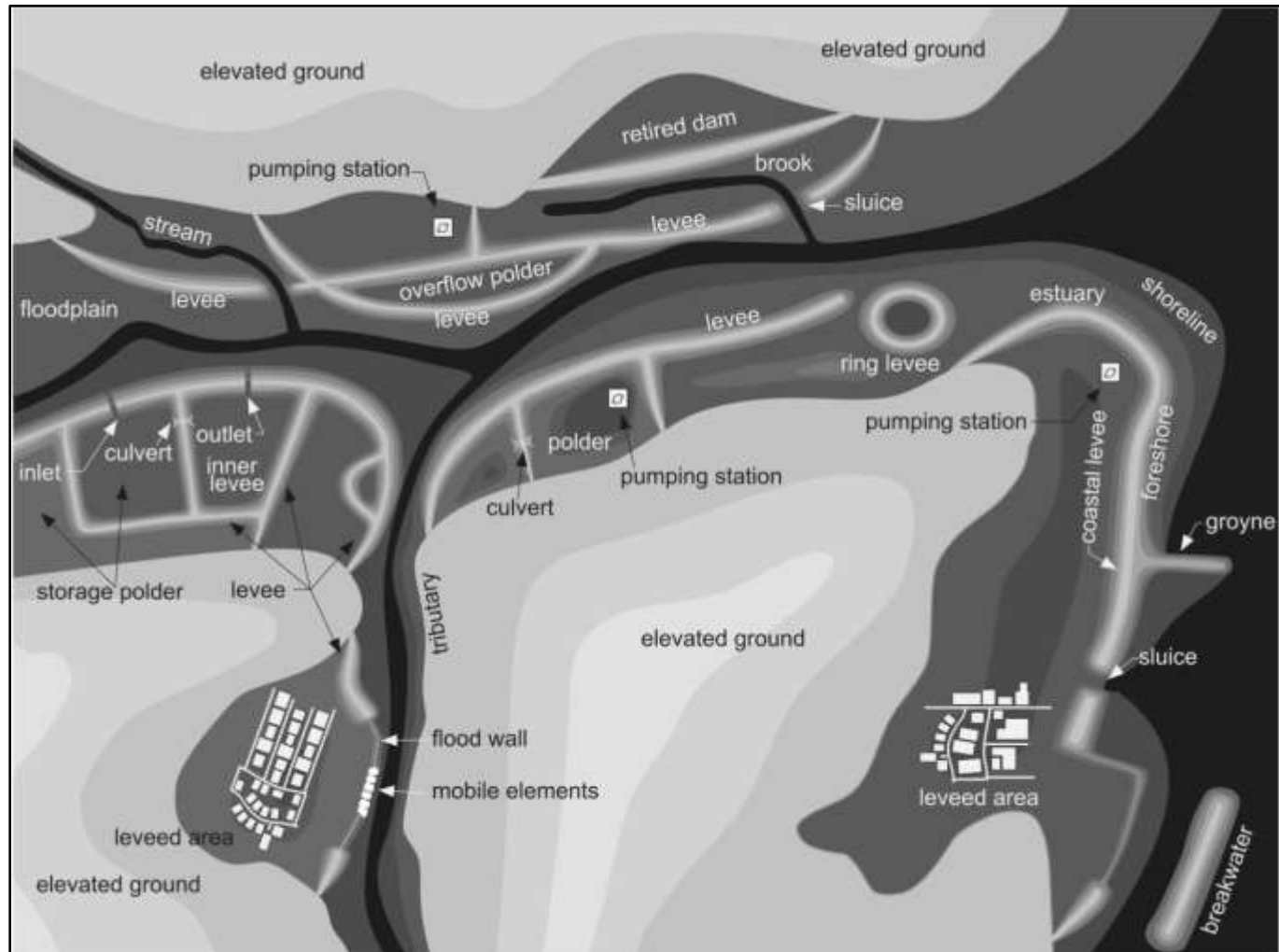


3.1 Functions of levees – overview

- Functions and types of levees
- Multifunctional role of levees
- Environment of levees highlighting:
 - primary loading conditions
 - morphology and evolution of different levee environments
 - climatic change effects
- Historical evolution of levees:
 - changes over time in levee system
 - change in conditions and areas surrounding levees
 - necessary coordination of levee functions through time



3.1 Functions of levees



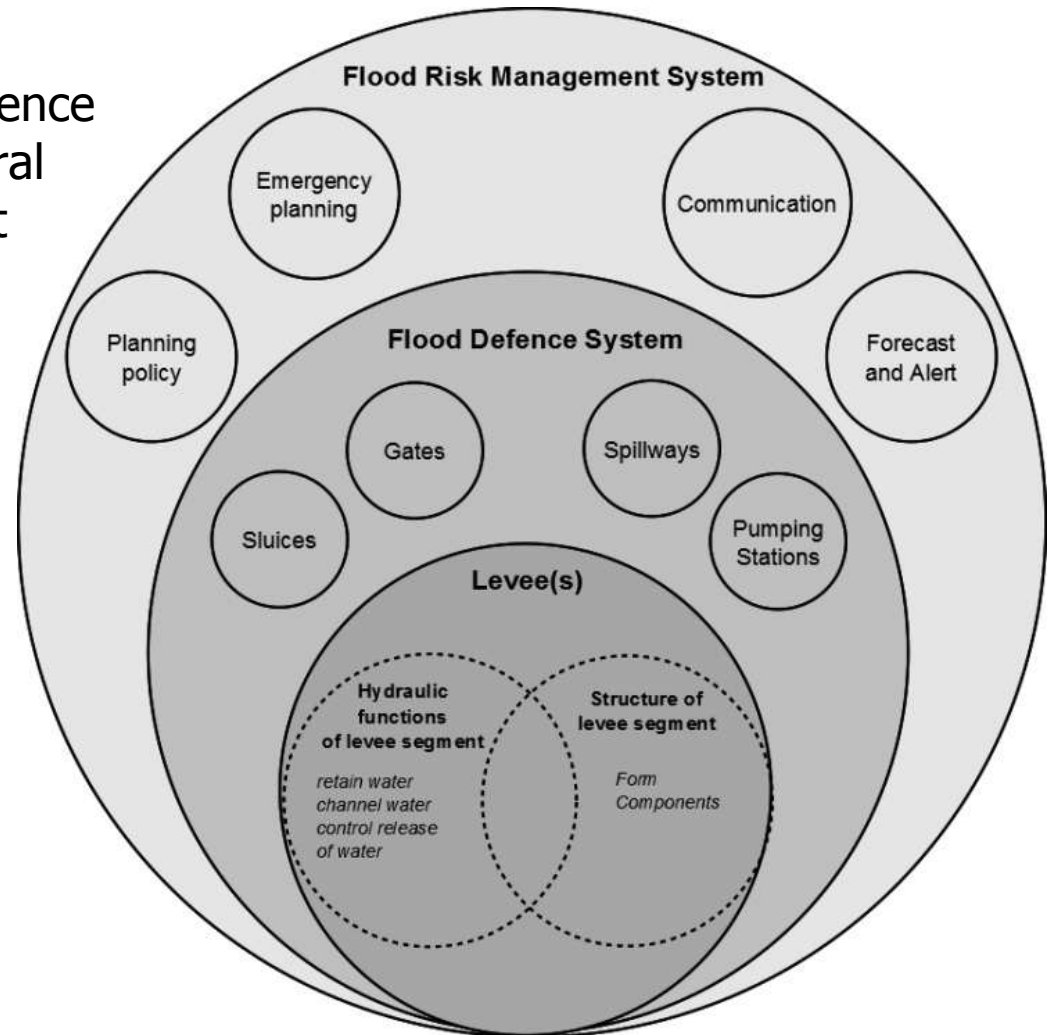


3.1 Functions of levees

Levees are included in a flood defence system, which is the main structural part of the flood risk management system.

Levees have three main hydraulic functions to perform :

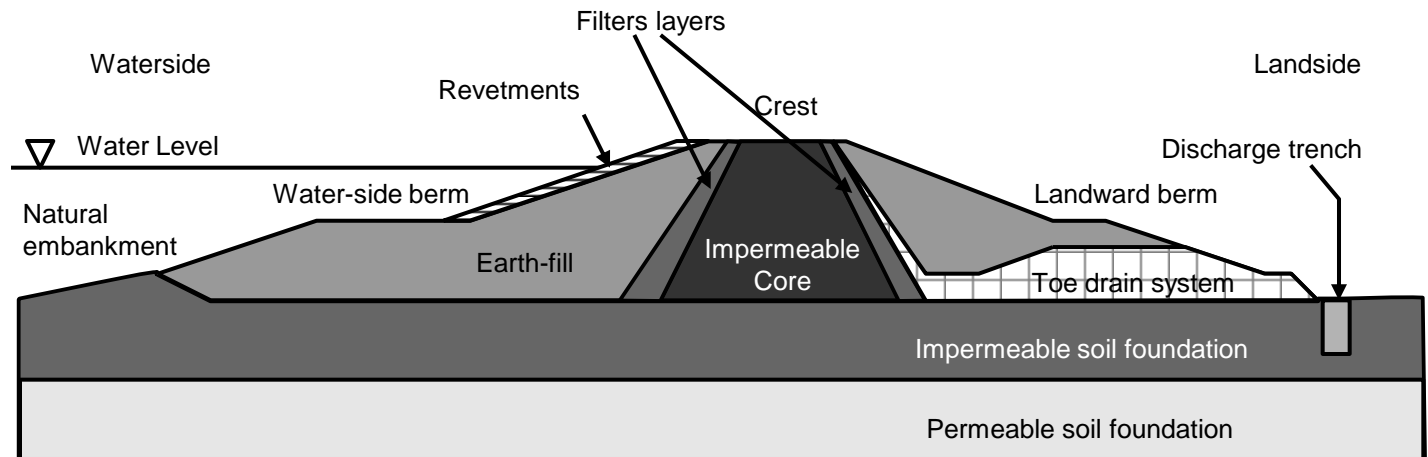
- to retain
- to channel
- to control release of water





3.2 Forms and functions of levee components

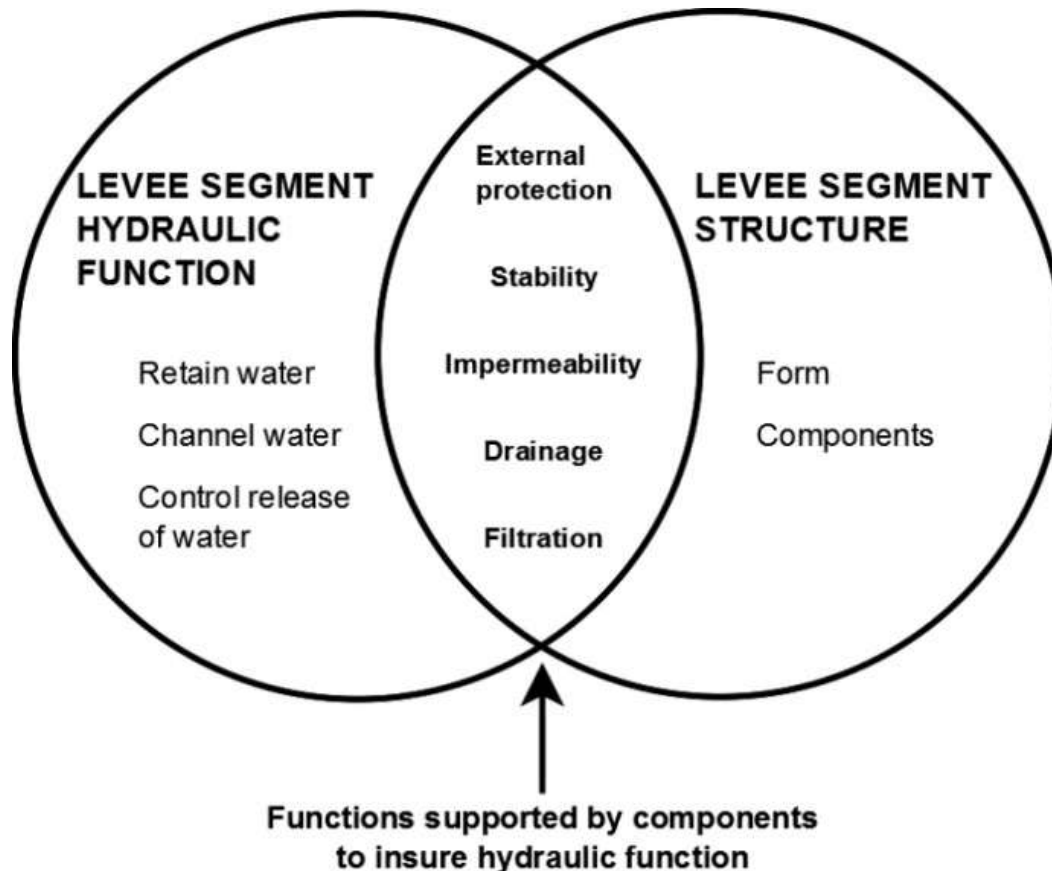
- Definition and functions of levee components
- Identification of several primary levee components in terms of:
 - Geometrical and technical description
 - Specific associated functions
 - Main technical issues and associated methods
- Combination and relationship of components working together





3.2 Forms and functions of levee components

Functionality is most often accomplished by several components working together.



Component functions and hydraulic and structural functions of a levee segment

(Courtesy Yann Deniaud, CETMEF)



3.2 Forms and functions of levee components:

Revetment example

Description

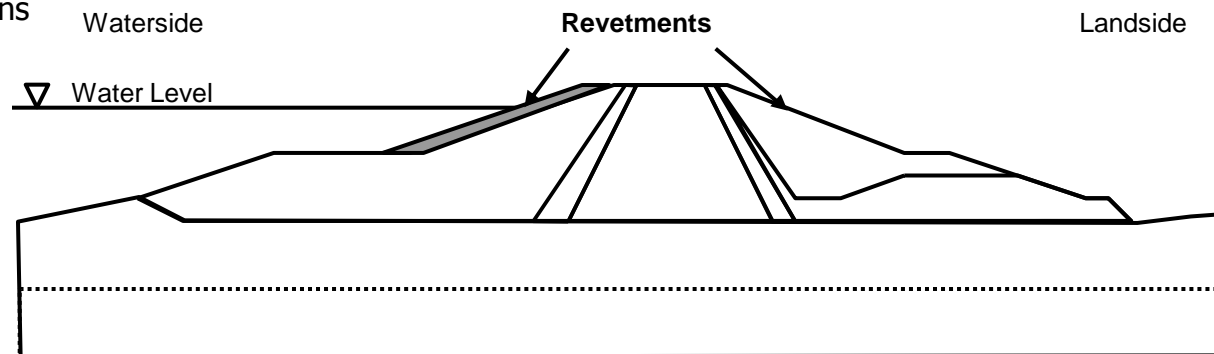
- Interface between levee & external environment
- “Armouring” the waterside slope as added assurance for levee stability
- Constituents / composition

Functions

- Waterside:
 - to protect from external erosion
- Landside:
 - to protect against erosion from surface run-off and other non-hydraulic agents.
 - to protect against erosion due to overtopping and overflowing

Technical issues

- Appropriateness of revetment type
- Appropriateness of materials
- Weakness of transitions
- Aesthetic & environmental considerations

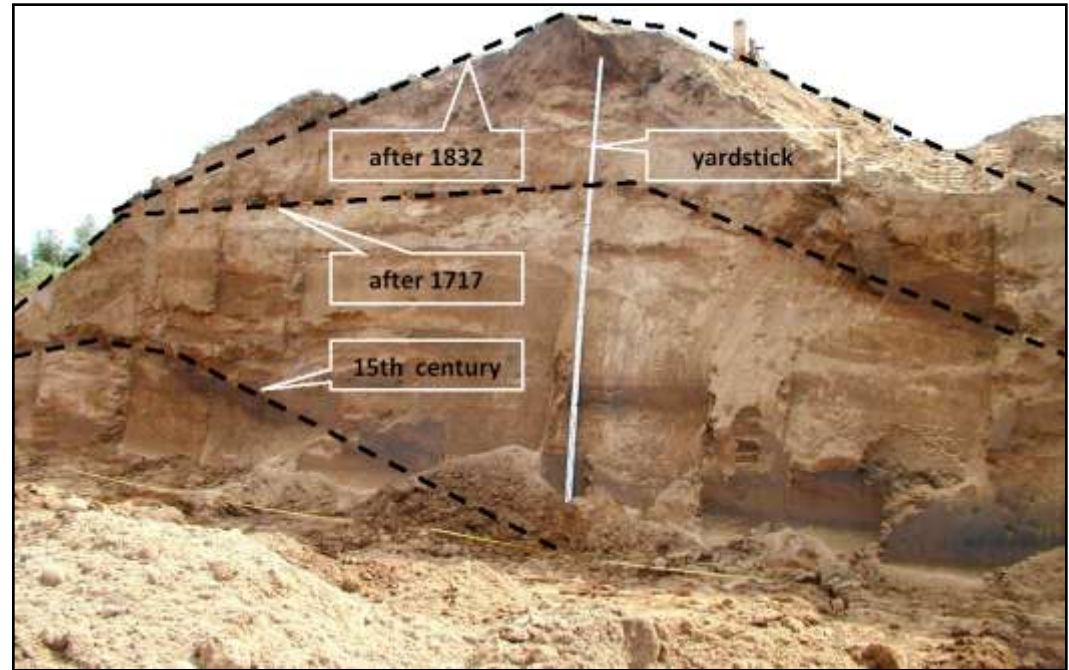




3.3 Forms of levees

The typology that has been defined and used comprises:

- .Earth-fill levee including
 - Homogenous levees
 - Zoned levees
- .Composite Levees including:
 - Superstructures
 - Structures on the waterside
 - Structures inside
 - Alternative structures
- .Historical Levee



Old levee km 3.200 (Courtesy of F. Krueger, Frankfort on Odra)

For each levee type, a general definition is given, the main components, schematics and typical cross-sections are presented and technical issues are discussed.



3.3 Forms of levees: Zoned levee example

Definition and general considerations

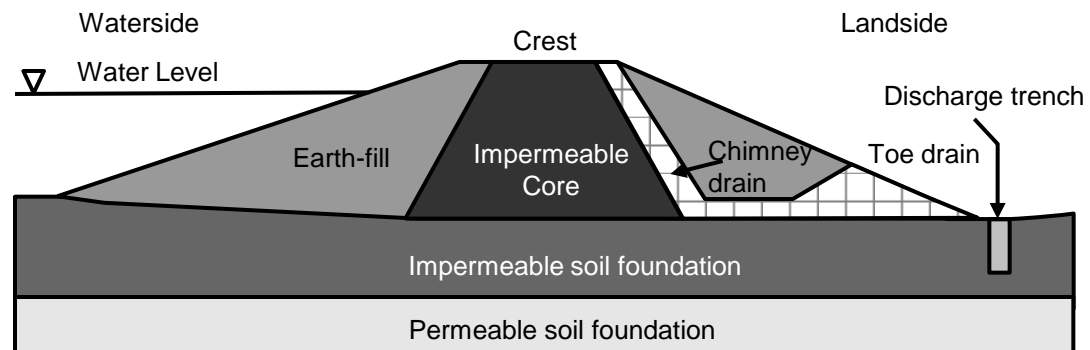
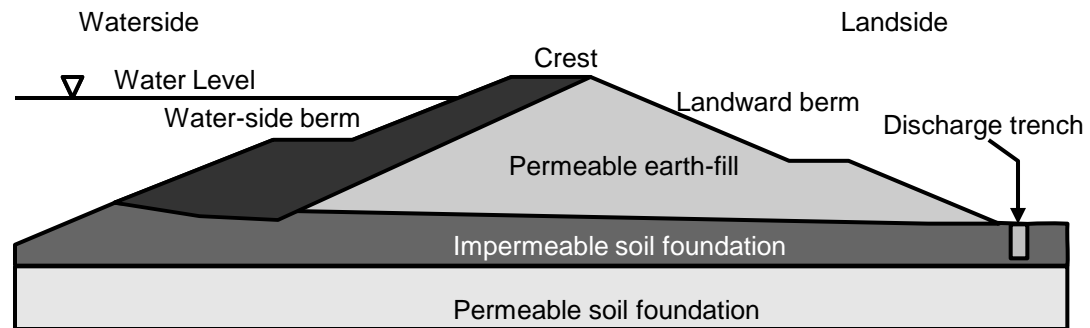
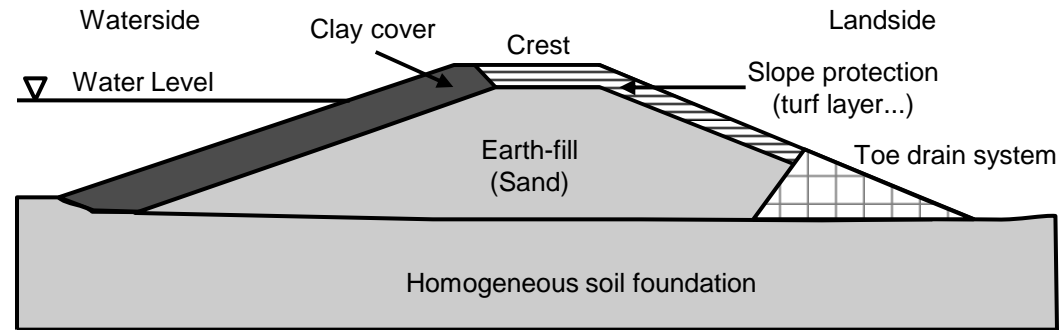
- Combination of permeable & relatively impermeable material cross section
- Two primary types:
 - Impermeable core
 - Impermeable mask

Main components

- Core or mask for impermeability
- Earthfill for stability

Technical issues

- Seepage control
- Filter layers
- External protection





3.4 Structures associated with levees

Definition and description of each structure

Typical sketches and illustrations of various structures

Structures linked and specially designed for flood risk reduction

Transition zones with natural or human-made structures





3.4 Structures associated with levees

Spillways and floodways example

Definition

- Design intent
- Controlled spillway (mechanical) vs. uncontrolled spillway (geometrical)
- Floodway: reserved property set aside to divert flood waters from a river channel or other watercourse

Function within the flood defence system

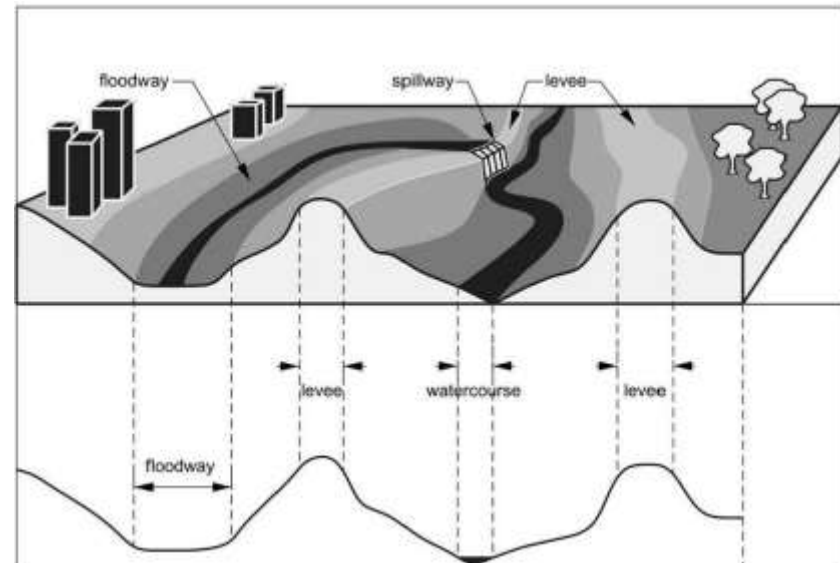
- Two types : Safety & Diversion Spillways

Issues

- Scour
- Crest instability
- Resiliency of material components
- Development
- Human error



Spillway on the Loire River (Courtesy Yann Deniaud, CETMEF)

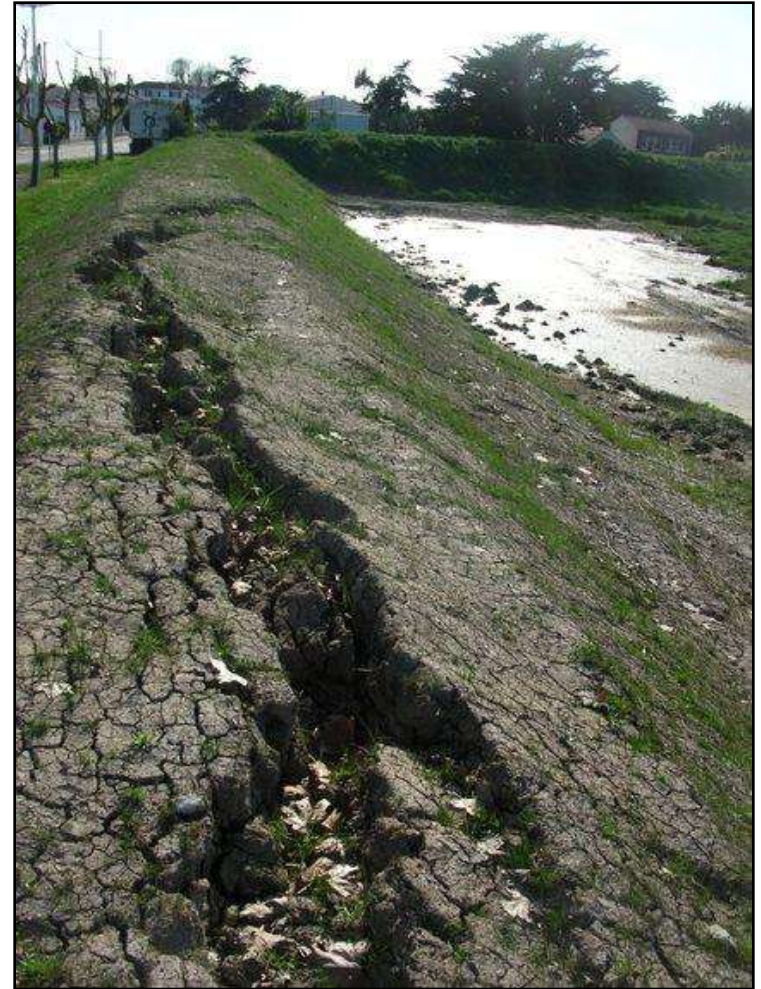


Spillway and floodway configuration (ILH)



3.5 Understanding failure of levees

- Definition of levee deterioration, damage, breach and failure
- Links between functions, forms and failure
- Description of the failure process
- Main physical processes of deterioration, damage & breach are grouped in three categories:
 - External erosion
 - Internal erosion
 - Instability
- Statistics about levee failure, resulting from analysis of historical flooding events or failure mechanisms



Rotational Sliding (Courtesy Remy Tourment, IRSTEA)



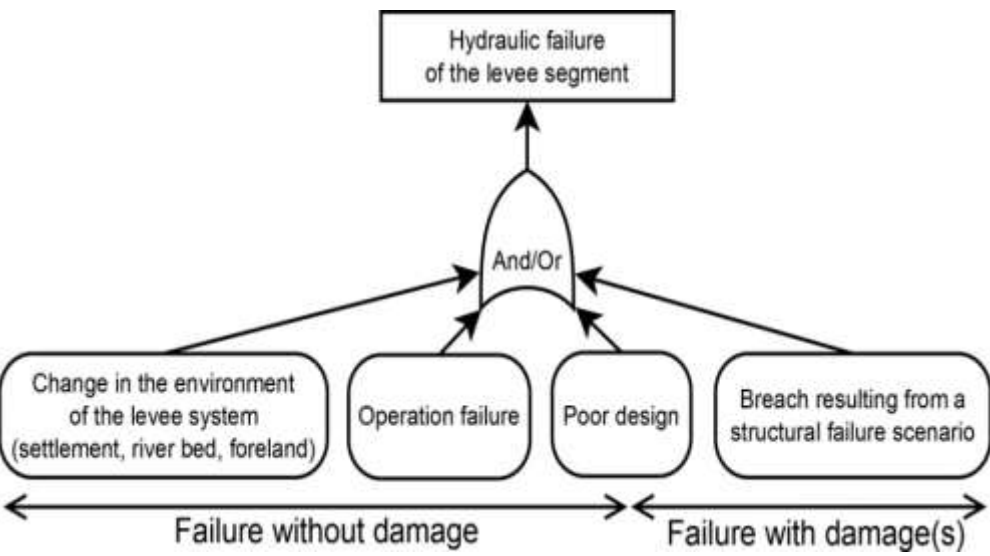
3.5 Understanding failure of levees:

Structural failure leading to breach with physical & functional phenomena affecting the levee

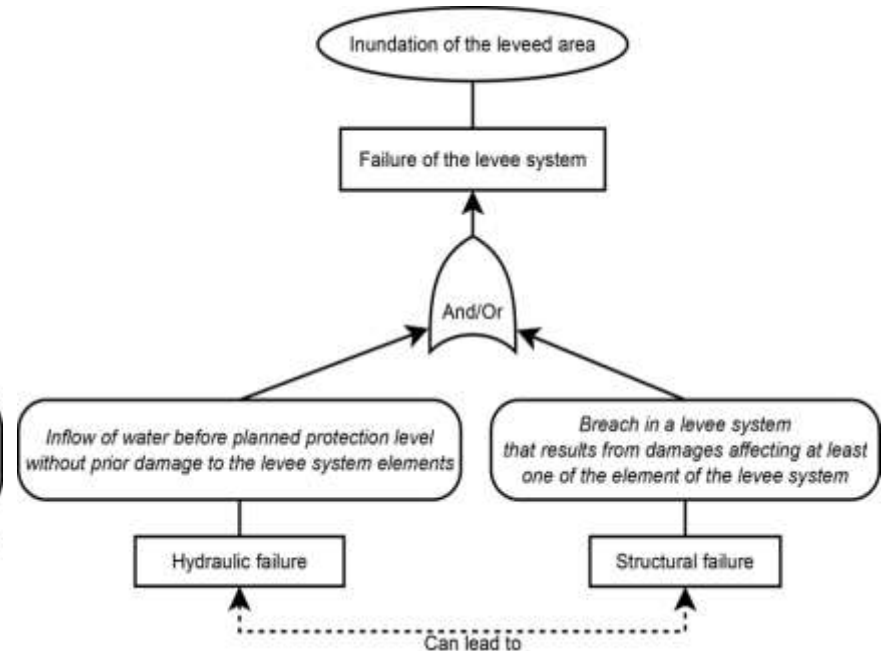
- Levee components undergo mechanisms leading to deterioration and damage
- Levee function can degrade to failure

Mechanism: time dependant process affecting components with a decline in the state of its structural properties

Breach: low crest situation or a significant hole resulting in degradation of a levee's hydraulic function



Possible sources of failure of a levee segment
(Courtesy of R. Tourment, IRSTEA)

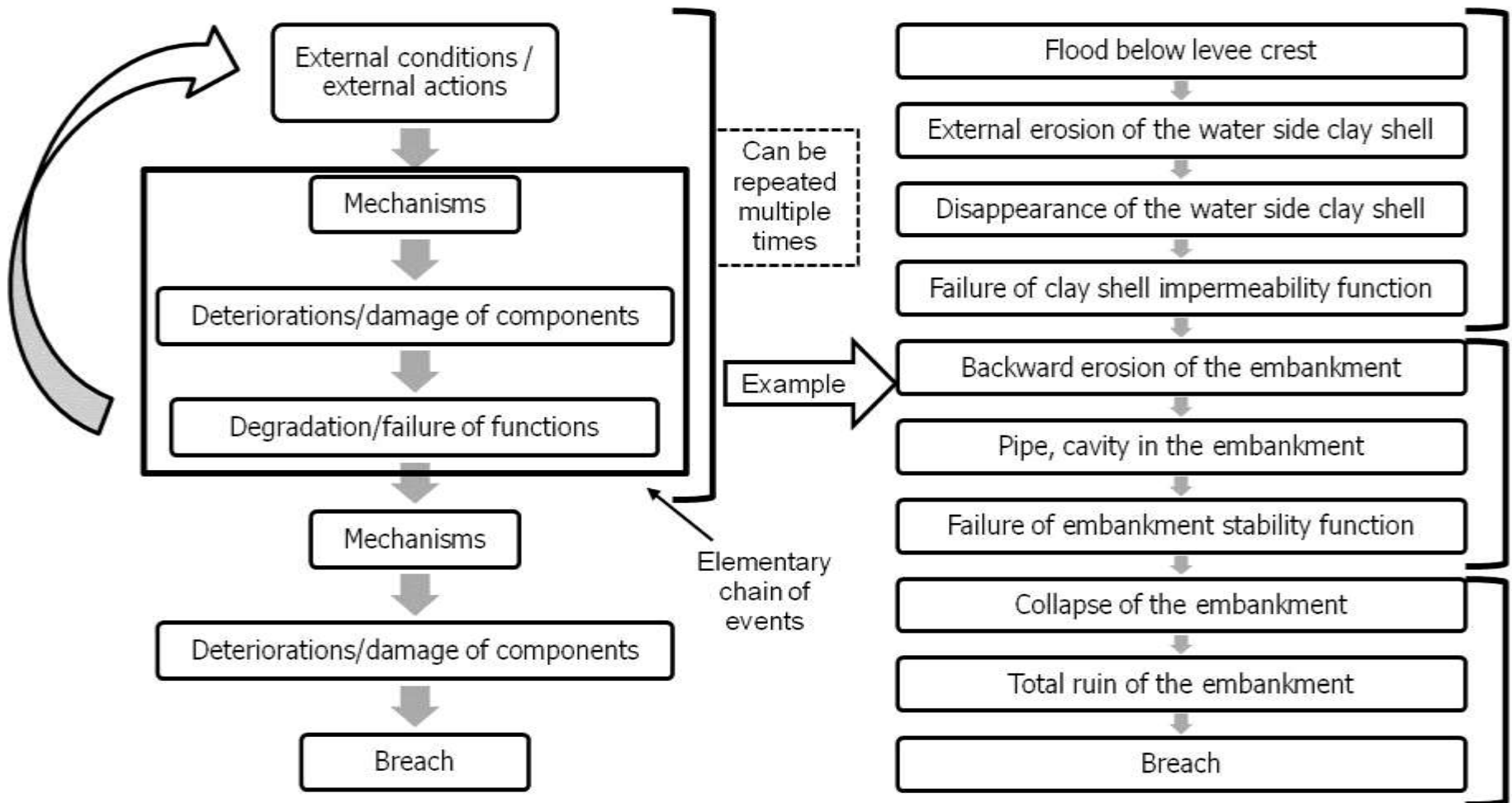


Levee system failure
(Courtesy of R. Tourment, IRSTEA and Y. Deniaud, CETMEF)



3.5 Understanding failure of levees:

Scenario - chain of events example





3.5 Understanding failure of levees: Internal erosion example

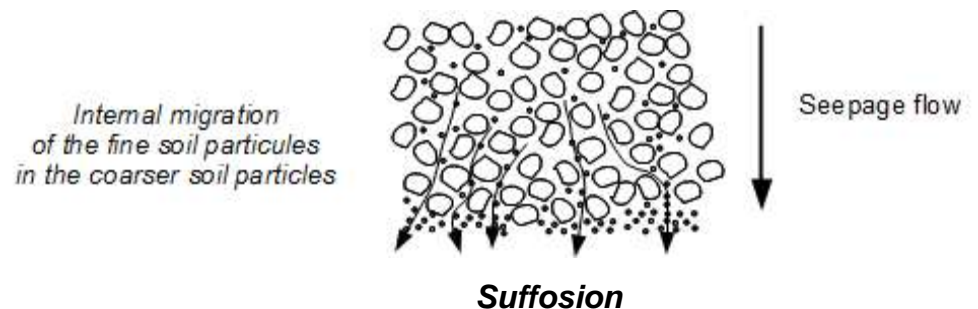
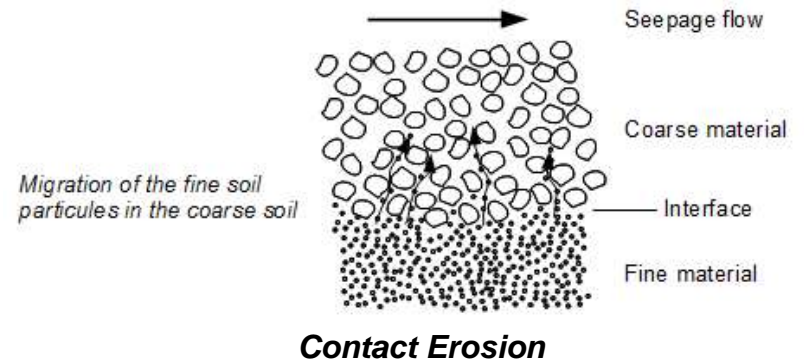
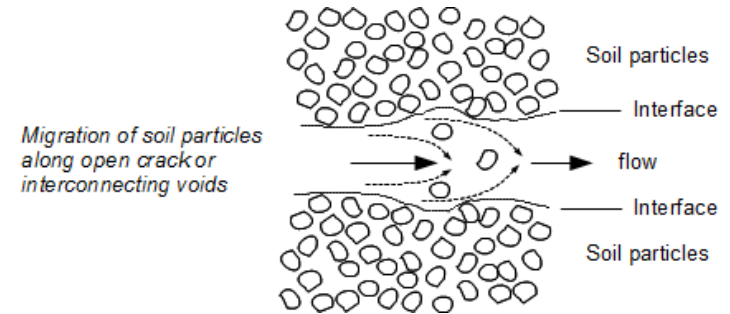
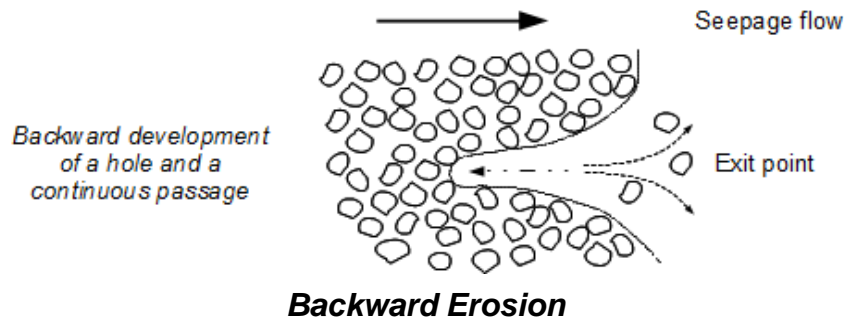
Internal erosion definition

- Soil particles carried downstream by seepage flow
- Initiated by hydrodynamic forces acting on soil particles

Factors of internal erosion

- Presence of permeable layers or lenses or existence of cracks or fine fissures
- Animal activities
- Unwanted vegetation
- Human activity

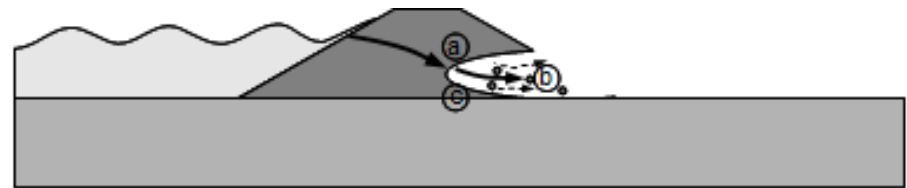
Mechanisms





3.5 Understanding failure of levees: Internal erosion example cont'd

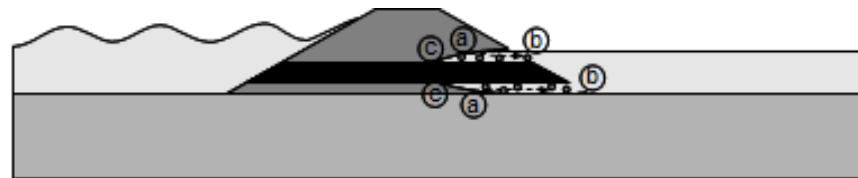
Internal erosion of the body



Water flows
Tearing of soil particles

(a – backward erosion, b – concentrated erosion, c – contact erosion)

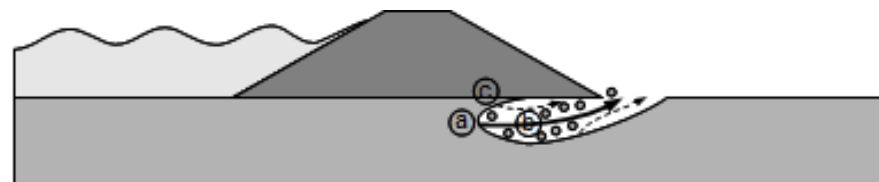
Internal erosion along a penetrating structure



Water flows
Tearing of soil particles

(a – backward erosion, b – concentrated erosion, c – contact erosion)

Internal erosion of the foundation soils



Water flows
Tearing of soil particles

(a – backward erosion, b – concentrated erosion, c – contact erosion)



3.5 Understanding failure of levees:

External erosion example

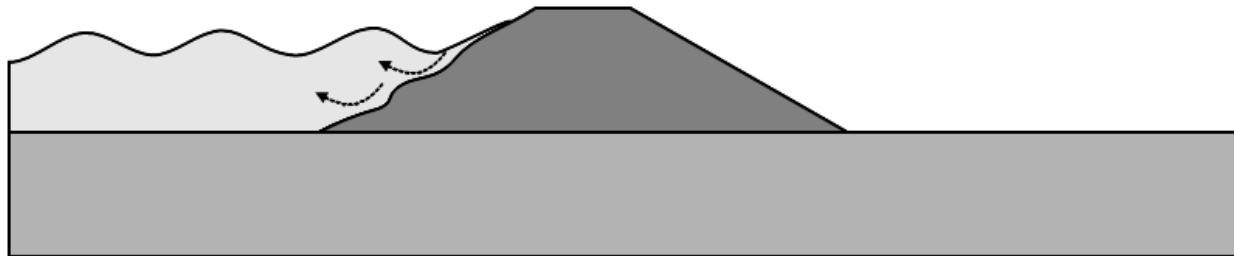
External erosion definition

- Surface wearing (bank, streambed, embankment, or other surface) by floods, waves, wind, or any other natural process
- Initiated by hydrodynamic forces acting on soil particles at the levee surface

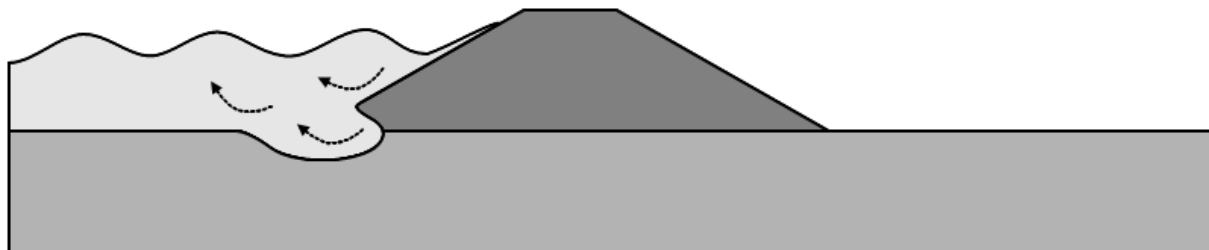
Factors of external erosion

- Movements of water directly against the levee surface or along the bank of the water body
 - Main factors: currents, waves and tides
 - Other contributing agents: wind, woody vegetation, animal and human activities

Mechanisms



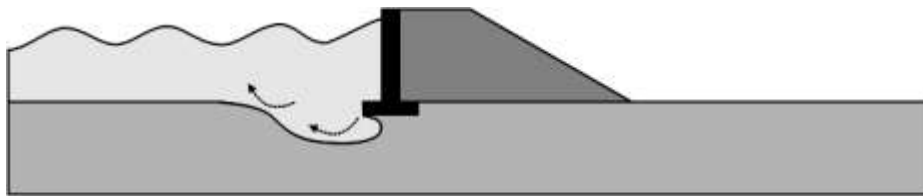
→ Tearing of soil particles



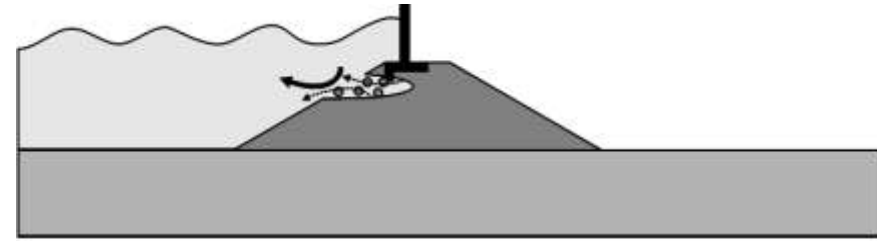
→ Tearing of soil particles



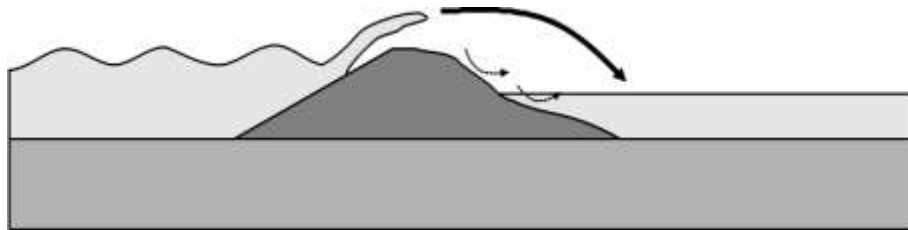
3.5 Understanding failure of levees: External erosion mechanisms cont'd



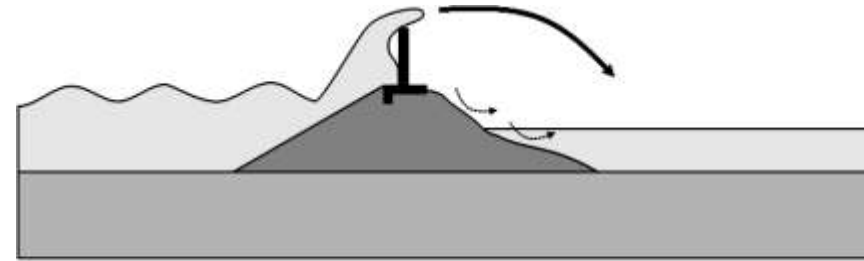
→ Tearing of soil particles



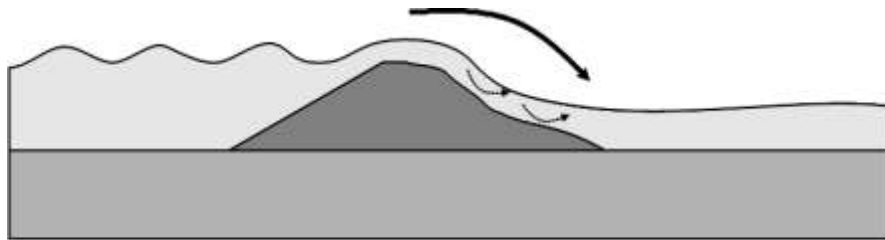
→ Water flows
→ Tearing of soil particles



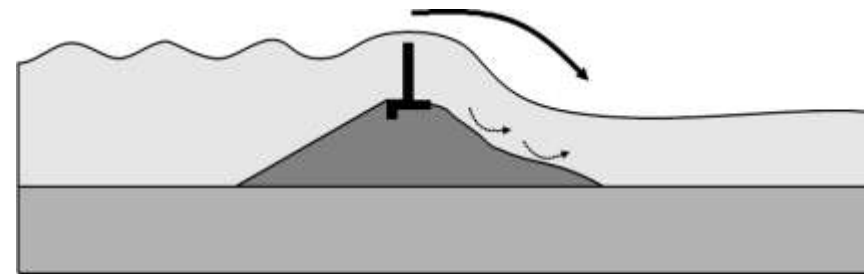
→ Water flows
→ Tearing of soil particles



→ Water flows
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→ Water flows
→ Tearing of soil particles



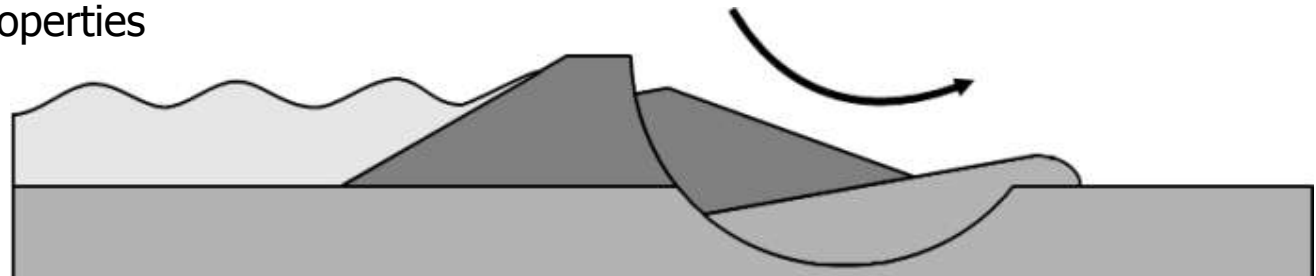
3.5 Understanding failure of levees: Instability example

Instability definition

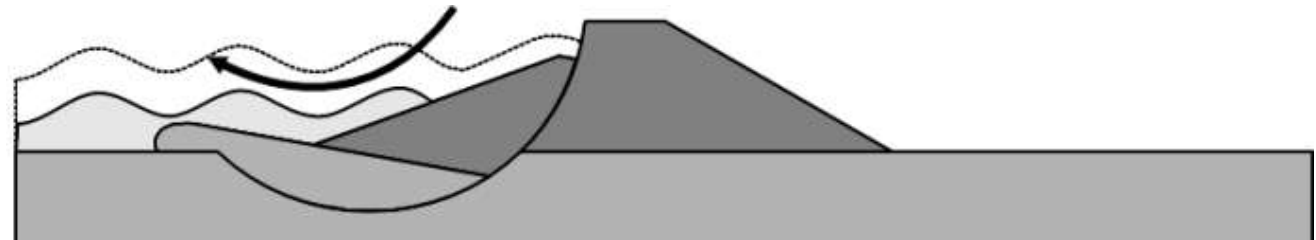
- Active strengths of soil particle movement exceeds resistant strengths
- Excess loading or weak physical properties generate sliding

Factors of instability

- Weight
- Saturated soil
- Decline in material properties
- Human activities
- Animal activities
- Impacts
- Seismic activity
- Erosion

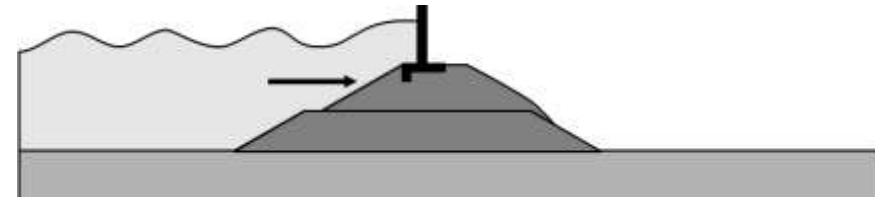
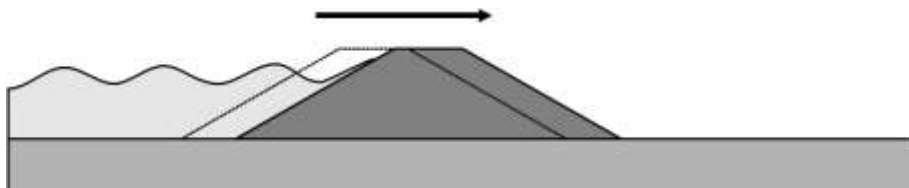


Mechanisms

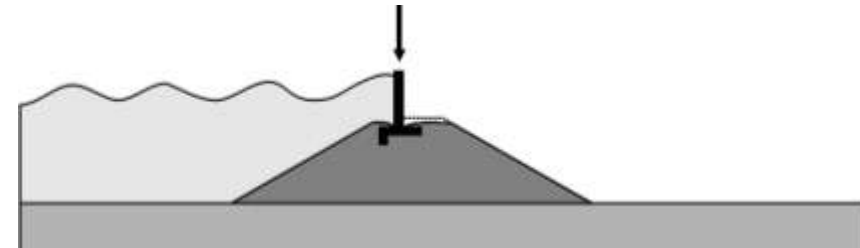
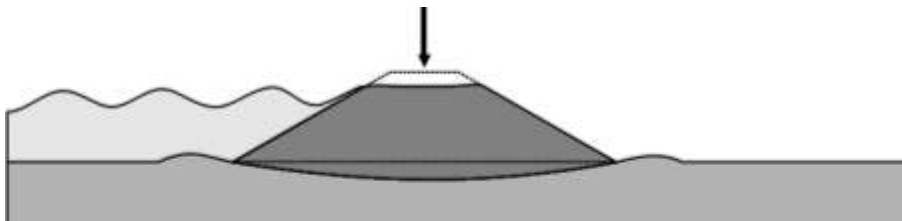




3.5 Understanding failure of levees: Instability example – mechanisms cont'd



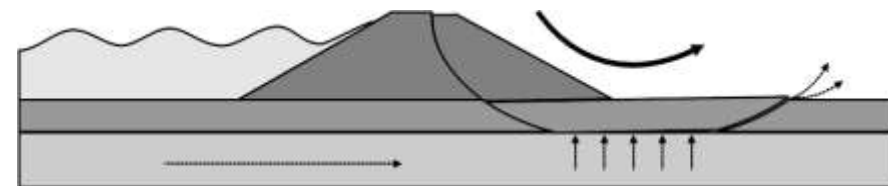
Transitional sliding



Settlement



Tilting of walls due to differential settlement

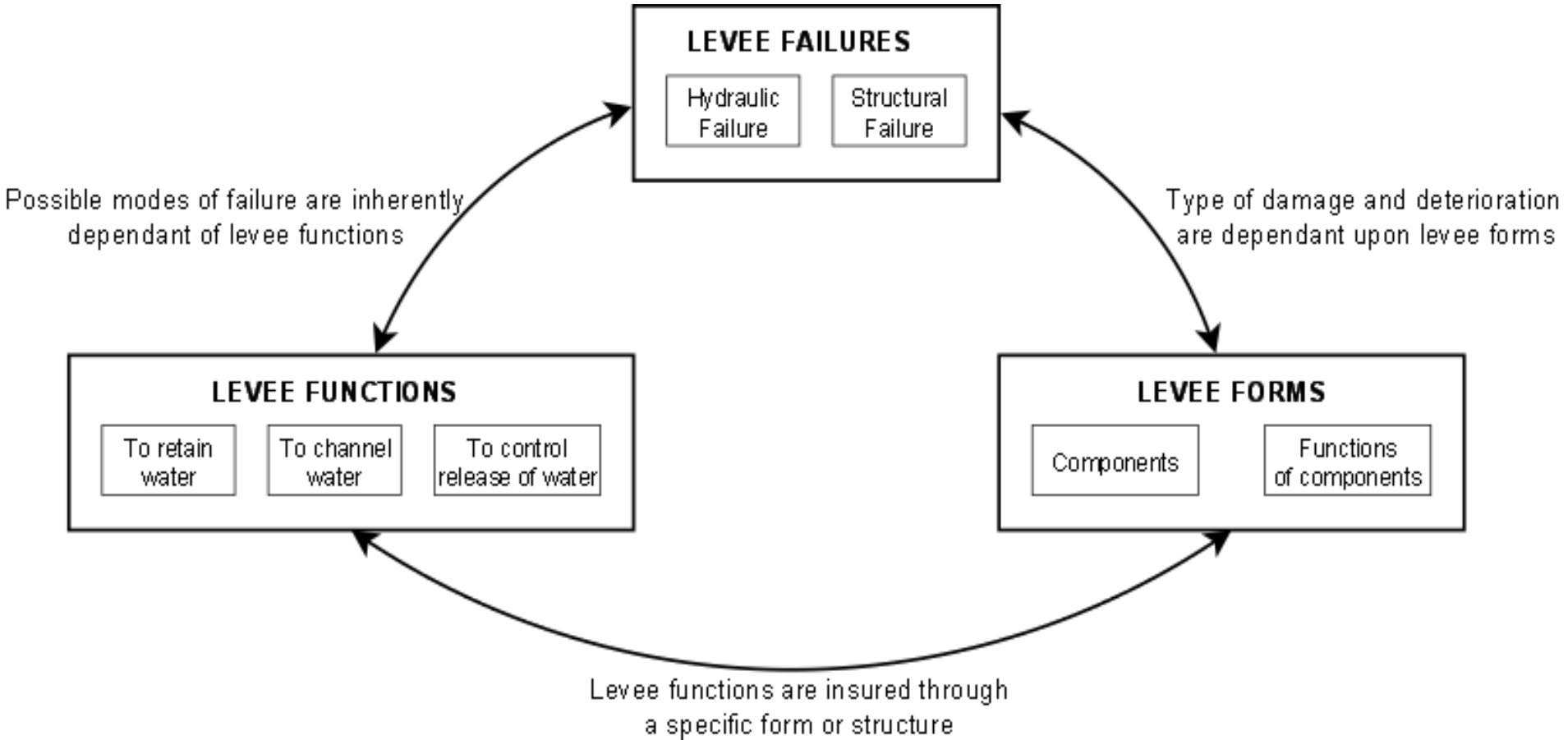


— Rotational movement
- - - Flows and underpressures

Uplift



Conclusion



Relationship between functions, forms and failures of levees
(Courtesy of Y. Deniaud, CETMEF)



Thank you

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