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**EUCOLD LFD WG**

**WEBINAR MARCH 16<sup>TH</sup> 2023**

**EMERGENCY WORKS  
ON THE RHÔNE DELTA LEVEES  
INTERVENTIONS PRINCIPLES  
&  
FEEDBACK ON RECENT FLOOD  
EVENTS FROM 1993 TO 2016**

**THIBAUT MALLET  
SYMADREM, FR**



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Syndicat Mixte Interrégional  
d'Aménagement

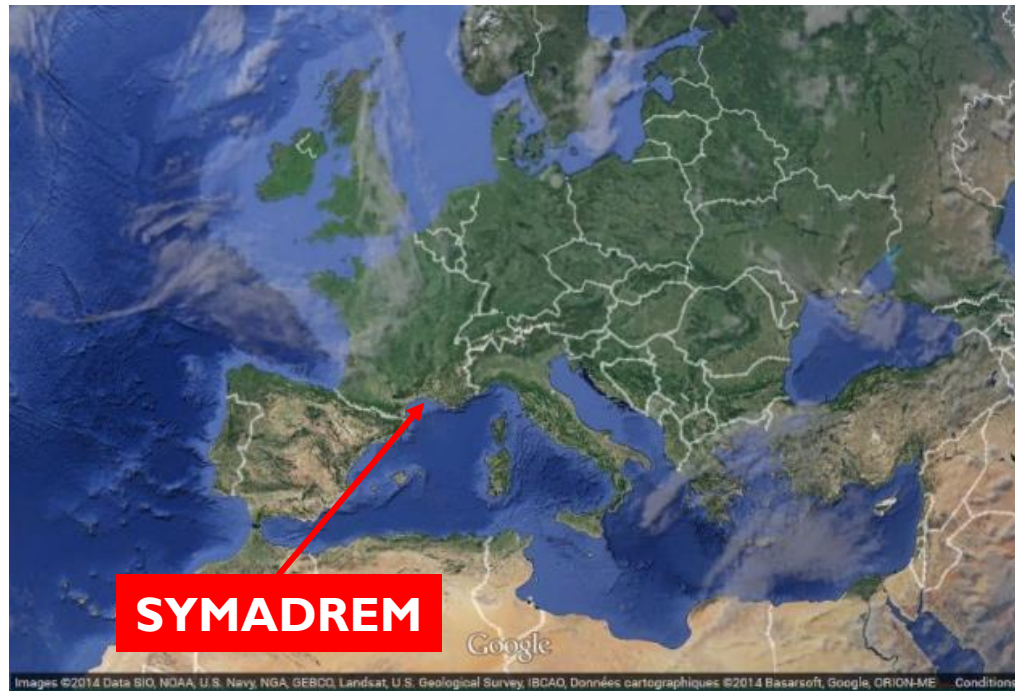
**SYMADREM**

des Digue du Delta  
du Rhône et de la Mer

# PRESENTATION OF SYMADREM

a public institution responsible (27 people) for :

- operations and maintenance of levees in all circumstances
- levees improvement works (450 millions euros over 25 years)



$$Q_{10} = 8\,800 \text{ m}^3/\text{s}$$

$$Q_{100} = 11\,800 \text{ m}^3/\text{s}$$

$$Q_{1000} = 14\,300 \text{ m}^3/\text{s}$$

# INUNDATIONS BY BREACHES

## IN 1840, 1841, 1843, 1846, 1856, 1993, 1994, 2002, 2003

December 2003

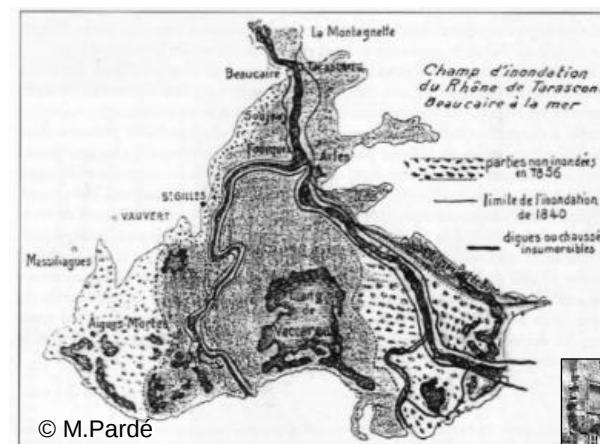
$Q = 11\,500 \text{ m}^3/\text{s}$

$T \approx 100 \text{ years}$



4 breaches and spilled volume  $\cong 230 \text{ million m}^3$   
People flooded : 12 000 à 14 400 (no dead)  
Cost of damages  $\cong 365 \text{ à } 700 \text{ million } \text{€}$

November 1840 & May 1856



$Q \cong 12\,500 \text{ m}^3/\text{s}$

$T \gg 100 \text{ years}$



Spilled volume in 1840 and 1856  $\cong 2,8 \text{ \& } 1,8 \text{ billion m}^3$   
Estimated cost of damages today  $> 2 \text{ billion } \text{€}$

# ACCIDENTOLOGY FROM 1840 TO TODAY

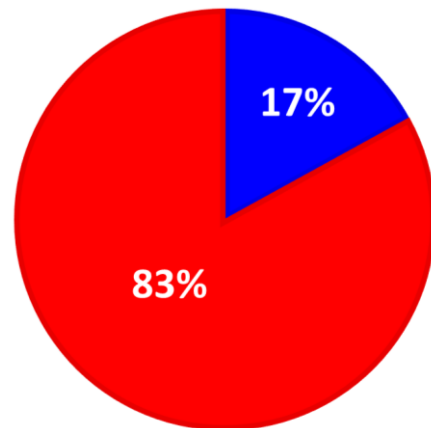
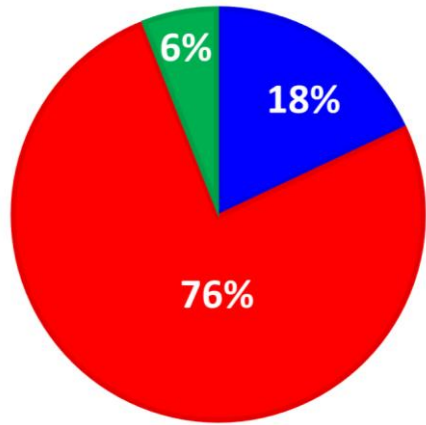
**57 breaches (with inundation) and 57 breaches in progress (no inundation)**

Internal erosion => **concentrated leak erosion**

80 % in badger burrows

1840-2022

1993-2022



Breaches and breaches in progress

■ overflowing ■ internal erosion ■ scour



20 % along crossing pipes



## INTERVENTION PRINCIPLES OF EMERGENCY RESPONSE (1/2)

- Intervention technique for emergency response should not be compared with maintenance or improvement work
- Such operations are most frequently carried out during periods of rain that are not adapted to compaction of fine materials
- Emergency operations are not intended to be permanent and must be assessed with a post-flood analysis.

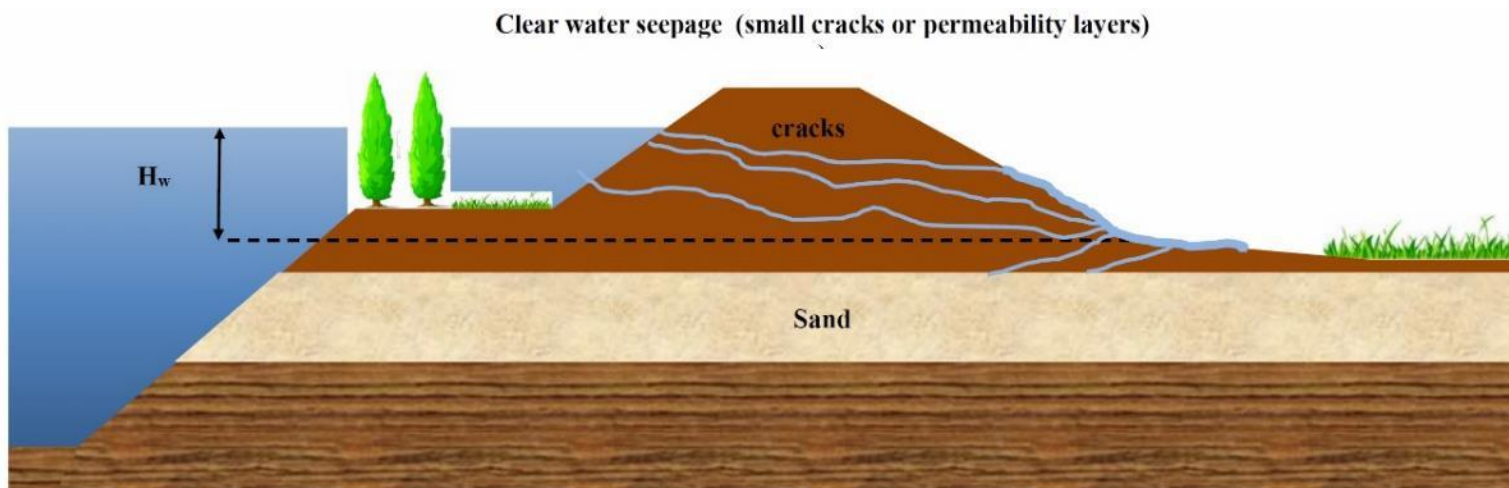
## INTERVENTION PRINCIPLES OF EMERGENCY RESPONSE (2/2)

- Use of conventional earthmoving techniques, since these are generally well mastered by the levees managers ;
- The use of non-cohesive materials on the landward side and the use of highly plastic materials as clay on the riverward side ;
- Intervention on the landward side (protected area side) is preferred to intervention on the riverward side ;
- The use of filler materials (black furnace slag, spall rocks, rockfill) stored in storage areas located near the levees.

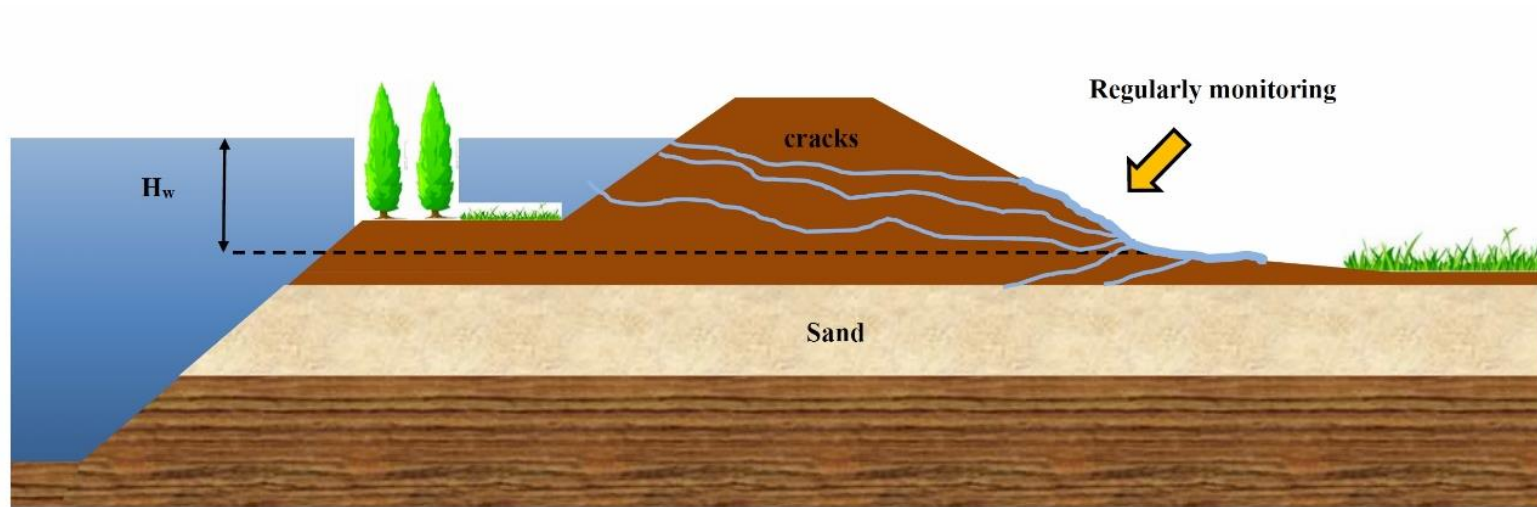
# WHAT IS THE RESPONSE TO CLEAR WATER SEEPAGE (NO EROSION) ?



Clear water seepage is fairly common during floods...



# RESPONSE TO CLEAR WATER SEEPAGE IS REGULARLY MONITORING



and most of the time, levee is monitored regularly

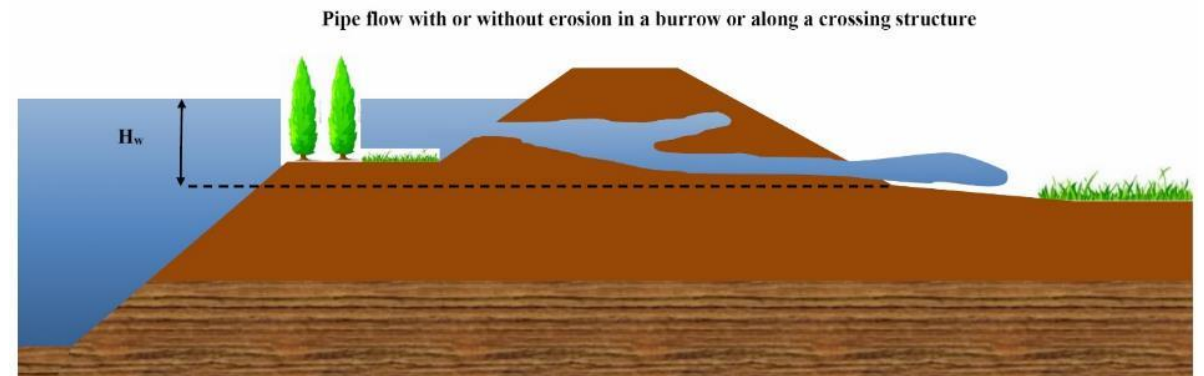
# WHAT IS THE RESPONSE TO CLEAR WATER LEAKAGE (NO EROSION) OR MUDDY WATER SEEPAGE OR LEAKAGE ?



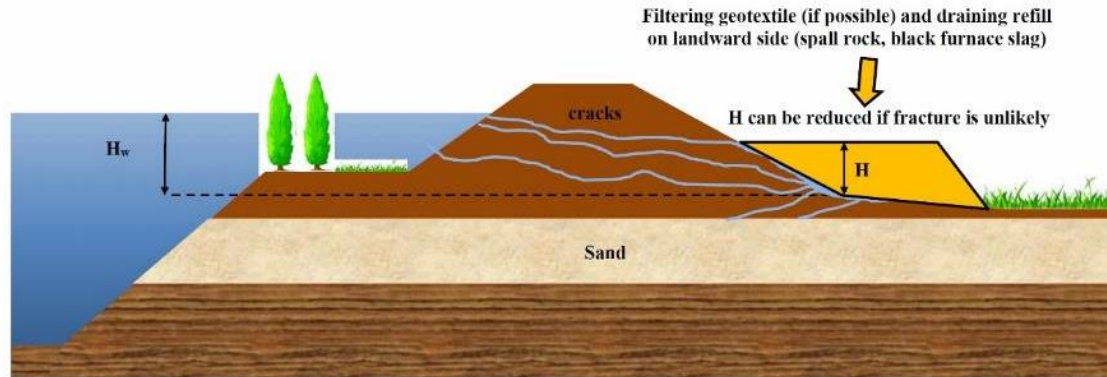
an excessive leakage rate can indicate the imminent initiation of concentrated leak erosion



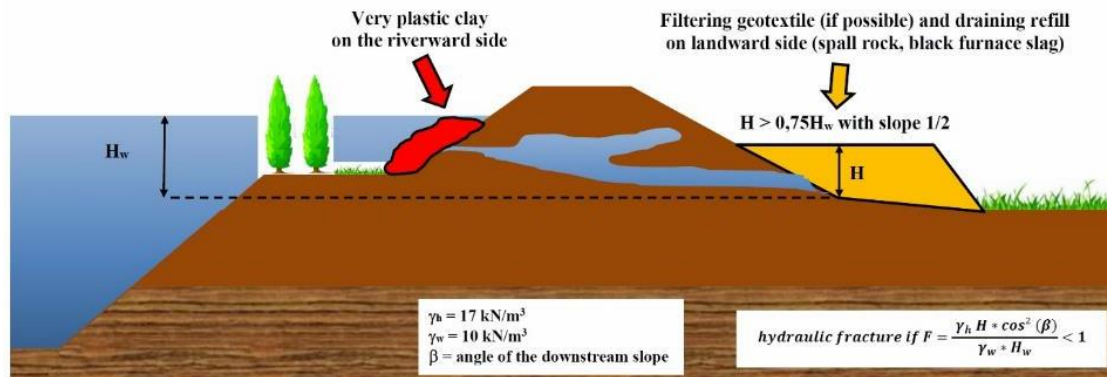
Muddy water seepage or leakage indicates a current internal erosion (mostly in badger burrow or along a crossing pipe)



# RESPONSE TO CLEAR WATER LEAKAGE (NO EROSION) OR MUDDY WATER SEEPAGE OR LEAKAGE (EROSION)



Muddy water seepage



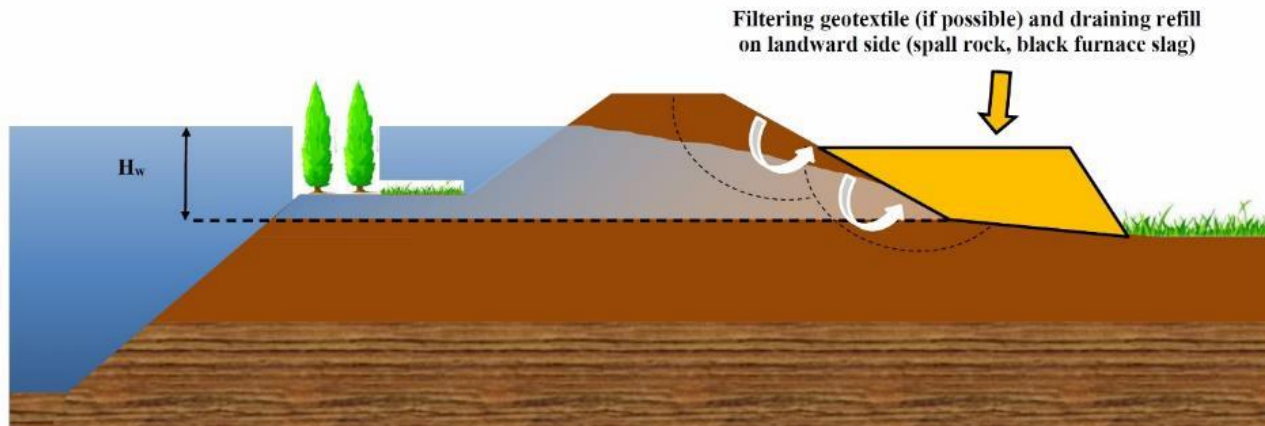
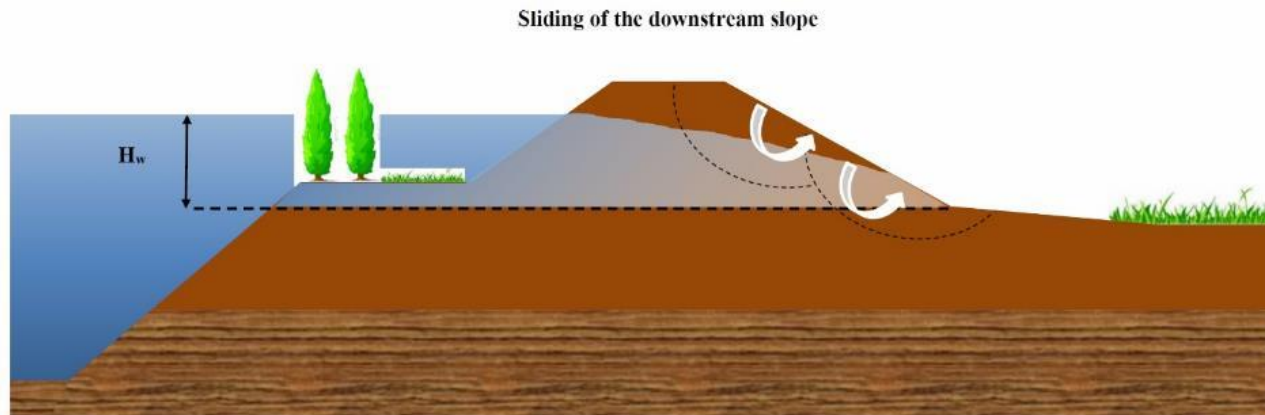
water leakage

Intervention technique consists of **limiting the flow rate by using highly plastic clay** on the riverward side and using a filtering geotextile (if possible) on the landward side with a **filtering/draining refill made of non-cohesive materials** such as gravels, black furnace slag or spall rocks. The height of the downstream refill must be sufficient to prevent hydraulic fracture of the berm during a flood.



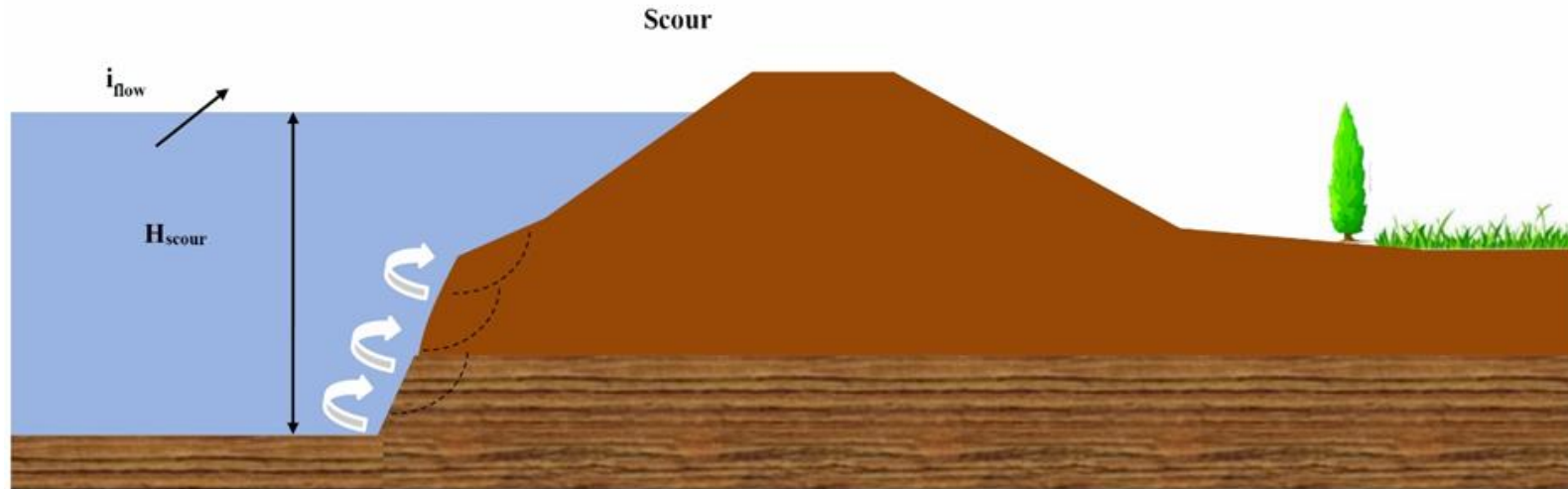
# RESPONSE TO INSTABILITY AND INTERVENTION TECHNIQUE

The intervention technique is identical. A draining refill placed on a filtering geotextile is used to stabilise the downstream bank.

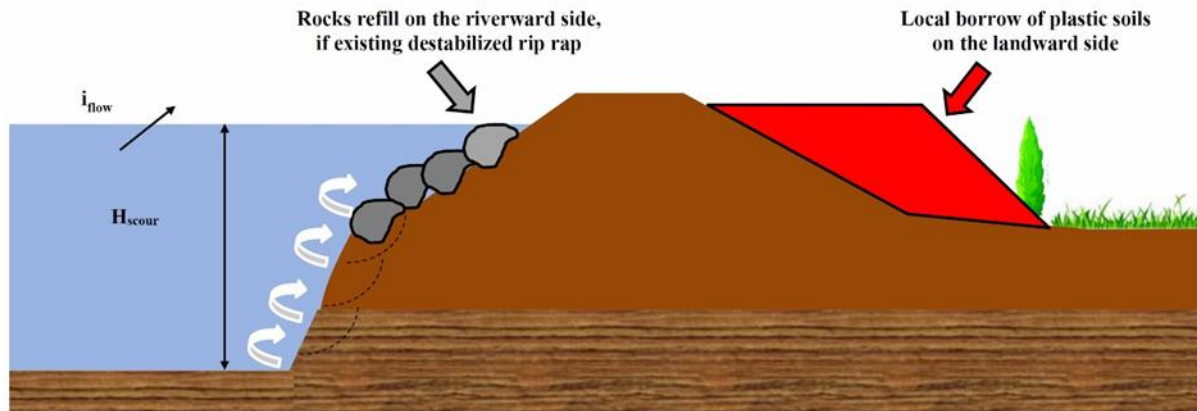


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# WHAT IS THE RESPONSE TO SCOUR ?



# RESPONSE TO SCOUR AND INTERVENTION TECHNIQUE.

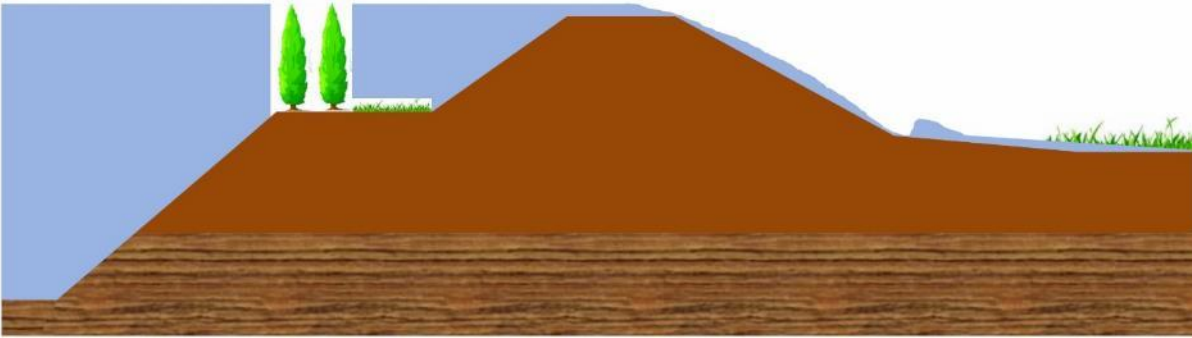


A berm on the landward side (protected zone) is carried out using locally obtained plastic clay, which resists external erosion by the current. This can be supplemented by laying of rockfill blocks on the riverward side.

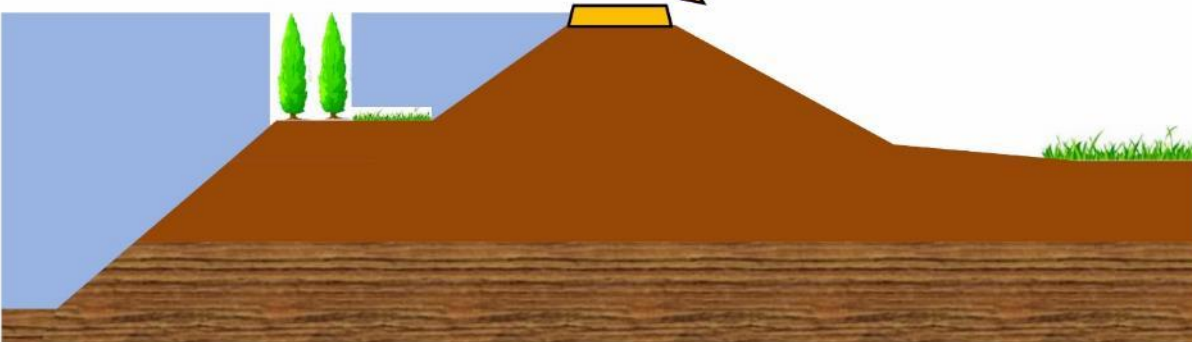


# WHAT IS THE RESPONSE TO LOCAL OVERFLOW ?

Local overflow or imminent local overflow



Gravels, black furnace slag or local borrow



Backfill is laid on the crest of the levee to contain the overflow.



# WHAT IS THE RESPONSE TO GENERAL OVERFLOW ?



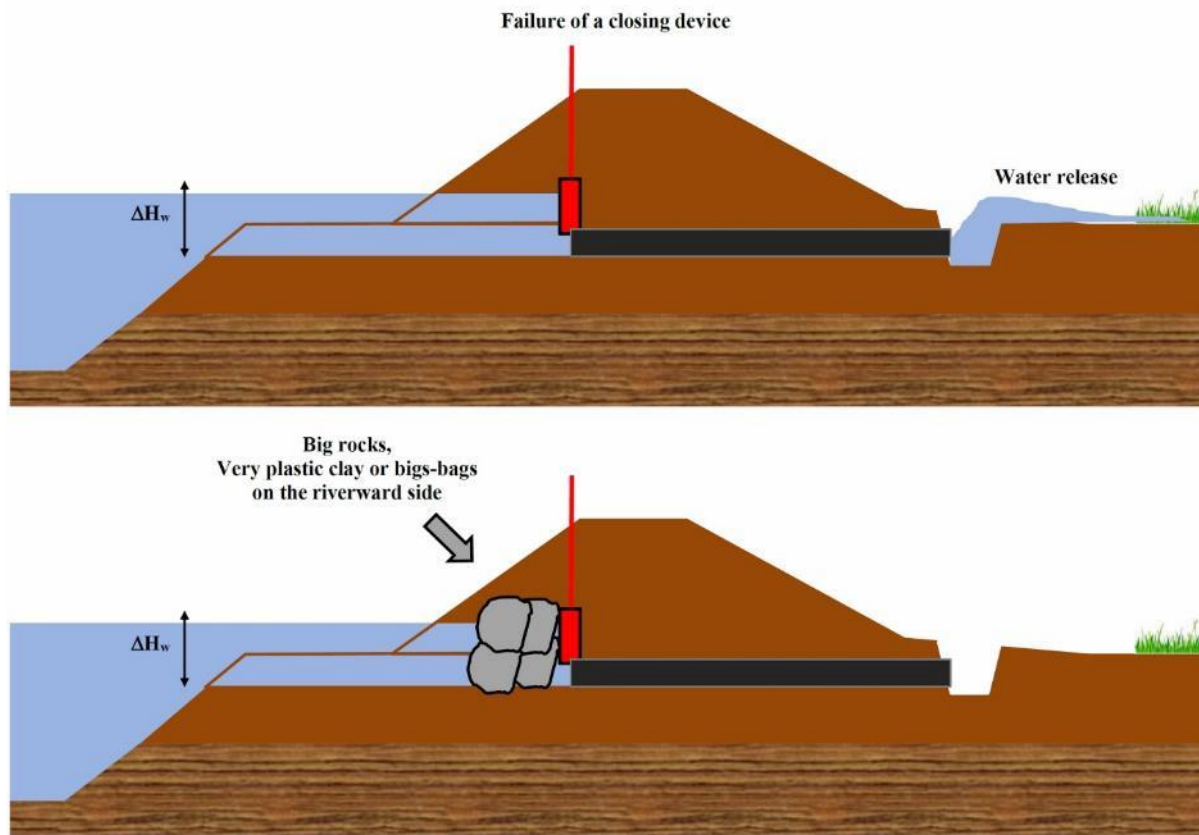
No response

General overflows are not dealt with, given their possible impact on the opposite bank or downstream.

## INTERVENTION IN CASE OF NON-CLOSURE OR FAILURE OF A CLOSING DEVICE

Works are preferentially carried out on the riverward side using blocks of 3 to 6 tonnes (given that speeds can reach 7 m/s) or equivalent big-bags.

The block size distribution is reduced if the speed is lower.



# INTERVENTIONS FOR SMALL BREACHES (STAGE 1)



If possible, duckbills made of large riprap are constructed on the upstream side to limit the flow through the breach



## INTERVENTIONS FOR SMALL BREACHES (STAGE 2)



We continue the operations by using small riprap

## INTERVENTIONS FOR SMALL BREACHES (STAGE 3)



Finally, clay is used between the rocky line and the levee to progressively stop the flow.



## FEEDBACK FOR BREACHES CLOSING

These techniques were successful in the Camargue in 1994 for the Beaumont breach (water head 1.6 m) and for the Ventabren breach in 2016 (water head 0.7 m).

It should be noted that no helicopter operations with dumping of big-bags have been able to plug a breach in the Camargue from 1993 to the present day.



**Thank you  
for attention**