Field tests on overtopping resistance of CS

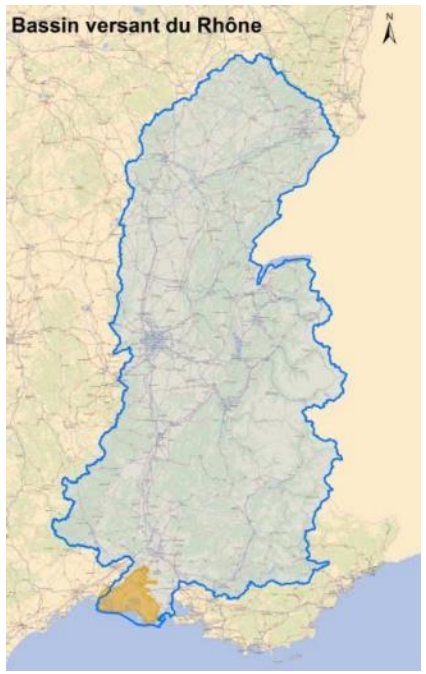
application to the project of building a levee resisting to overflow in the Rhone delta (Salin de Giraud)

Thibaut MALLET, *SYMADREM*

Syndicat Mixte Interrégional d'Aménagement
SYMADREM
des Digues du Delta du Rhône et de la Mer

Symadrem is a public institution (27 people) responsible for

- operations and maintenance of levees in all circumstances
- levees improvement works

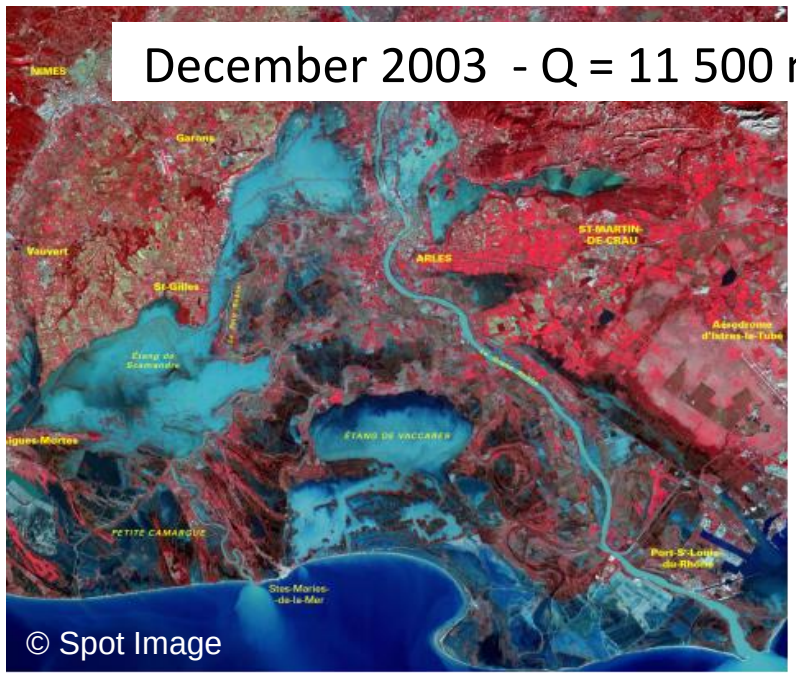


Q_{10} = 8 800 m³/s
Q_{100} = 11 800 m³/s
Q_{1000} = 14 300 m³/s

Rhone delta is very exposed to inundations by breaches

in 1840, 1841, 1843, 1846, 1856, 1993, 1994, 2002, 2003

December 2003 - Q = 11 500 m³/s T ≅ 100 years

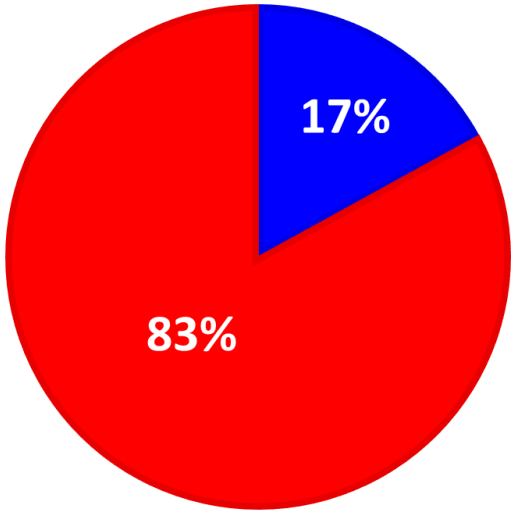


4 breaches and spilled volume ≅ 230 million m³

People flooded : 12 000 à 14 400 (no dead)

Cost of damages ≅ 365 à 700 million €

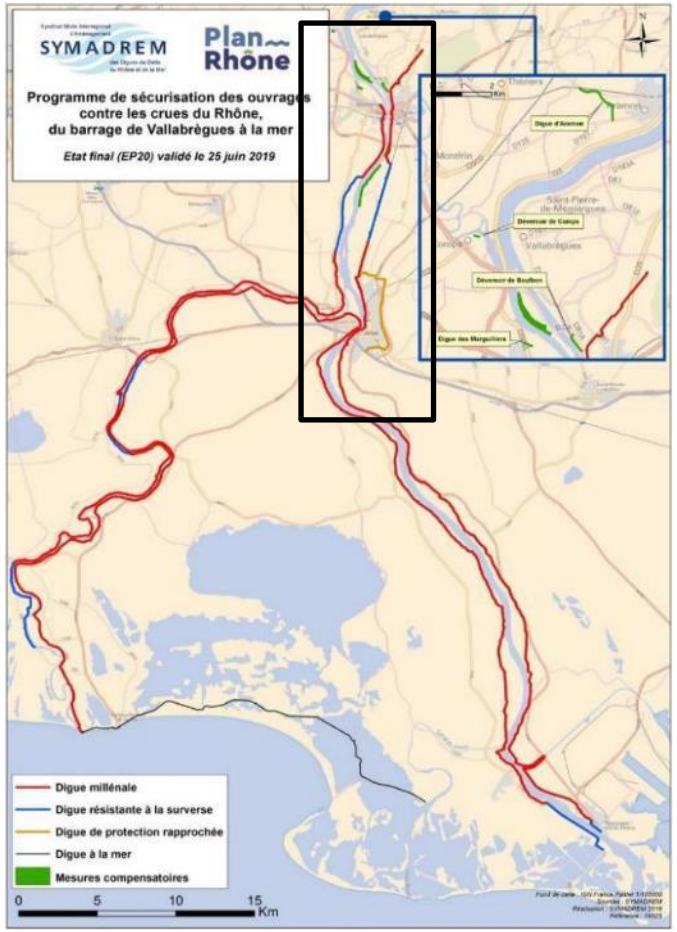
Recent period since 1993



Breaches and breaches in progress

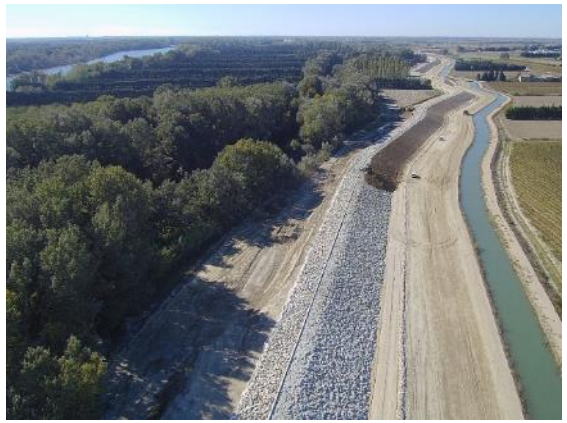
■ overflowing ■ internal erosion

The response : a global plan of improvement works



Response of Rhône plan :

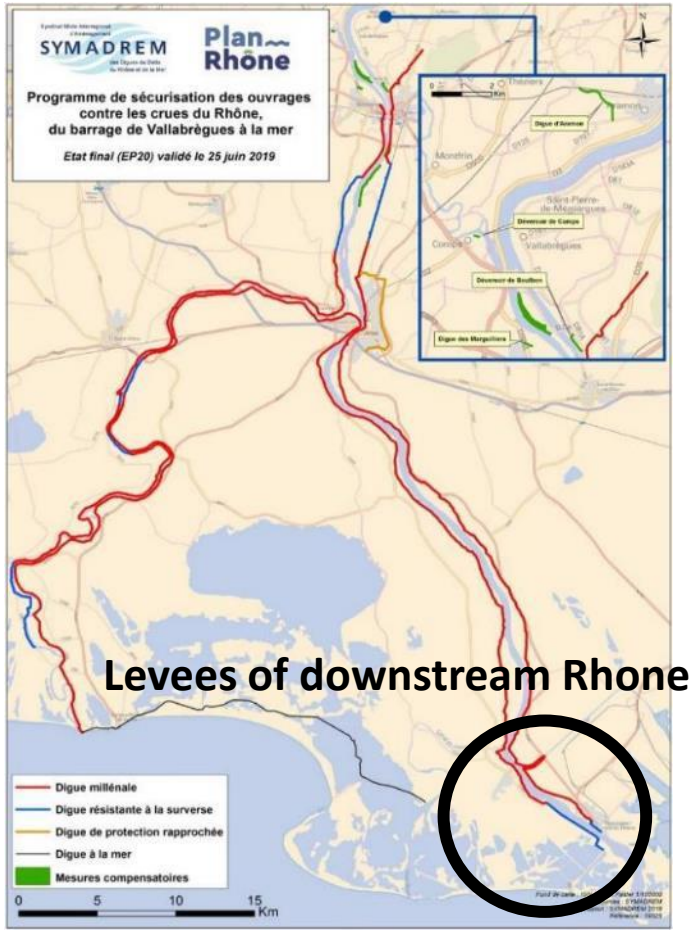
- **do not raise the levees**
- **accept overflowing for rare floods** (T = 100 or 50 years)
- **do not accept breaches** in the levees until millenium floods



Levees with long spillways
(5 km respectivement by banks) set at Q_{50} or Q_{100}
and resisting to overflow until Q_{1000}

« millenium » levees
set at Q_{1000} + 50 cm

An alternative to concreted rip rap : soil treated with quicklime ?



Levees of downstream Rhone

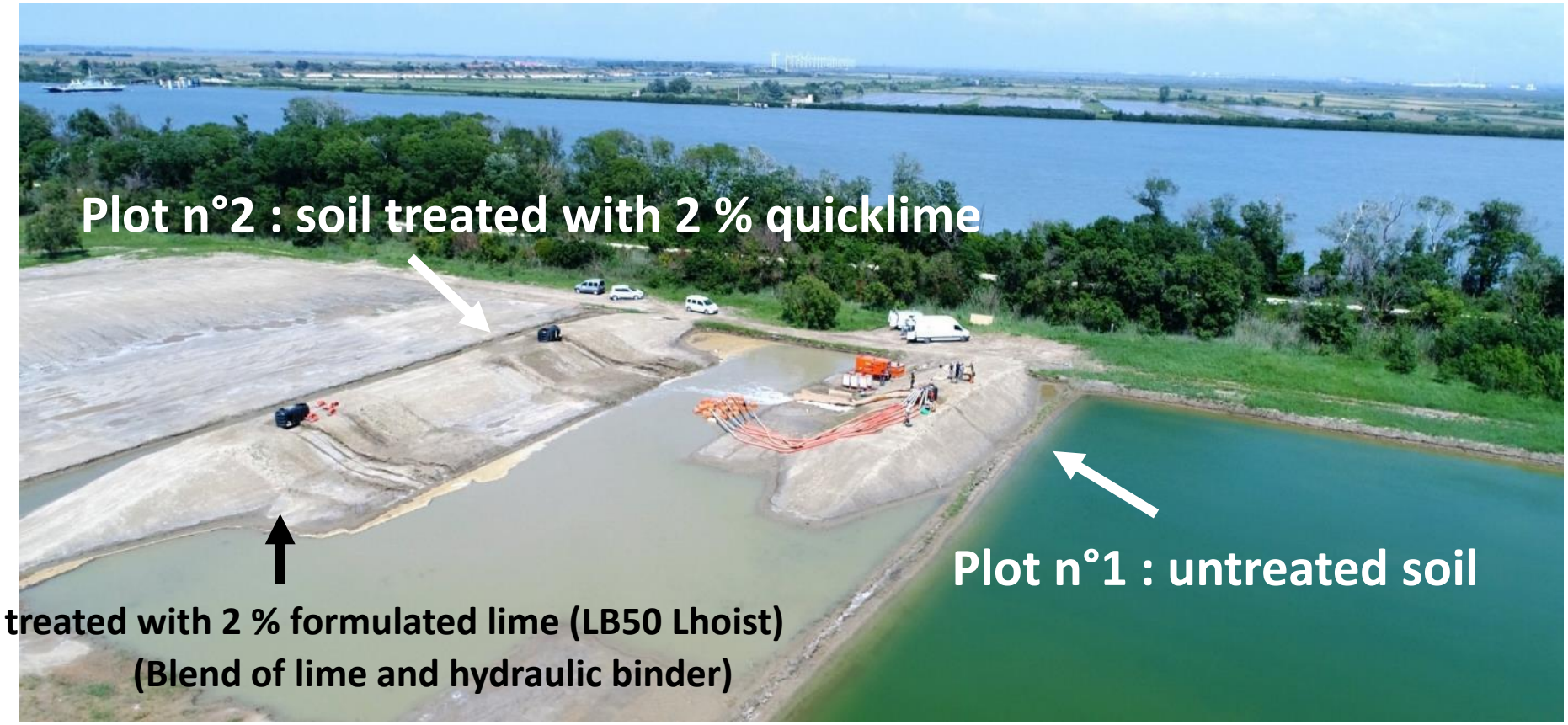
- Levees downstream the delta are less high
- Flooding levels, in the protected area, in case of breaches, are less high (1 m against 4 m upstream the delta)
- Spillway on levees (called levees resisting to overflow) is implemented downstream the urban area

Field experience was carried out between march 2017 and June 2018

EDF INRAE DPST CONSULTING Masoni

Lhoist Recherche et Développement S.A.

3 test levees were built in novembre 2017 to assess the interest of lime-treated soils to prevent overflow erosion



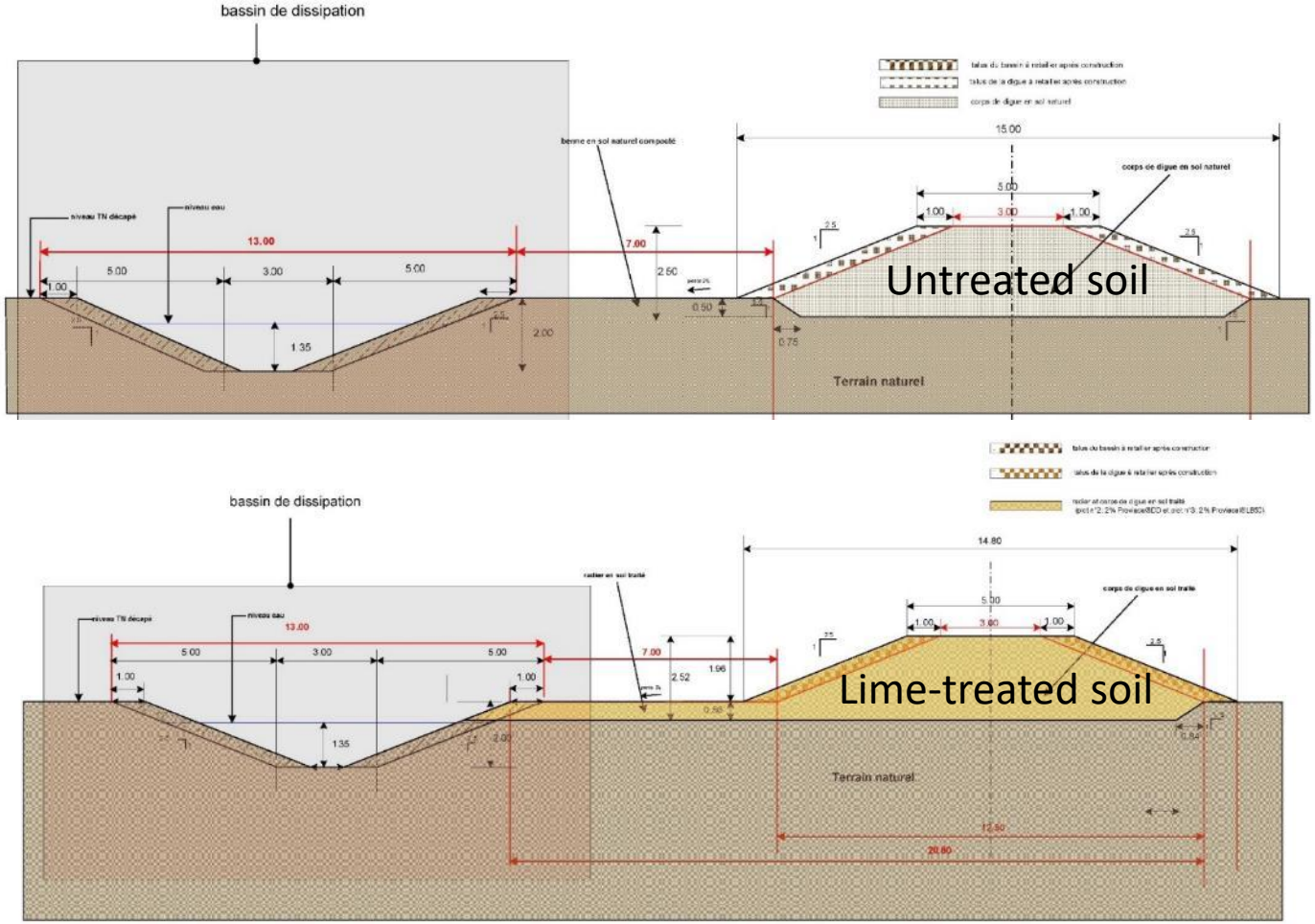
Tested soil : a mixture of a silty soil and a clay soil (main characteristics)

stockage des limons beiges

stockage des argiles bleues/grises

- 13 % clay (< 2 μm)
- 87 % (< 80 μm)
- 100 % (< 2 mm)
- PI = 9
- Wn : 26 to 42 % (just after extraction)
- OMC : 16,1 % (untreated) ; 18 % (2% quicklime) and 19 % (LB50)
- $\rho_{d,\,OMC}$ = 1,77 t/m³ (untreated) ; 1,63 t/m³ (2% quicklime - compacity 95 %) ; 1,63 t/m³ LB 50 compacity 95 %)
- Organic matters : 0,9 %

Cross section of plots (building in november 2017)



Levee characteristics

- Height : 2 m and slope (2,5H/1V)
- 0,3 m thick topsoil layer

Building method

- The treatment was carried out in place, layer by layer, on dedicated platforms
- Once treated, each layer was removed, transported, placed on the corresponding levee and compacted by a vibrating padfoot roller.
- The thickness of each layer once compacted was 30 cm and W ≅ OMC X 1,07 to 1,08

Photos of equipments and of the works

bulldozer Komatsu D61 EX

pelle liebherr 714 et tombereau

MASONI TP equipments

épandeur Streumaster SW 16 SC

malaxeur Wirtgen 240

camion citerne

silo de stockage

LHOIST equipments

malaxage du sol naturel sur plate-forme avant traitement

épandage de la chaux sur la plate-forme de traitement (600 m²)

malaxage sur la plate-forme de traitement

reprise du sol traité à la pelle sur la plate-forme de traitement

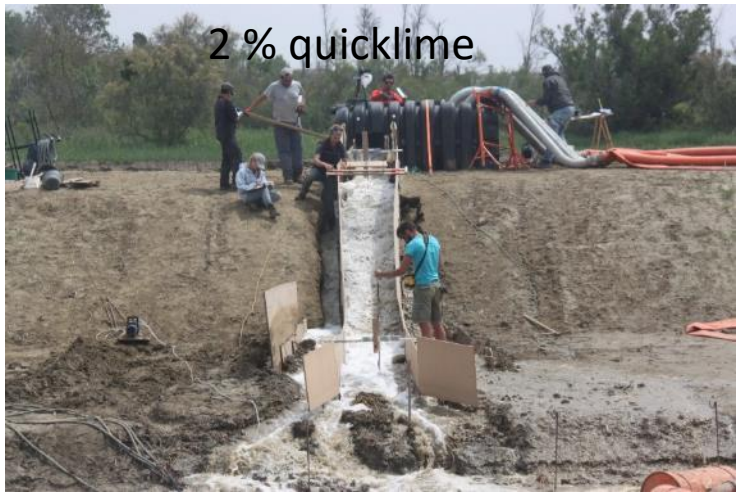
approvisionnement et régalage du sol traité sur le fond de fouille du

compactage de la couche C1 du plot n°2

Real scale overflowing tests series were performed by Inrae (ex-Irstea) 6 months after the construction (may 2018)

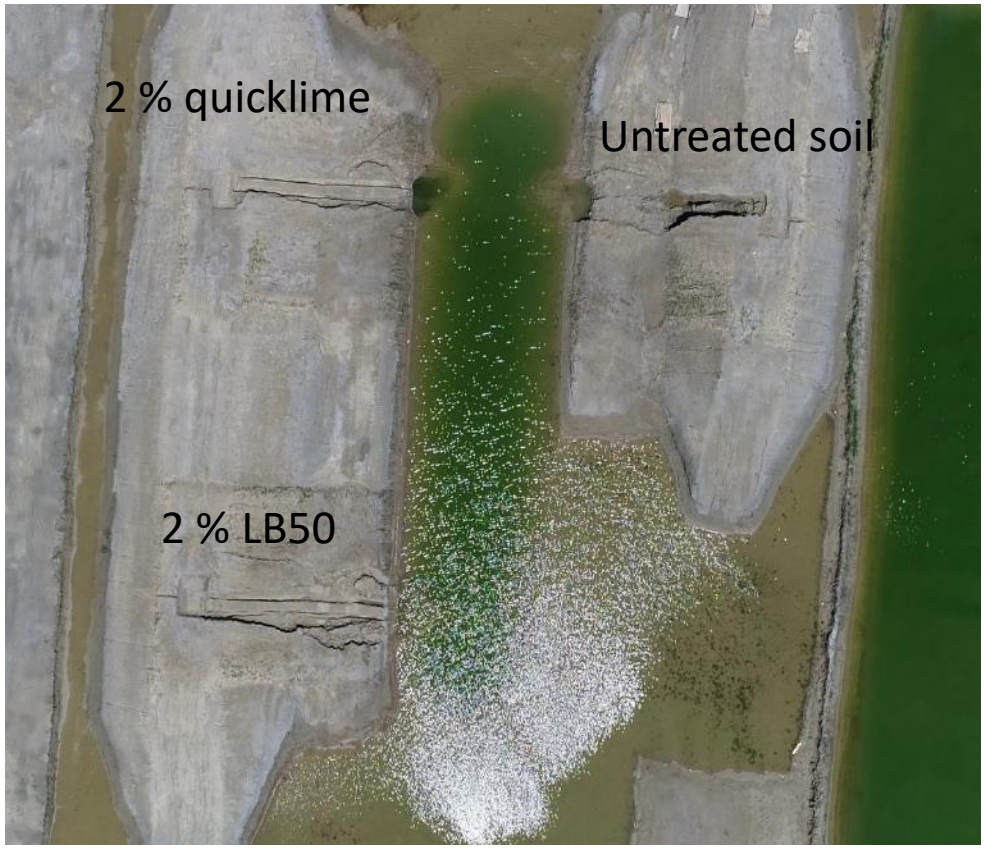
Design criteria (SYMADREM) : overflowing water level – 20 cm for Q_{100} and 50 cm for Q_{1000}

Overflowing duration : 3h30 from 0 to 50 cm and 5h00 with a 50 cm permanent level



Effective criteria : overflowing water level 42 cm for untreated soil and 35 and 38 cm for lime-treated soils. The overflowing duration was respected

Visual results



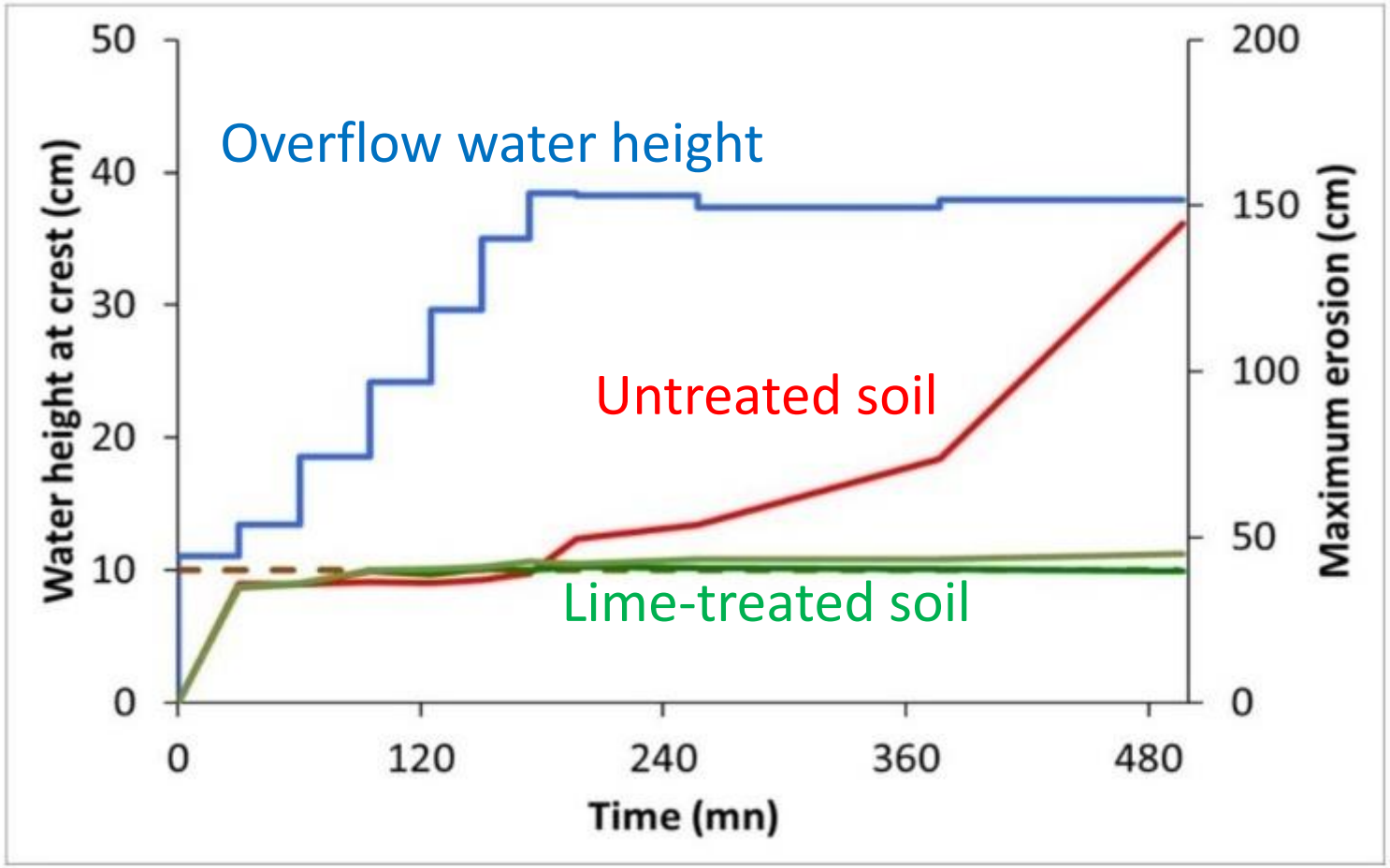
Visual results

Untreated soil

2 % quicklime

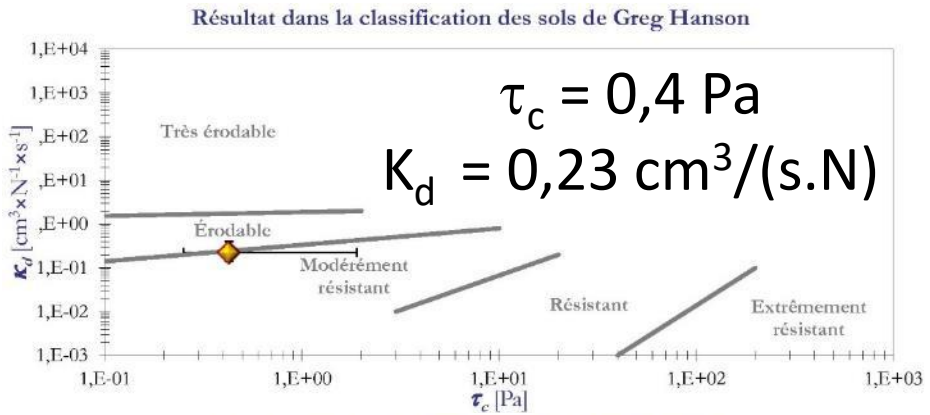
2 % LB50

Visual results

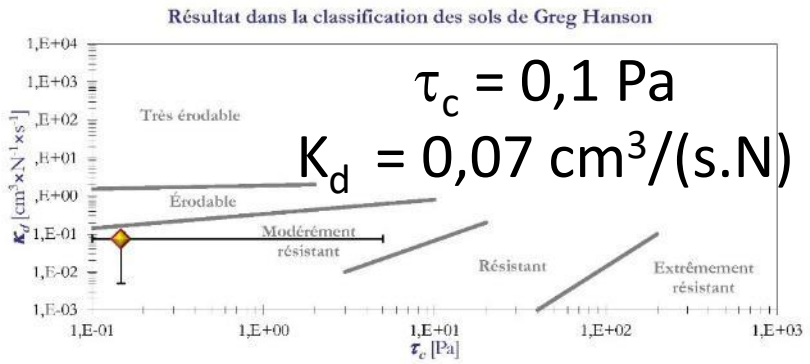


JET results on undisturbed samples (J + 180) to determine the critical stress τ_c and the Hanson erosion coefficient K_d

Untreated soil

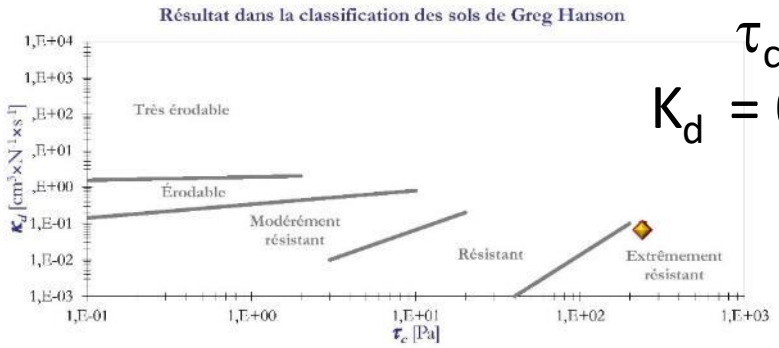


τ_c = 0,4 Pa
K_d = 0,23 cm³/(s.N)



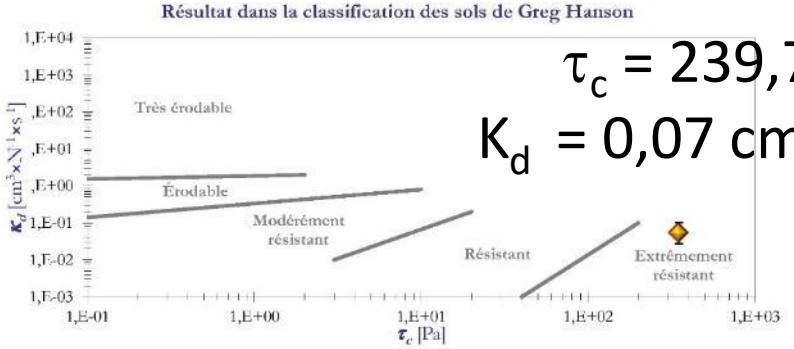
τ_c = 0,1 Pa
K_d = 0,07 cm³/(s.N)

2 % quicklime



τ_c = 349,3 Pa
K_d = 0,05 cm³/(s.N)

2 % LB50



τ_c = 239,7 Pa
K_d = 0,07 cm³/(s.N)

HET on undisturbed samples (J + 180)

Untreated soil

τ_c = 99 Pa

Ie = 3,48

HET on laboratory reworked samples (J + 91)

2 % quicklime

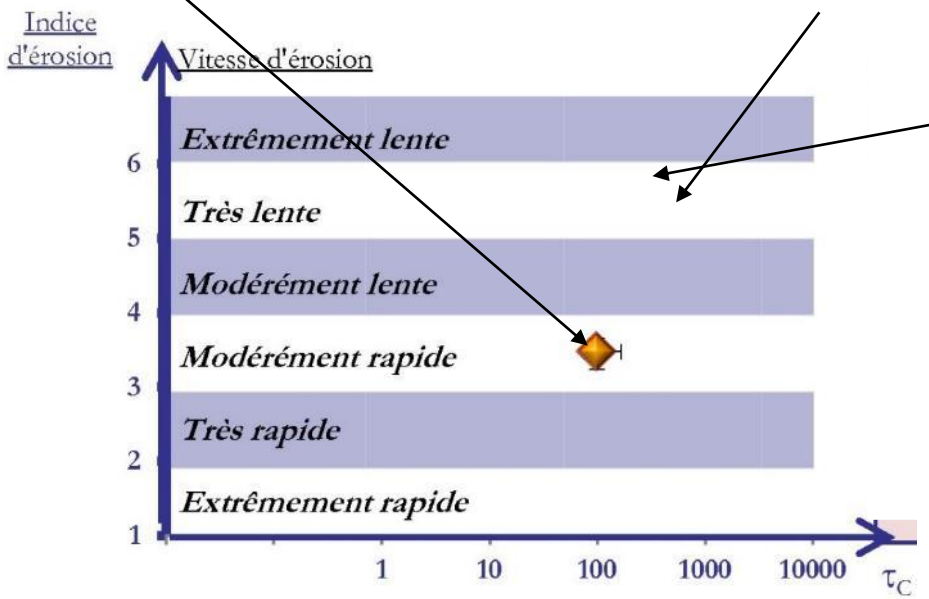
τ_c = 753,1 Pa

Ie = 5,37

2 % LB50

τ_c = 720,0 Pa

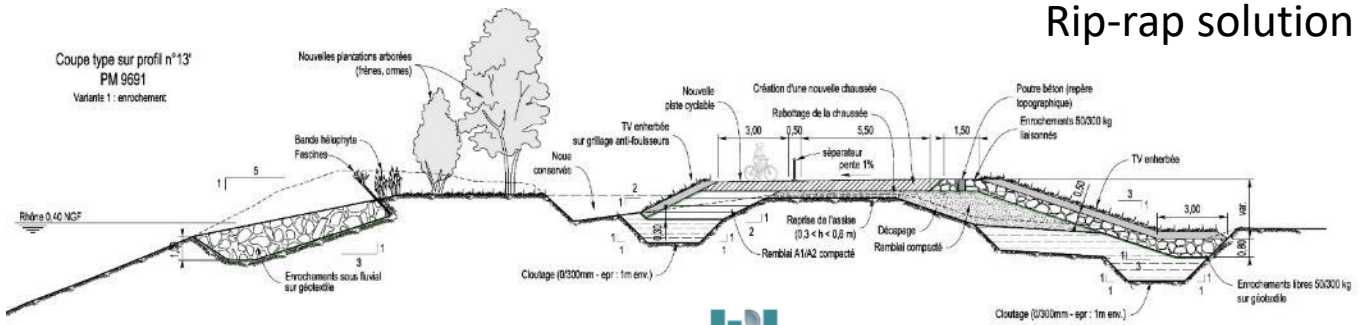
Ie = 5,87



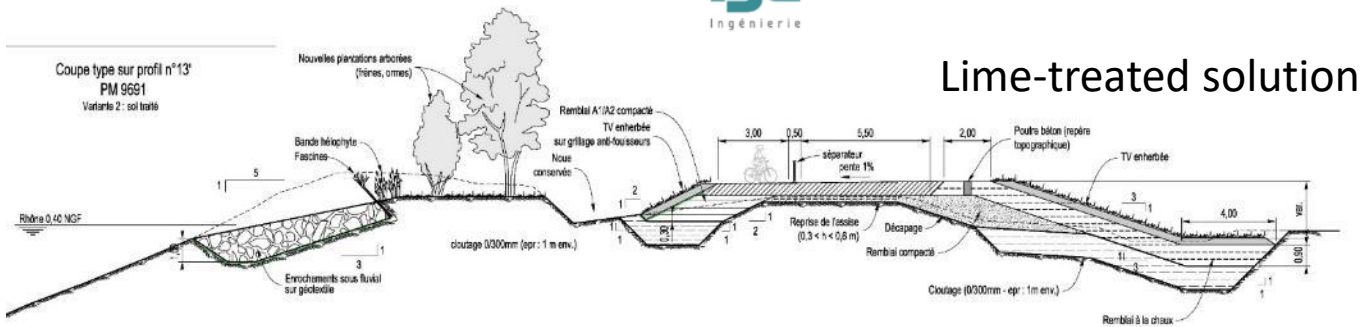
Conclusion

Lime-treated soil to resist to overflow seems to be an interesting alternative to classical design with rip-rap in the context of Salin de Giraud Levee resisting to overflow

Rip-rap solution



Lime-treated solution



- Costs, based on design studies, are equivalent
- At this stage, we keep both of designs and will make our choice in function of the results on the public tender (2023/2024)

Thank you for attention

and welcome for the technical visit on may 31th

Levees resisting to overflow between Beaucaire and Arles

Beaucaire-Fourques (right bank)

Tarascon-Arles (left bank)

Join us