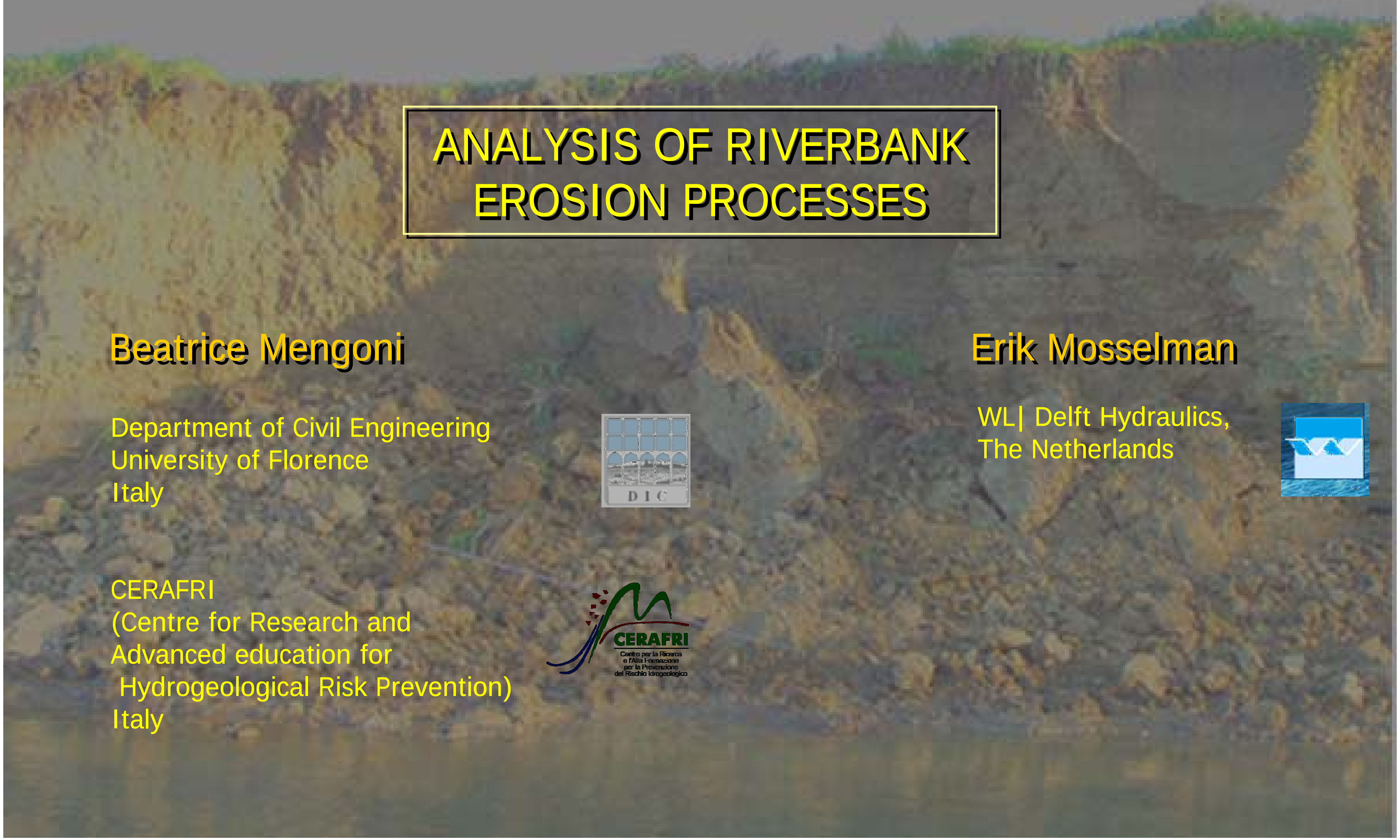

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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
River Coastal and Estuarine Morphodynamics
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ANALYSIS OF RIVERBANK EROSION PROCESSES

Beatrice Mengoni

Department of Civil Engineering
University of Florence
Italy

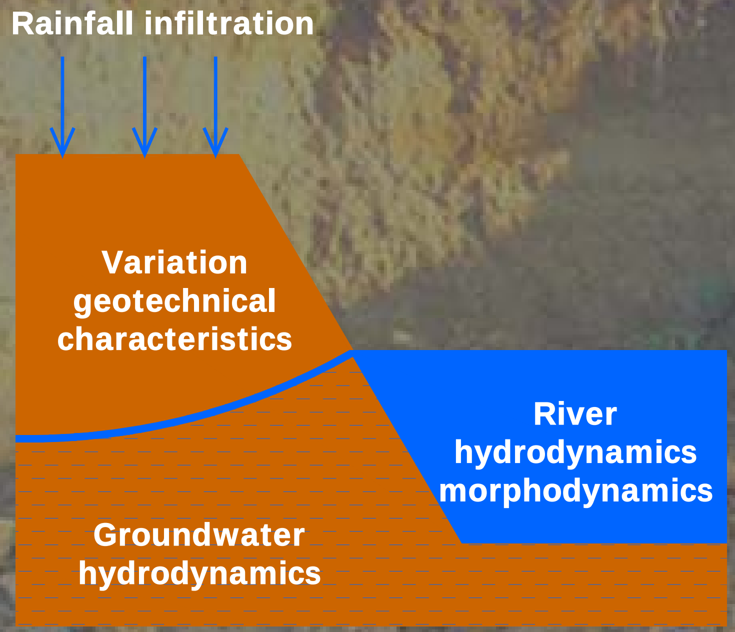
CERAFRI
(Centre for Research and
Advanced education for
Hydrogeological Risk Prevention)
Italy

Erik Mosselman

WL| Delft Hydraulics,
The Netherlands

INTRODUCTION

Bank erosion is the result of the simultaneous interaction between several factors:



Main processes

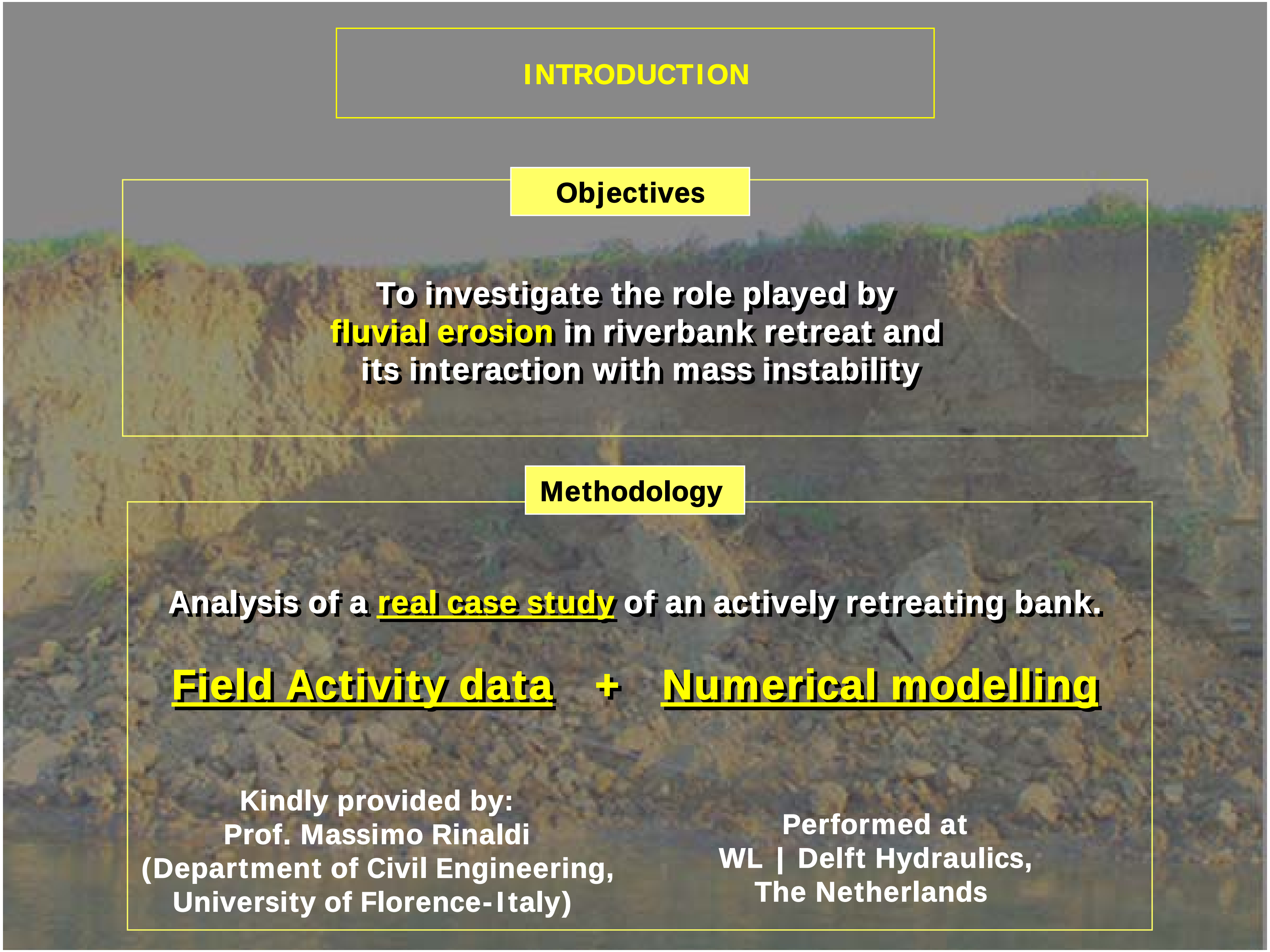
- Fluvial erosion
- Mass-wasting
- Weathering-weakening
- Seepage

Approach n°1:

Processes are simulated in a single simplified numerical model (e.g. Langendoen 2000; Mosselman 1992; Darby et al. 2002)

Approach n°2:

Processes are simulated by separated numerical models (Dapporto 2002, Dapporto & Rinaldi 2003, Simon et al. 2003, Rossi Romanelli et al. 2004).



INTRODUCTION

Objectives

To investigate the role played by
fluvial erosion in riverbank retreat and
its interaction with mass instability

Methodology

Analysis of a **real case study** of an actively retreating bank.

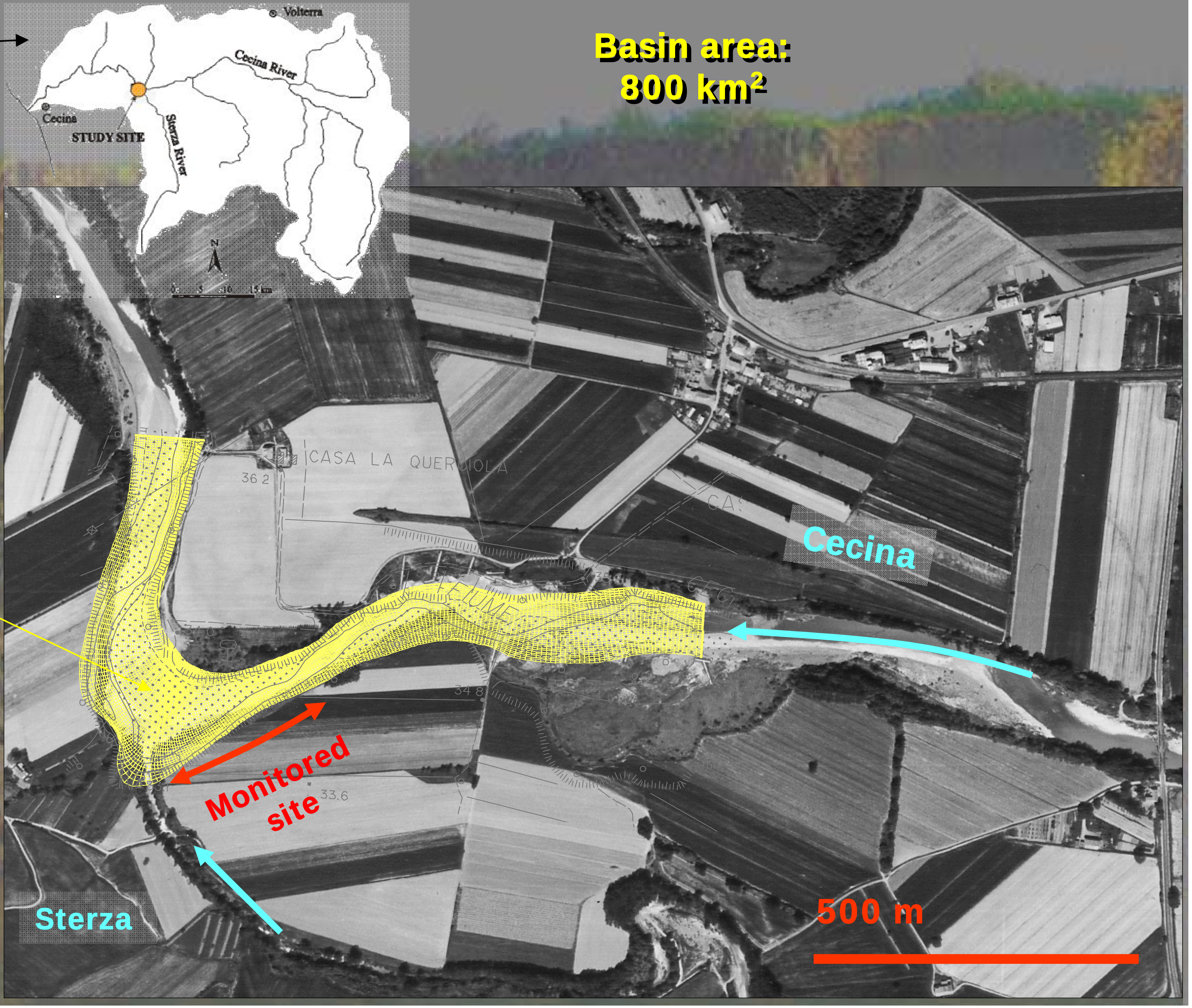
Field Activity data + **Numerical modelling**

Kindly provided by:
Prof. Massimo Rinaldi
(Department of Civil Engineering,
University of Florence-Italy)

Performed at
WL | Delft Hydraulics,
The Netherlands

THE CASE STUDY

Cecina river

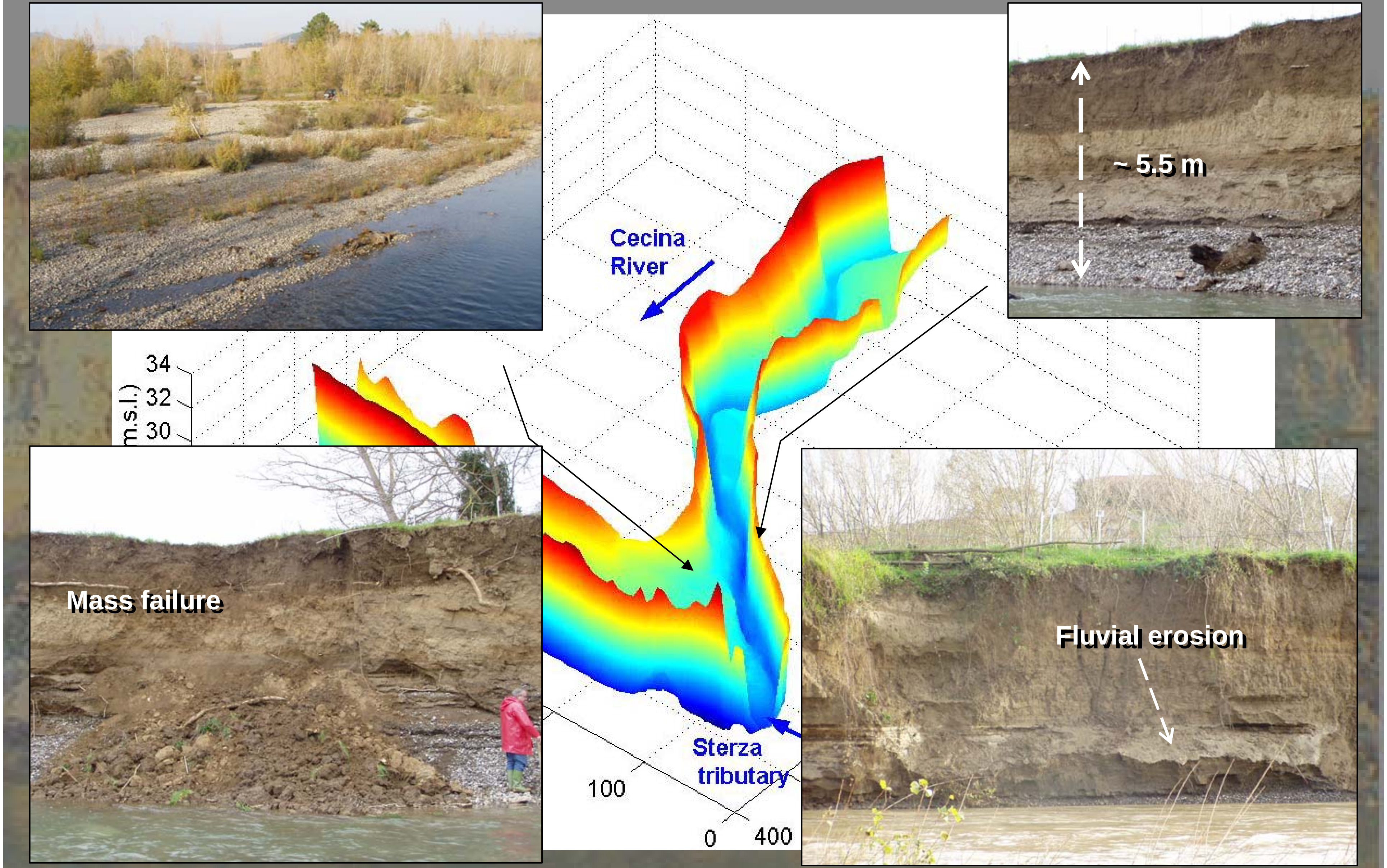


Basin area:
800 km^2

Study area

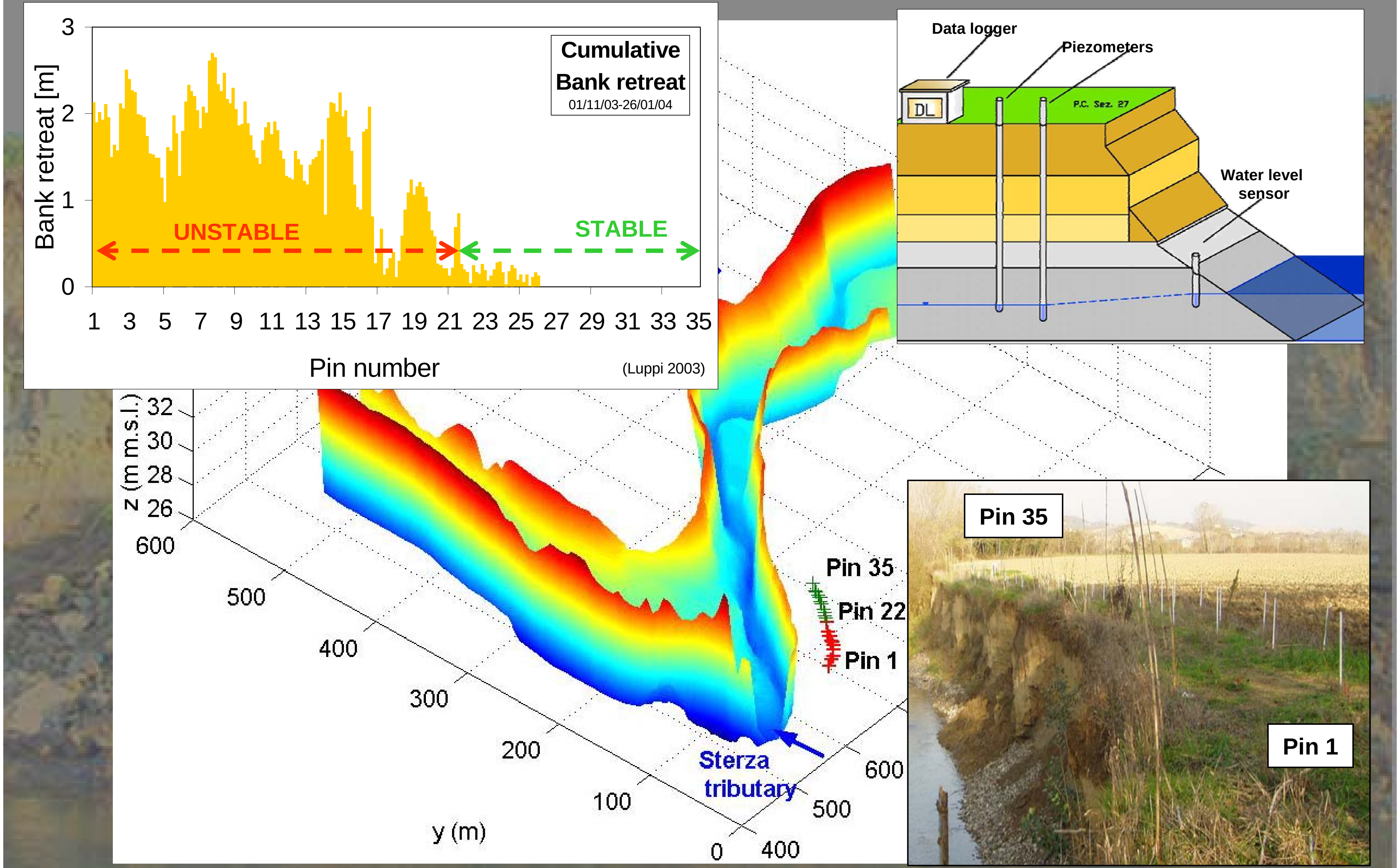
Length: 1300 m
Width: 45-150 m
Slope: 0.0021

THE CASE STUDY

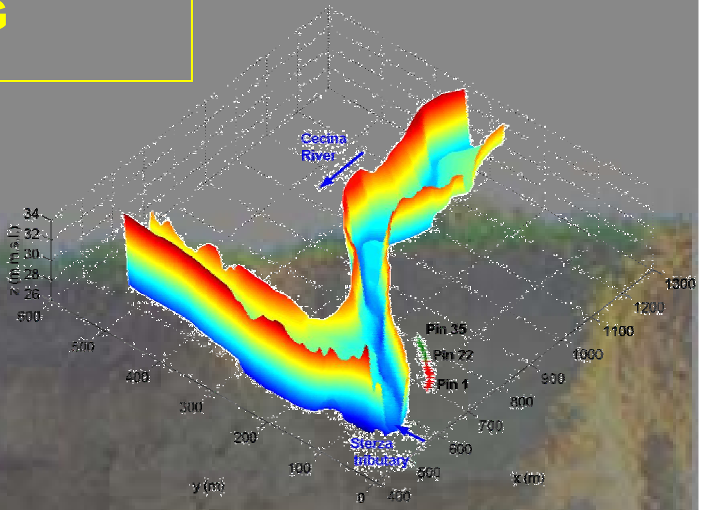


Photos courtesy of Rinaldi

THE CASE STUDY



NUMERICAL MODELLING

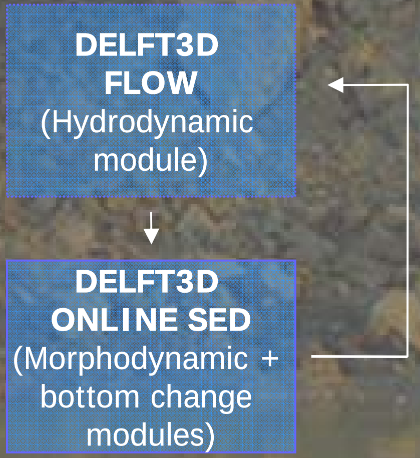


Hydrodynamic + Morphodynamic numerical modelling

DELFT3D Modelling system[1]

[1] WL | Delft Hydraulics,
Delft University of Technology

- **2D depth-averaged morphodynamic numerical model**
- **Fixed orthogonal curvilinear grid**
- **Secondary flow**
- **Influence of transverse slope on magnitude and direction of the bedload transport vector**



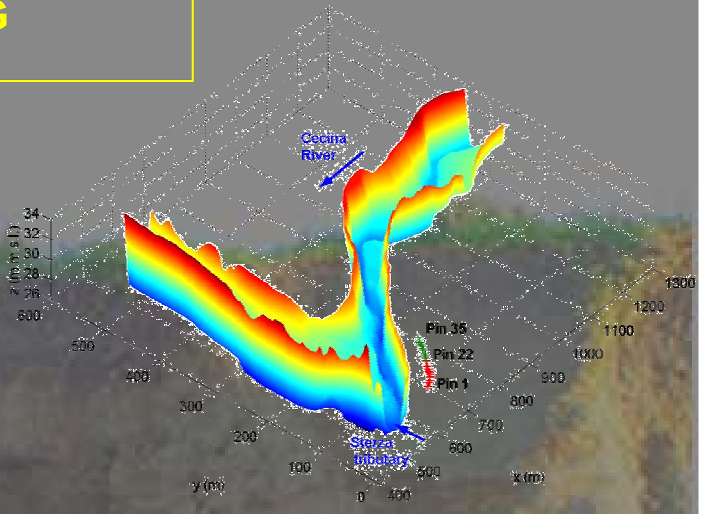
DELFT3D FLOW
(Hydrodynamic module)

DELFT3D ONLINE SED
(Morphodynamic + bottom change modules)

NUMERICAL MODELLING

THE MODEL SET UP

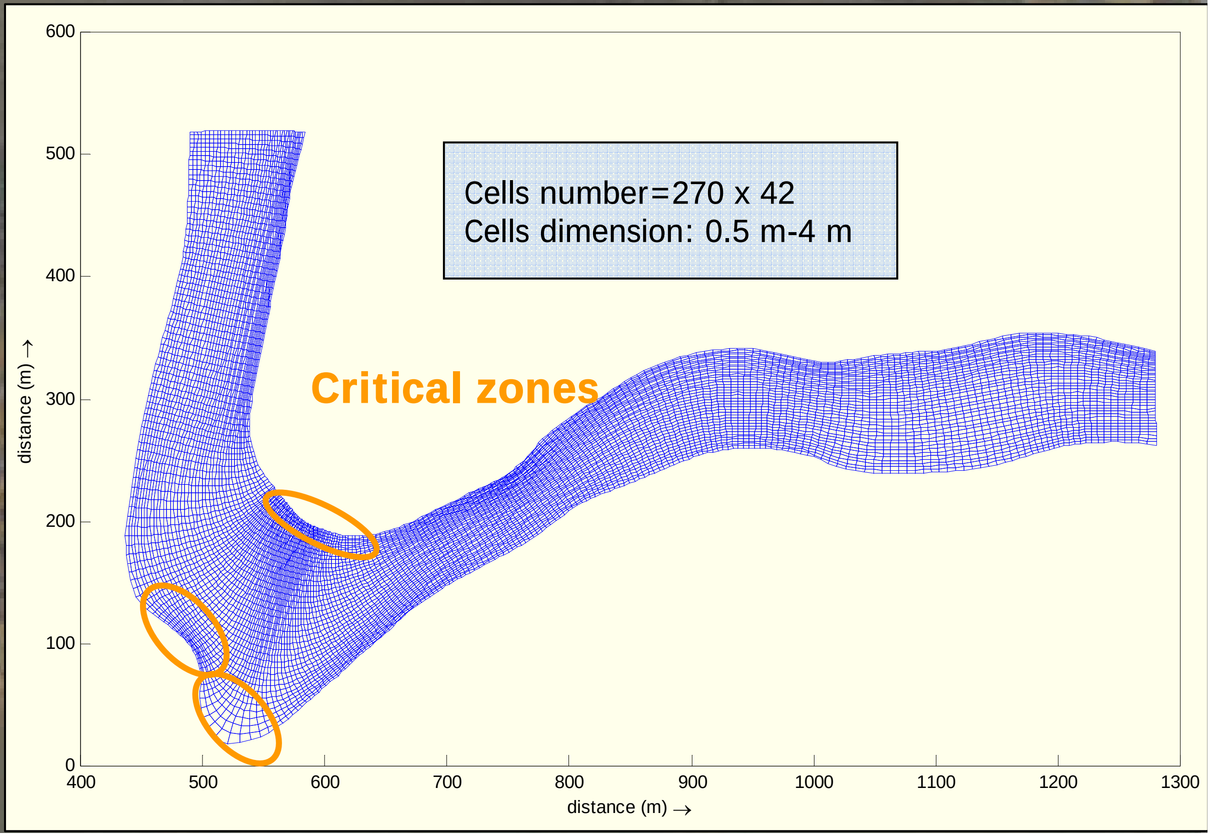
The Numerical Grid



Complex geometry:

- shape of the bend
- steep bank
- flow pattern strongly variable

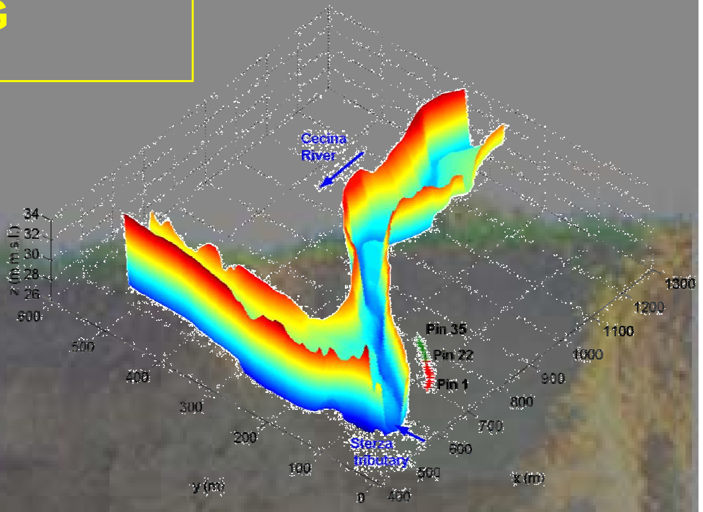
Compromises for resolution in the bank zone.



Cells number=270 x 42
Cells dimension: 0.5 m-4 m

NUMERICAL MODELLING

THE MODEL SET UP



Roughness

$$C_{2D} = 18\log_{10}\left(\frac{12H}{k_s}\right)$$

H = water depth
k_s= Nikuradse roughness length.

in case of no-vegetation $k_s = 3\,D_{50}$

in case of vegetation: averaged value of k_s has been computed, employing as vegetation' roughness the plants height

Sediment transport

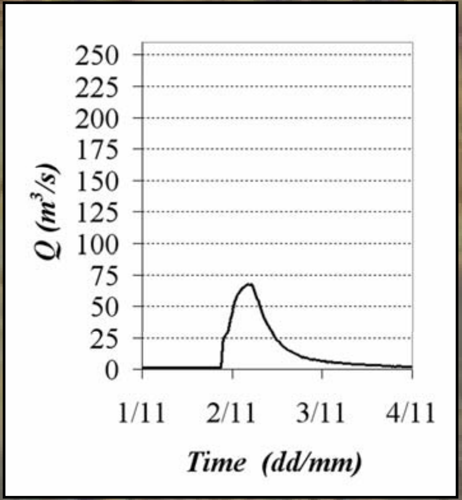
- Sediment transport formula: Meyer Peter Muller
- Variable sediment size

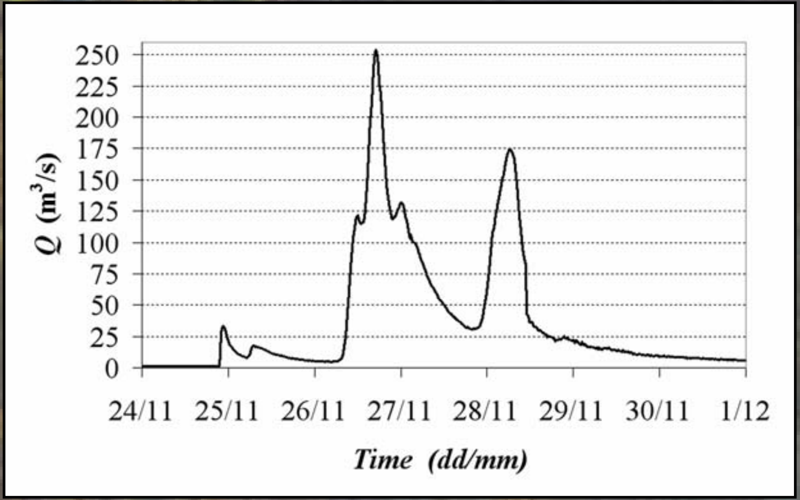
Boundary conditions

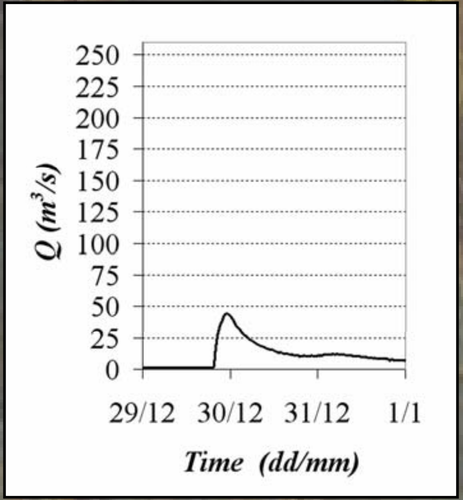
- Upstream water discharge, downstream water level
- Downstream unchanged bed level

NUMERICAL MODELLING

THE SIMULATED FLOW EVENTS







Return period:
< 1 year

Return period:
1.5 year

Return period:
< 1 year

Flow events very rapid and intensive

HYDRODYNAMIC MODELLING RESULTS

Lower Q

- main flow in the low-water bed and between lateral bars :

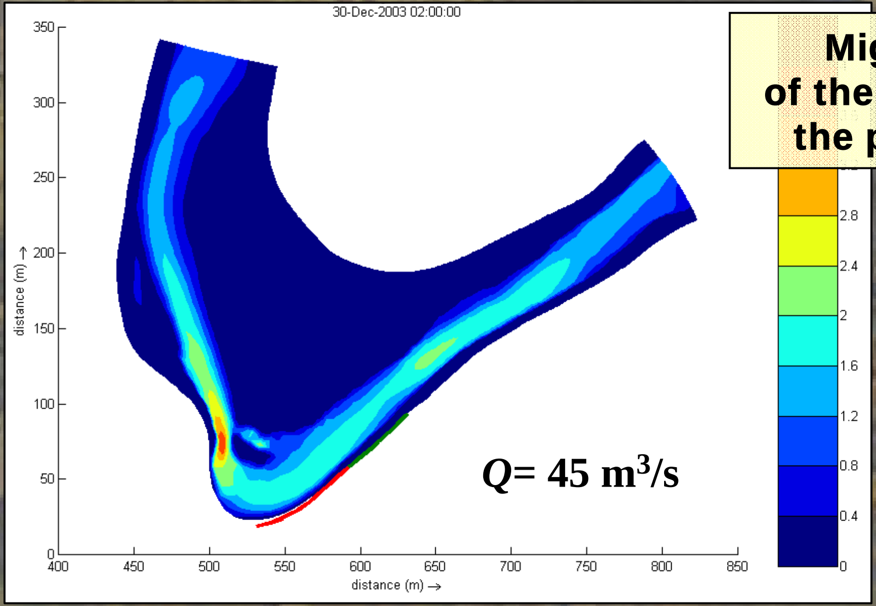
Higher sinuosity

Higher Q:

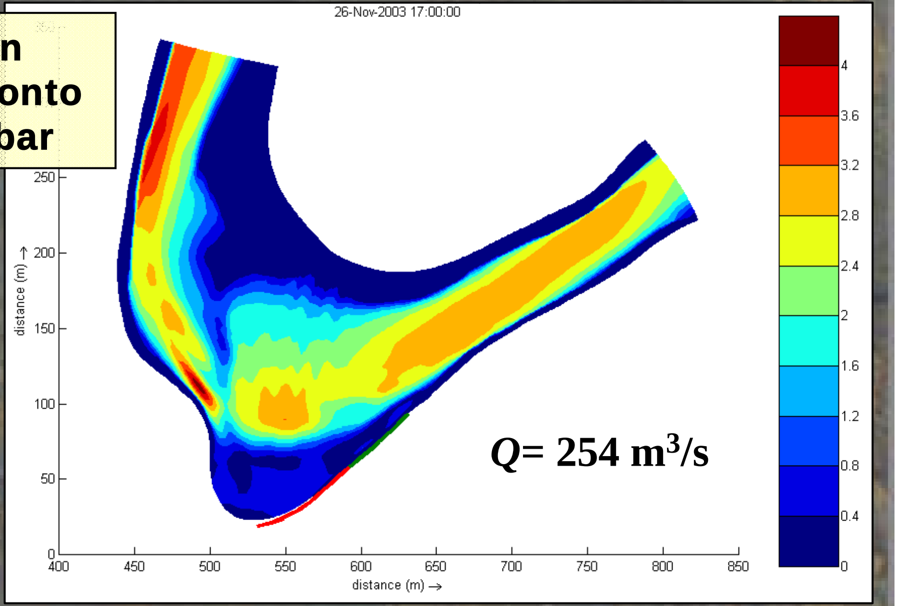
- flow submerges the bars and occupies the entire cross section:

Lower sinuosity

DEPTH AVERAGED VELOCITY

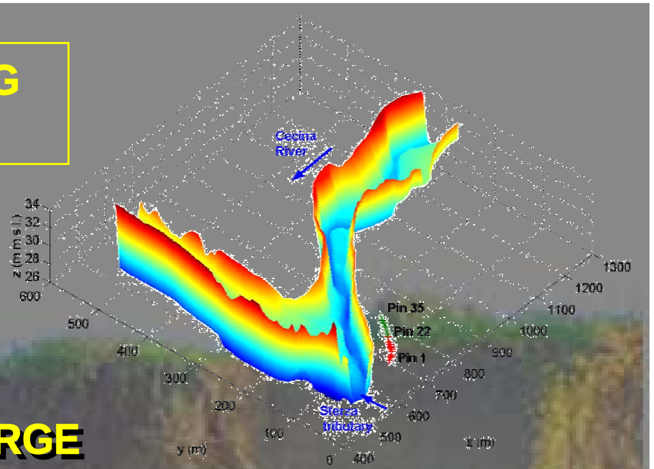


Migration of the flow onto the point bar



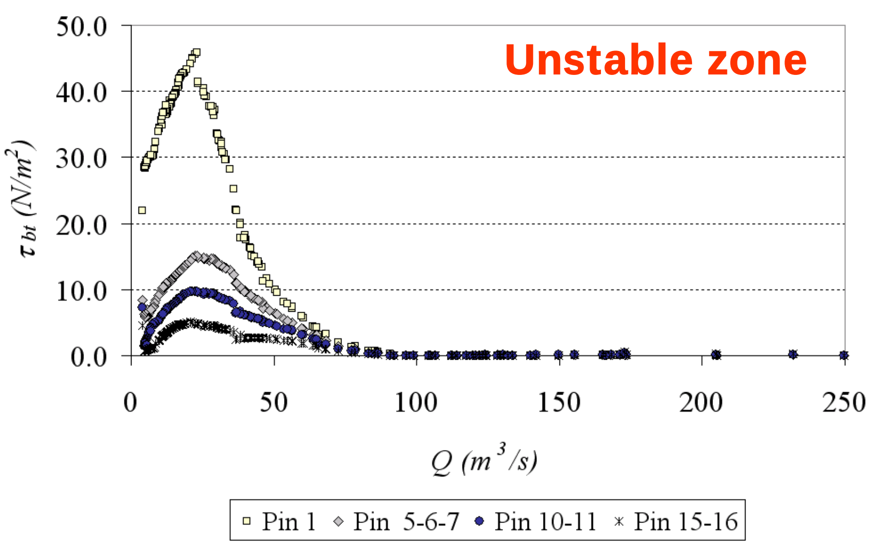
- higher U near the bank zone
- higher U far from the bank zone

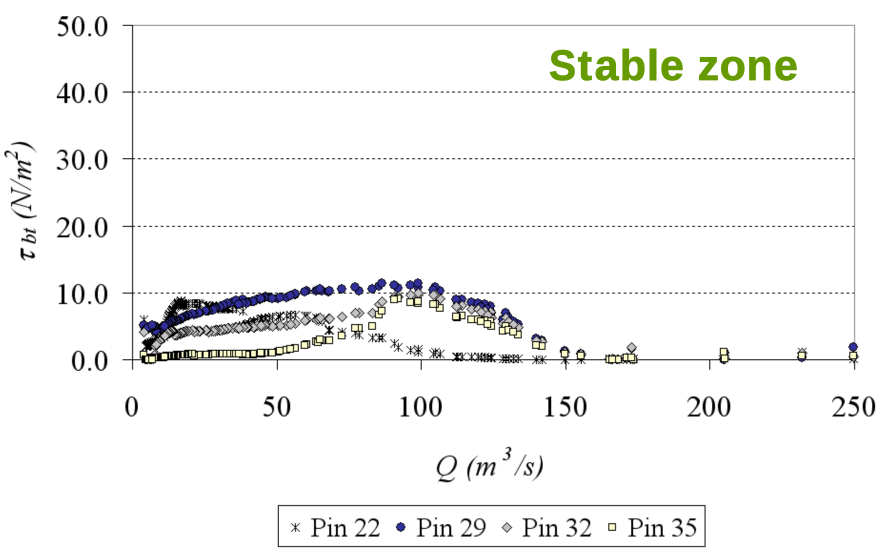
HYDRODYNAMIC MODELLING RESULTS



BANK TOE

SHEAR STRESS VERSUS DISCHARGE



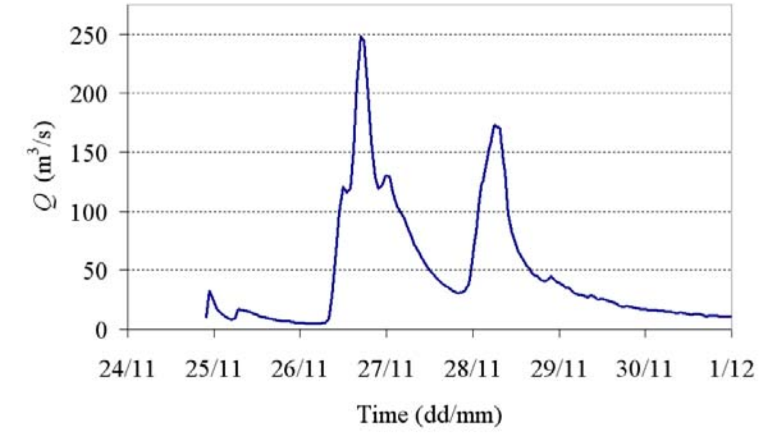


Downstream zone:
higher values and
higher variability

Upstream zone:
lower values and
lower variability

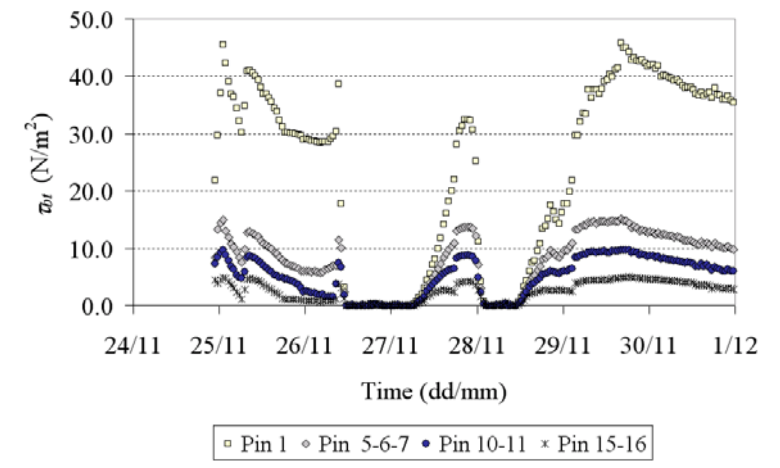
In both cases:
Lower Q generate
highest τ_{bt}

HYDRODYNAMIC MODELLING RESULTS



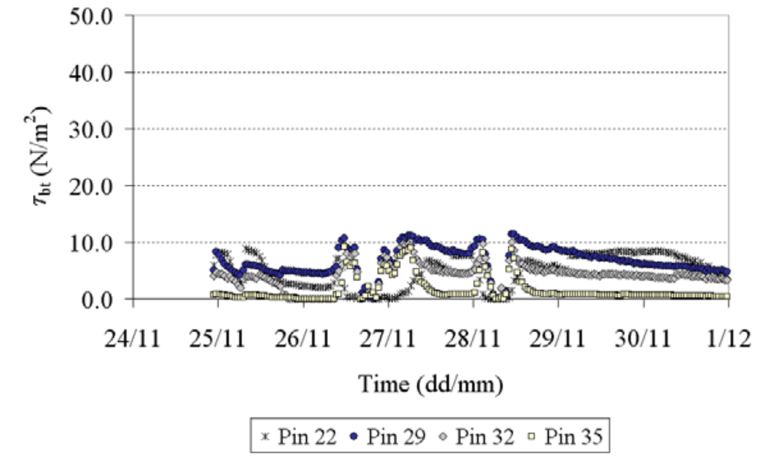
UNSTABLE ZONE

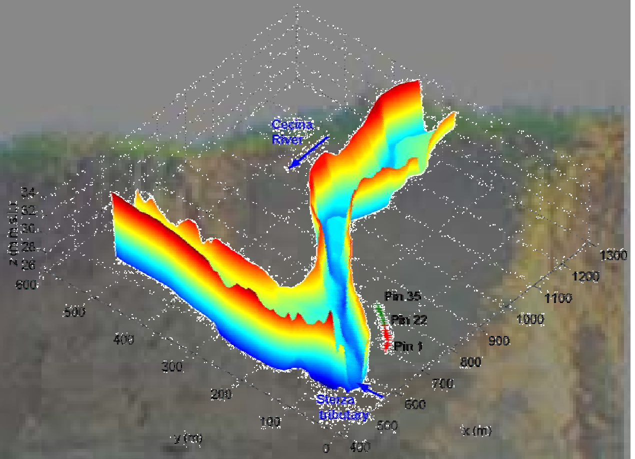
Higher and articulate τ_{bt}



STABLE ZONE

Lower and more uniform τ_{bt}

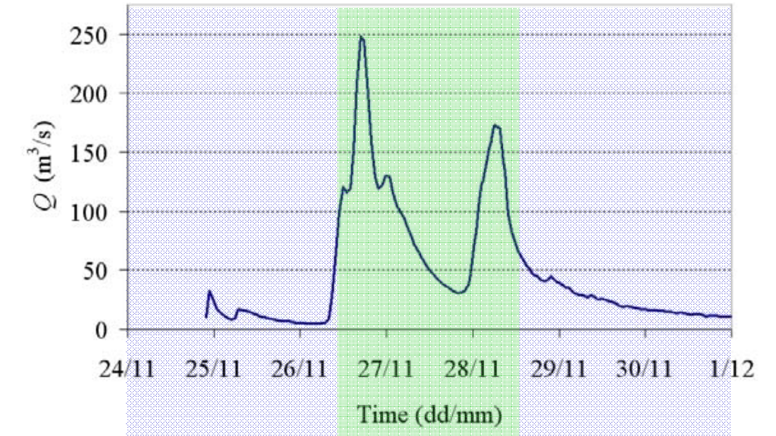


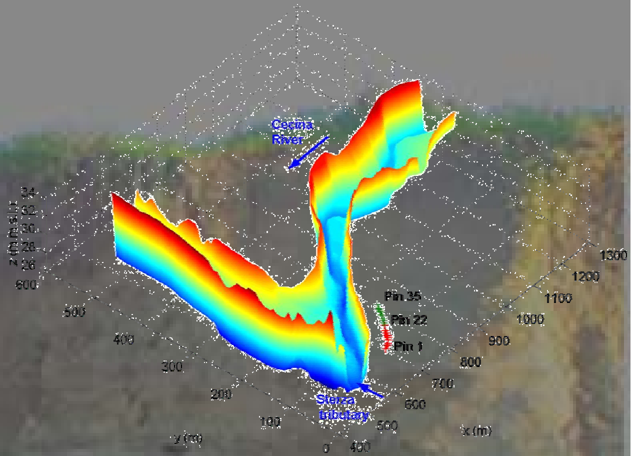


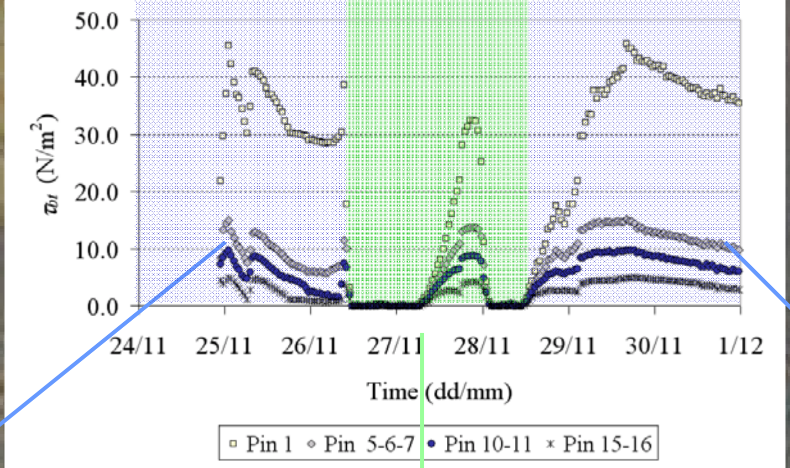
Highest τ_{bt}
at the beginning
and at the end
of the flow event

POSSIBLE INTERPRETATION

HYDRODYNAMIC MODELLING RESULTS





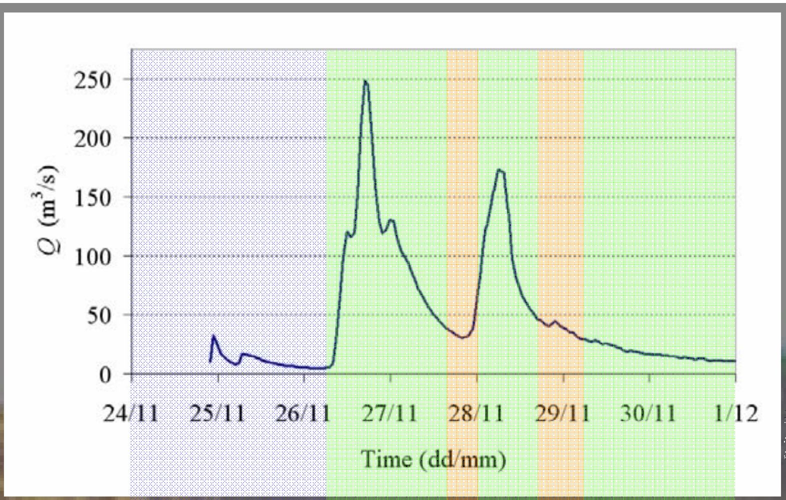


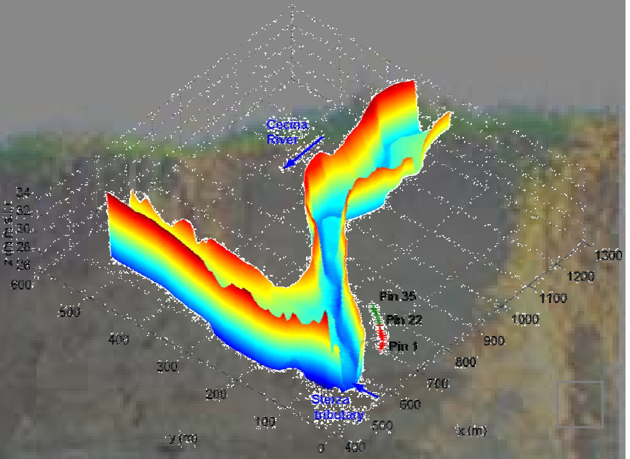
Fluvial Erosion: variation of bank geometry

No fluvial erosion but higher risk of mass instability

Fluvial Erosion: removal of failed material

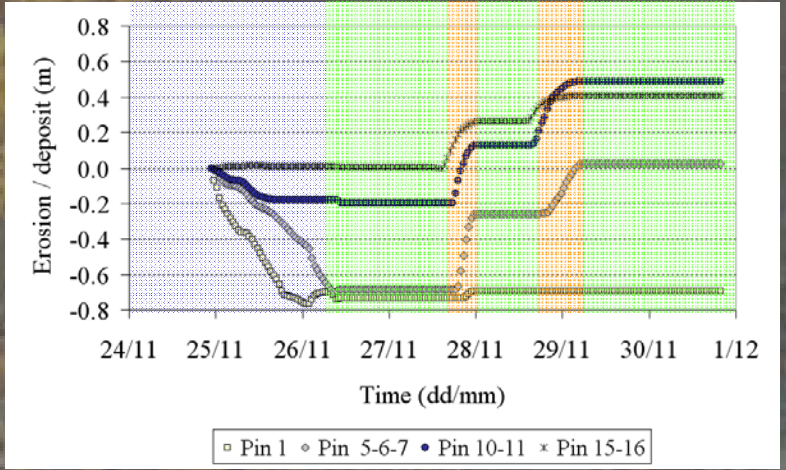
MORPHODYNAMIC MODELLING RESULTS





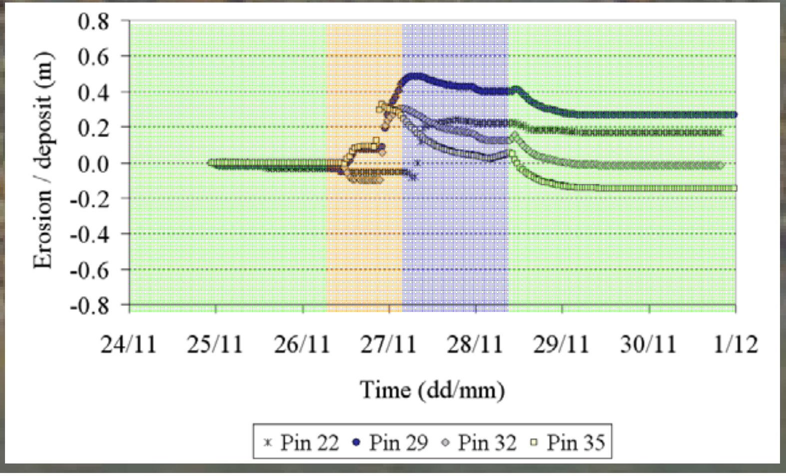
UNSTABLE ZONE

Articulate deposition and erosion processes

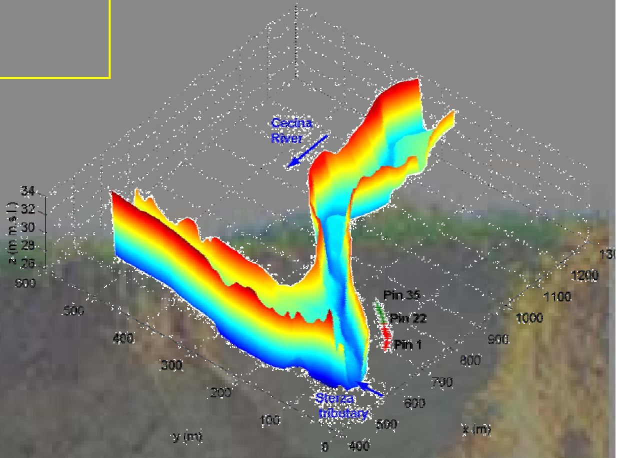


STABLE ZONE

Less articulate processes



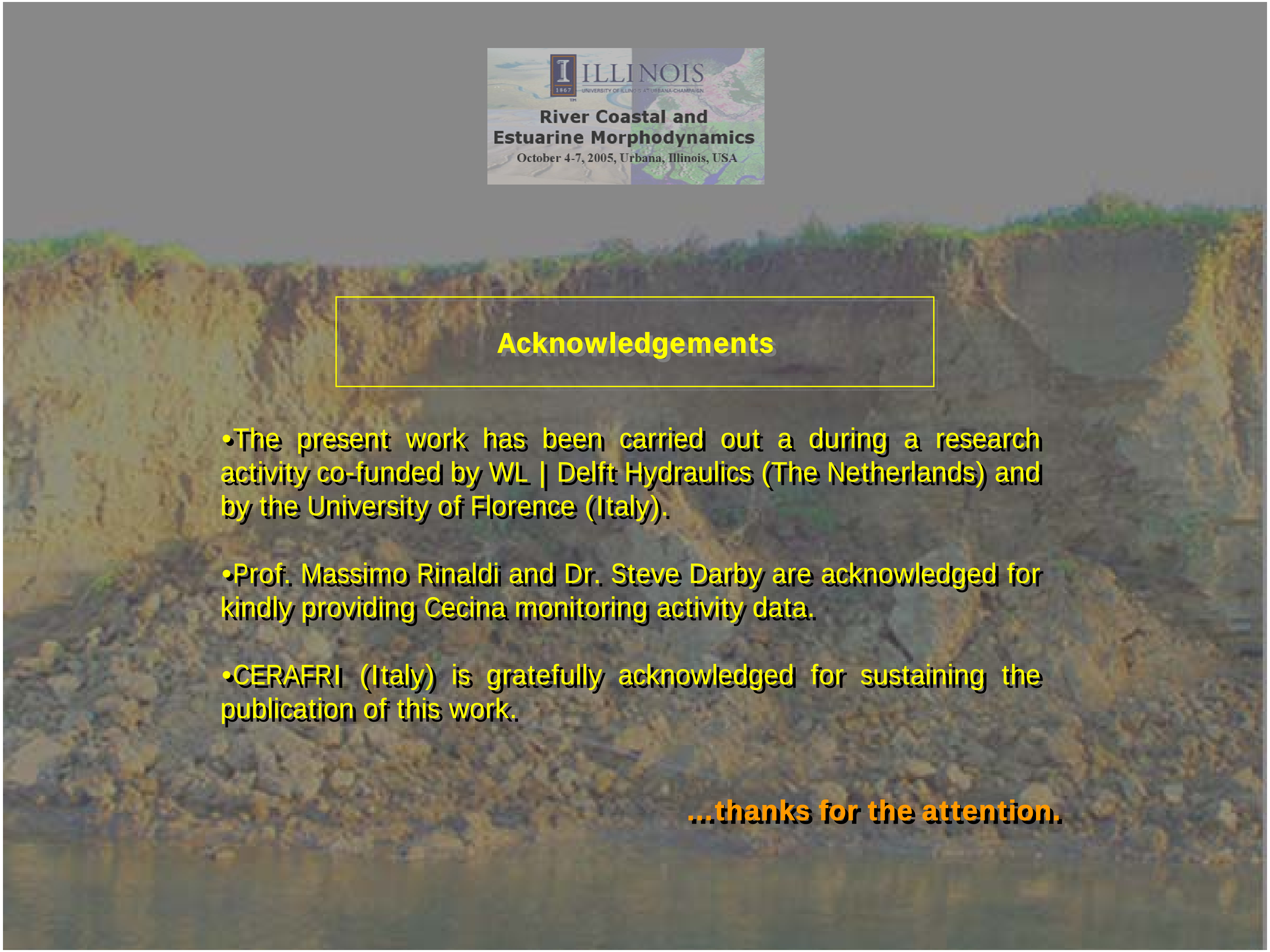
CONCLUSIONS



By analyzing information collected from monitoring activities and from 2D numerical simulations it has been shown that:
in case of alternate lateral bars channel, **higher shear stresses at the bank toe** are experienced mainly **at the beginning and at the end of flow events**, when discharges are low and the flow is manly concentrated in the low-water bed.

This could explain interactions with mass failure processes and timing of bank collapse:

- **at the beginning** of the flow event **fluvial erosion processes are likely to occur**, bringing the **bank closer** to a condition of **limiting mass stability**; .
- in the **peak part of the flow event**, **fluvial erosion stops** whereas **risk of mass instability rises** due to groundwater effects, reaching the most critical point during the drawdown of the hydrograph;
- **finally fluvial erosion** at the bank toe **starts again** definitely increasing risk of collapse of the bank and explaining the **removal of part of the bank material failed** during the previous phases.



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- Prof. Massimo Rinaldi and Dr. Steve Darby are acknowledged for kindly providing Cecina monitoring activity data.

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...thanks for the attention.