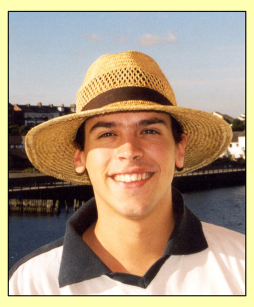
Flow and sediment properties of the river Rhine:

A reconstruction of historical changes due to human impact

Roy Frings, Bas Berbee,
Gilles Erkens & Maarten Kleinhans

Department of Physical Geography, Universiteit Utrecht, P.O. box 80115, 3508 TC, Utrecht, the Netherlands. R.Frings@geo.uu.nl



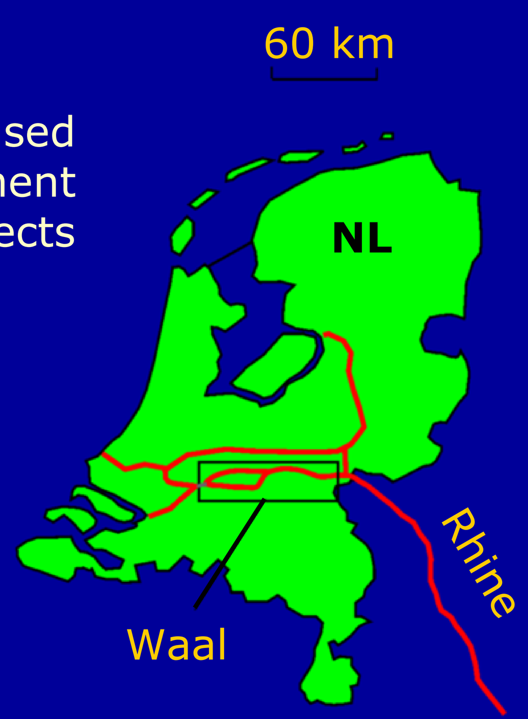
Introduction

Human impact on lowland rivers has strongly increased during the past centuries. As a result, the flow and sediment properties of the rivers changed, often with adverse effects on channel stability, flood risk and biodiversity.

Objectives

(a) Reconstruction of the change in bed shear stress (τ)
(b) Reconstruction of the change in bed grain size (D)
(c) Identification of the main causes of these changes

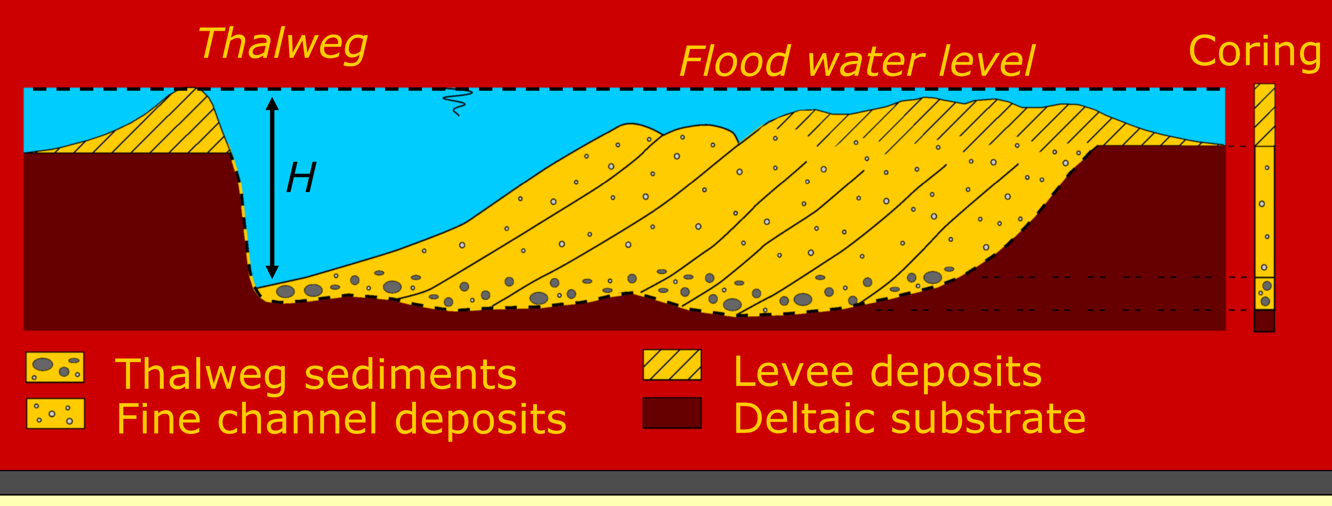
Time period of interest: ~1000 y
River reach: Waal (a Rhine branch in the Netherlands)



The principle: analysis of thalweg sediment

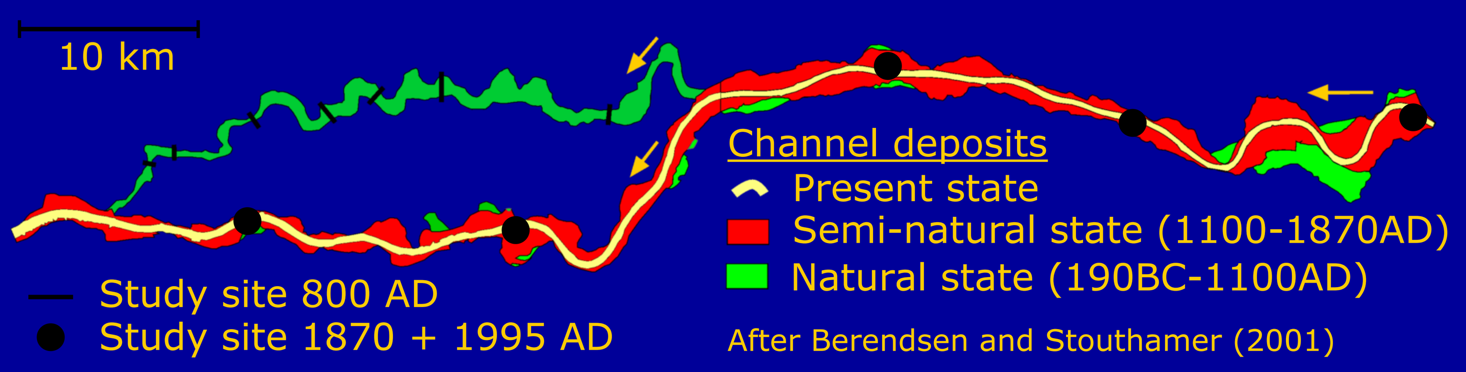
The thalweg is the deepest part of the river. At this location, where the bed shear stress is typically high, fine sediments are washed away from the bed, leaving behind a coarse layer of thalweg sediments. Thalweg sediments often lie discordantly upon the underlying deposits, their thickness corresponding to the height of the dunes that reworked the river bed. In freely meandering rivers, thalweg sediments underlie the entire channel belt.

Because thalweg sediments can easily be recognised in corings, they are ideal to study historical grain size changes.



Methods

D and τ were computed for three time periods: ± 800 AD, ± 1870 AD and ± 1995 AD. These periods represent the natural, semi-natural and present state of the Waal. All computations were done for several locations along the river.



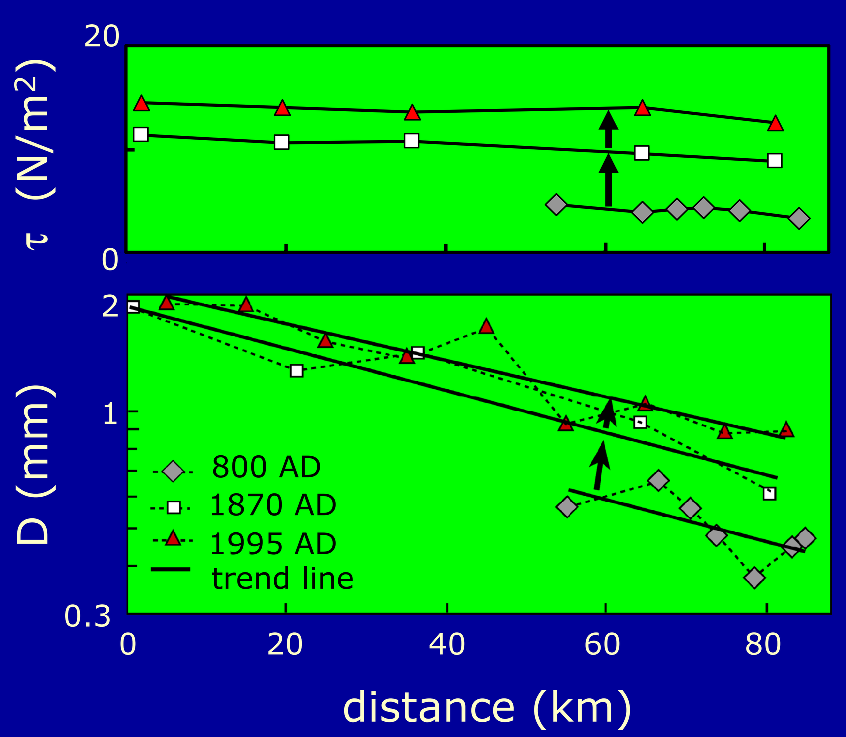
τ was calculated as: $\tau = \rho g H I$, with ρ and g constants, H the flood water depth and I the slope.

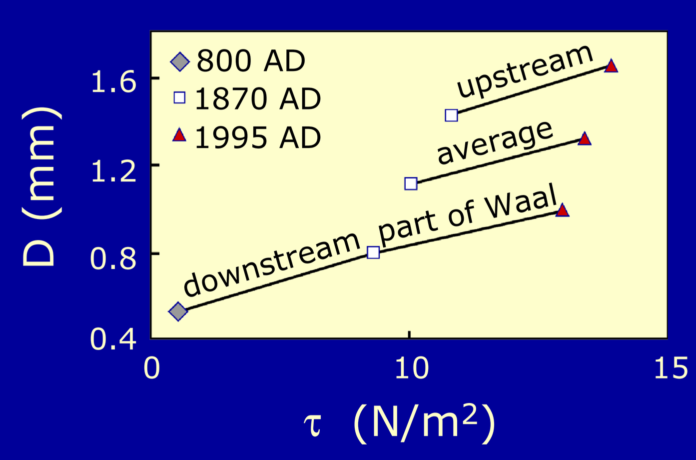
- For 1870 and 1995 AD, H was derived from depth measurements in the thalweg of the river.
- For 800 AD, H was derived from geological corings. H was assumed equal to the elevation difference between the top of the levee deposits and the top of the thalweg sediments (see upper red box).

D was determined from sediment samples taken in the thalweg of the present river (1995 AD) or from samples of the thalweg sediments preserved in the geological record (1870 and 800 AD). To this end, about 100 cores were taken.

Results

Our analysis shows that τ strongly increased from 800-1995 AD. Simultaneously, the gravel content of the sandy river bed increased, causing a coarsening of the bed. The changes occurred rather homogeneously over the river length.





Discussion and conclusions

Analysis of possible natural and human factors shows that:

- the τ-increase before 1870 AD is mainly due to the embankment of the river.
- the τ-increase after 1870 AD is due to (1) narrowing of the river by groynes, (2) dredging activities.

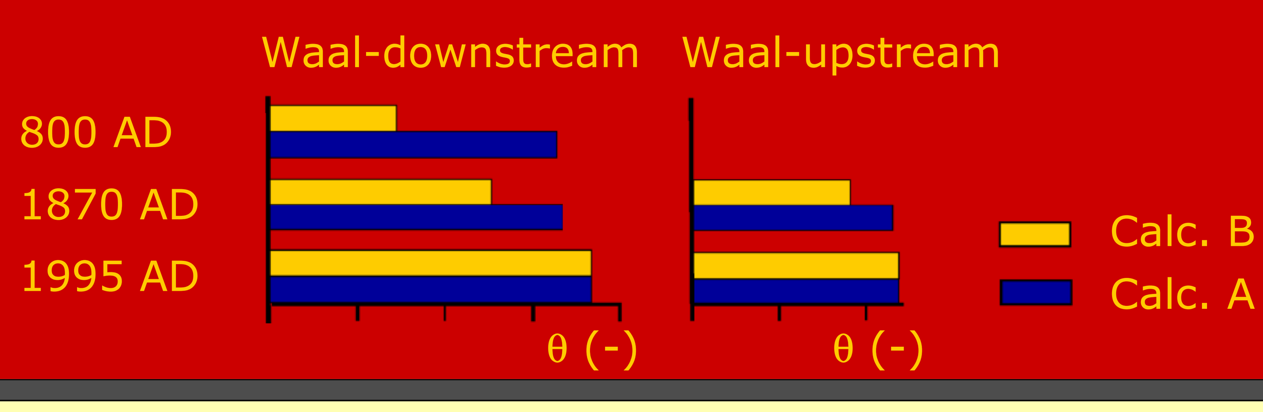
All these activities caused an artificial increase in H, and therefore an increase in τ.

The fact that the increase in D is proportional to the increase in τ *and* occurred simulteneously, suggests a causal relation:

- the increase in τ probably caused winnowing of fine grains from the bed, thus leading to an increase in bed grain size.

Application: river restoration studies

Modern river management often attempts to restore canalised rivers to a more natural state. A key problem is to estimate the Shields parameter θ (as measure of sediment dynamics) for the historical (natural) situation. Because $\theta = f(\tau, D)$, information is needed on the historical bed grain size. If this is unavailable, the historical grain size is often assumed to be equal to the present one. To illustrate that this assumption is erroneous, we calculated the historical Shields value (θ) in the Waal in two ways: (A) from the correct (historical) grain size and (B) from the present grain size. This shows that θ remained constant over time, although the calculation using the assumption described above suggests that it strongly increased.



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More information: A journal article based on this poster has been submitted to Earth Surface Processes and Landforms.

The research presented on this poster was part of the PhD research of R.M. Frings. Ask for a free copy of the thesis!