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The influence of subsurface heterogeneity on scour hole development in the Rhine-Meuse delta, the Netherlands

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Introduction

River dikes are the primary form of flood protection in the Rhine-Meuse delta, the Netherlands. The stability of dikes may be compromised where deep scour holes develop in the rivers nearby (Fig. 1). They impose increased probability of channel bank instability (e.g. flow slides along steepened sides of the bed) and hence of dike failure. Scour hole growth is influenced by local channel morphology, hydrodynamic conditions and subsurface architecture. Subsurface architecture is an external factor and is therefore of special interest in the study of scour holes. Scour holes reveal where the subsurface locally was erodible. Erodibility is determined by the geological heterogeneity that the river truncated (e.g. crossing an older channel belt sand body). In addition to hydrodynamic conditions, substrate conditions may just as well co-control the rate of deepening, permanency and fixation in depth. Linking occurrence and evolution of scour holes to 3D subsurface architecture contributes to better insight into the geologic boundary conditions for their formation and geometry.

Aims

- Present an inventory of scour holes in the entire Rhine-Meuse delta.
- Link the occurrence of scour holes and their characteristics (e.g. geometry) to the subsurface architecture of the study area.

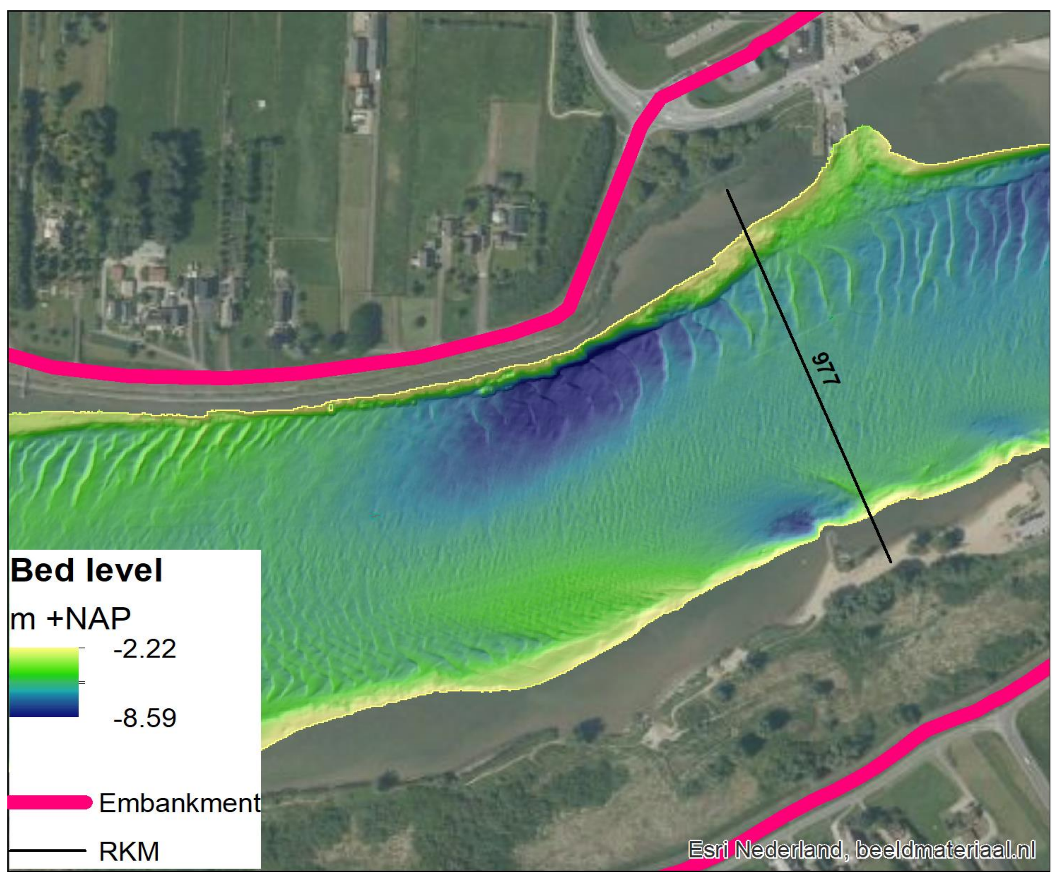

Figure 1. Example of a scour hole (dark blue) close to the northern embankment (pink) in the river Lek near Bergambacht downstream of river kilometer (rkm) 977.

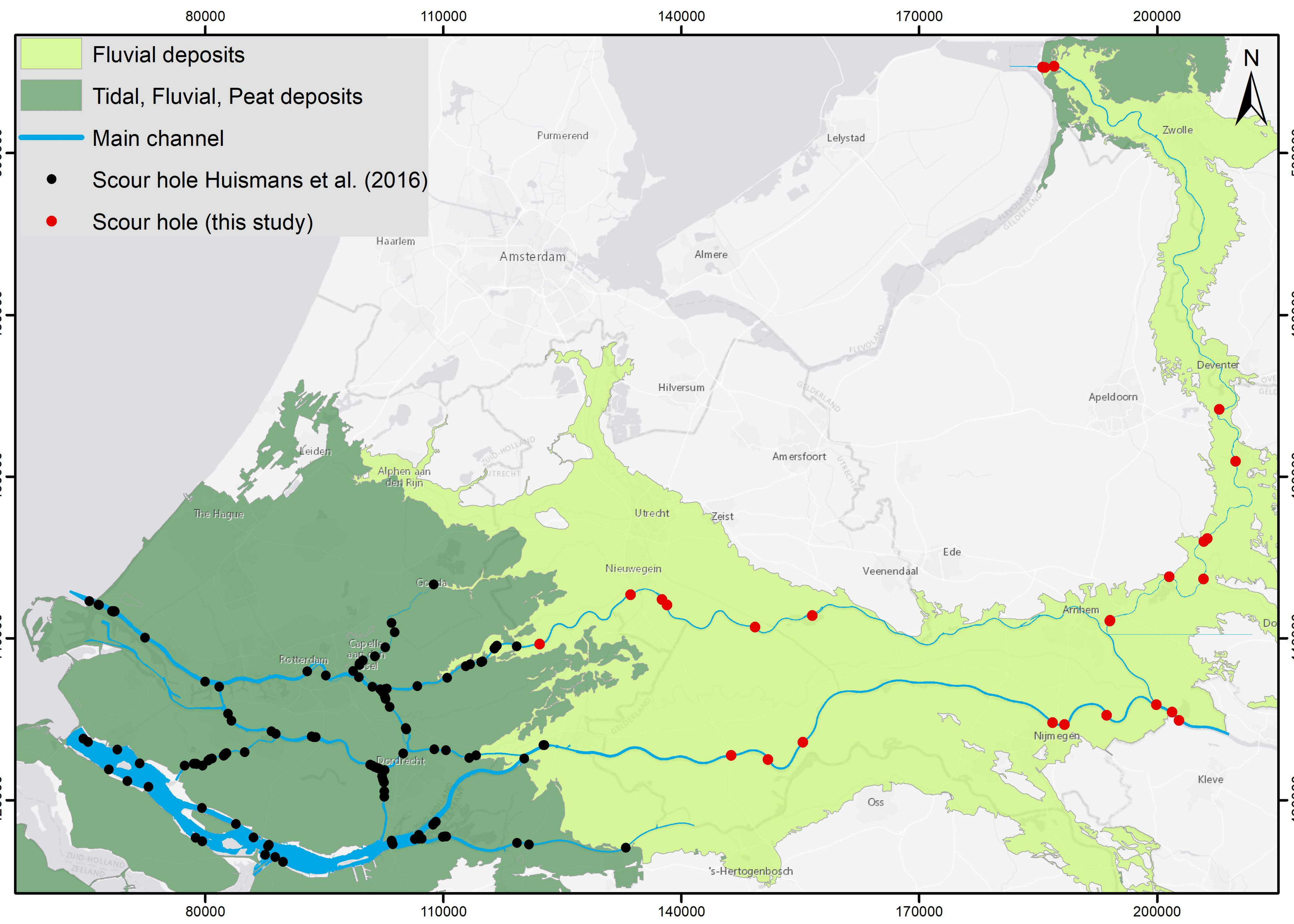

Figure 2. Locations of scour holes identified in the active channels in the study area in relation to the large scale buildup of the subsurface. The central and upper parts of the delta are dominated by fluvial deposits and the lower part is generally made up by an alternation of tidal, fluvial and peat deposits. Black dots (n=120) are lower (tidal) delta scour holes (Huismans et al., 2016). Red dots (n=26) are central and upper delta scour holes (this study).

Methods

1. Identification

We identify scour holes using a time series of bathymetry data (Fig. 1 and Fig. 2):

- Period: 1990 – 2018.
- Time step: 1 year.
- Resolution: 1 m, 5 m.
- Study area: Rhine-Meuse delta, including IJssel (Fig. 2).

2. Database

We create a combined database of new identified scour holes and Koopmans (2017) containing:

1. Location.
2. Geometric attributes (slope, max. depth, area)
3. Additional conditions (e.g. engineering structures, confluence/bifurcation.)

3. Subsurface architecture

Geological data is compiled to characterize regional subsurface buildup and architectural elements (Fig. 3) around scour holes:

- High-resolution channel belt mapping (UU: Cohen et al., 2012)
- Subsurface geological data and models (DINO-TNO)

Preliminary results

Analysis of bathymetric data for the period 2014-2018 has resulted in 26 locations in the central and upper delta where potential new scour holes are identified (Fig. 2). Most of these objects have been relatively stable in their geometry and location during the last four years.

Future research

Historic development of newly identified scours will be studied using full time series of bathymetry data (1990-2018). The rate of change will be documented and linked to the buildup of the subsurface. The results from this part of the study will be compared to the large scale subsurface buildup of the study area.

To study development and identify potential weak spots regarding (new) scour holes, it is important to know the subsurface directly at the base of modern river channels. Because this is a challenging area, useful geological data here is relatively scarce. By combining different datasets we aim to improve subsurface mappings for this area and study the lateral distribution of the lithostratigraphic units in the channel-bed. Next, we aim to make more detailed characterizations based on depositional environment by subdividing the lithostratigraphic units into architectural elements (Fig. 3). By integrating knowledge of fluvial and tidal systems, with other datasets, the goal is to incorporate this in a geological map covering the study area. This is a first step towards the identification of the relevant architectural elements and lithostratigraphic sequences regarding channel-scour.

Architectural elements

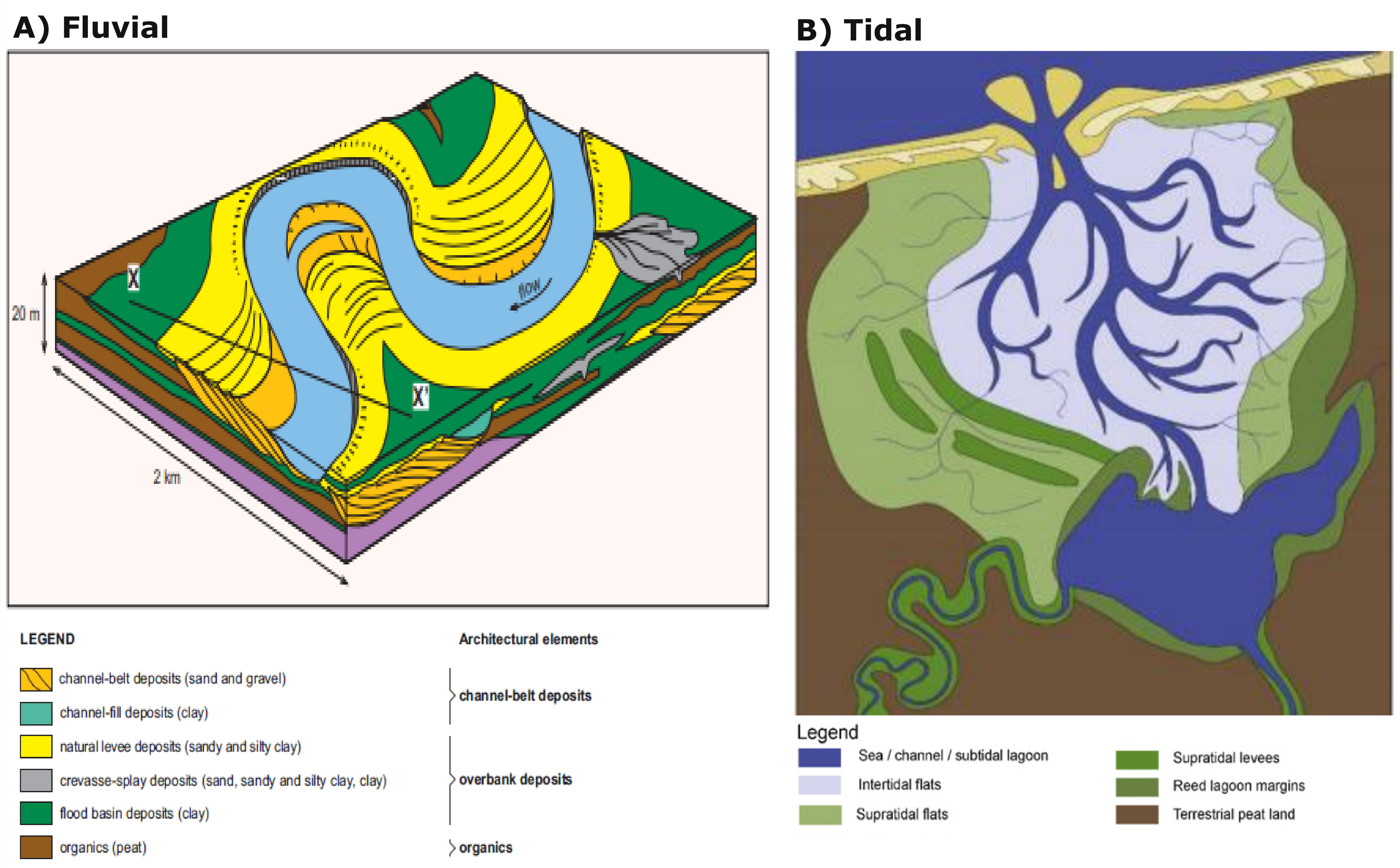

Figure 3. A) Conceptual 3D block diagram of meandering river and associated architectural elements (adapted from Gouw, 2007). B) Conceptual outline of a tidal system with associated elements in the Netherlands (adapted from Pierik et al., 2016).

References

Cohen, K.M., Stouthamer, E., Pierik, H.J., Geurts, A.H., (2012). Digitaal Basisbestand Paleogeografie van de Rijn-Maas Delta. Dept. Fysische Geografie. Universiteit Utrecht. Digitale dataset. http://persistentidentifier.nl/ ?identifier=urn:nbn:nl:ui:13-nqjn-zl.
Gouw, M.J.P., (2007). Alluvial architecture of fluvio-deltaic successions: a review with special reference to Holocene settings. *Netherlands Journal of Geosciences – Geologie en Mijnbouw, 86 – 3, 211-227.*
Huismans, Y., Velzen, G. Van, Mahoney, T. S. D. O., Hoffmans, G., & Wiersma, A. P. (2016). Scour hole development in river beds with mixed sand-clay-peat stratigraphy. In: ICSE 2016 (8th Int. Conf. on Scour and Erosion), 12-15 September 2016, Oxford, UK. (2016).
Koopmans, H. (2017). Scour holes in tidal rivers with heterogenous subsoil under anthropogenic influence. uuid:64dd5428-7b82-46c8-91b8-48f442283b40.
Pierik, H.J., Cohen, K.M., Stouthamer, E., (2016). A new GIS approach for reconstructing and mapping dynamic late Holocene coastal plain palaeogeography. *Geomorphology 270 (2016), 55-70.* http://dx.doi.org/10.1016/j.geomorph.2016.05.037.