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Scour hole location and characteristics linked to subsurface architecture in the Rhine-Meuse delta, the Netherlands

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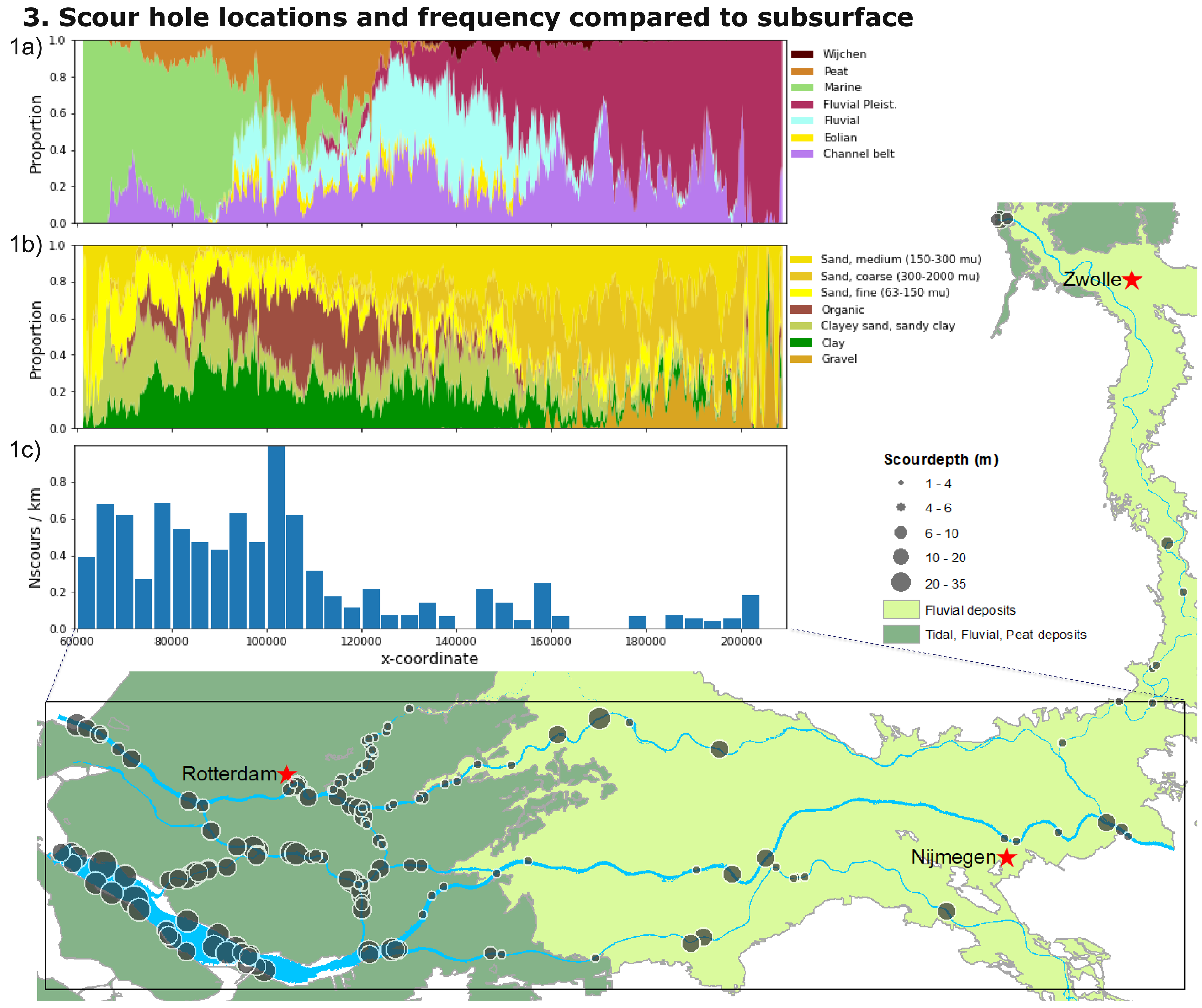
1. Introduction

Channel scour is a form of river bed erosion that is influenced by, besides channel morphology and hydrodynamics, subsurface architecture. Subsurface architecture is controlled by the processes that formed the deposits in the past. This study links the occurrence, characteristics and evolution of scour holes to these processes to achieve better understanding of the geologic boundary conditions for scour hole formation.

2. Methods

We used a time series of bathymetry data for the major river branches of the Rhine-Meuse delta to identify scour holes and derive subsequent attributes. We compared this to trends in subsurface buildup derived from the GeoTop subsurface model (Stafleu et al., 2011), geological mappings (Cohen et al., 2012; 2017) and detailed cross-sections (e.g. Hijma, 2009; Stouthamer et al., 2011b).

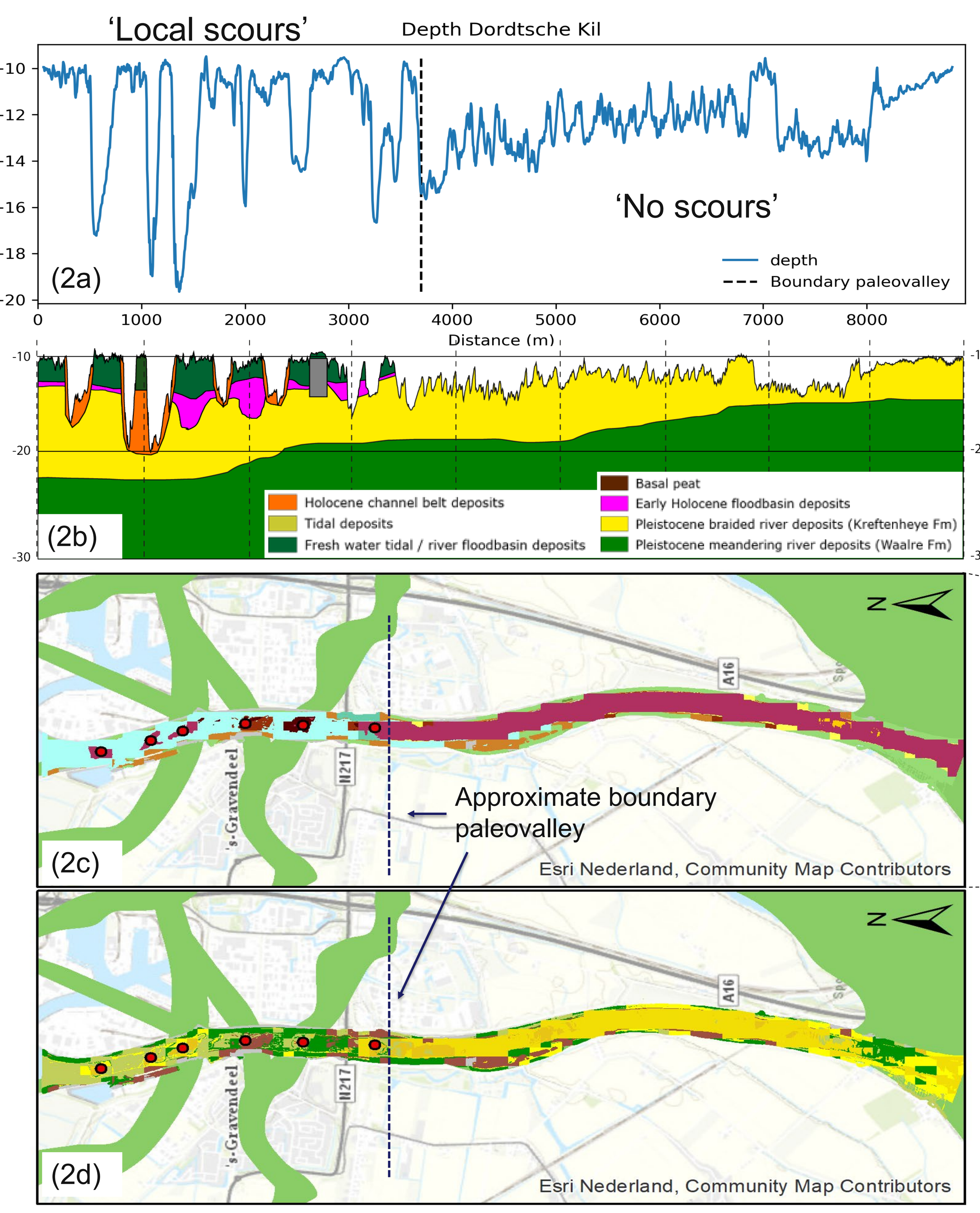
3. Scour hole locations and frequency compared to subsurface



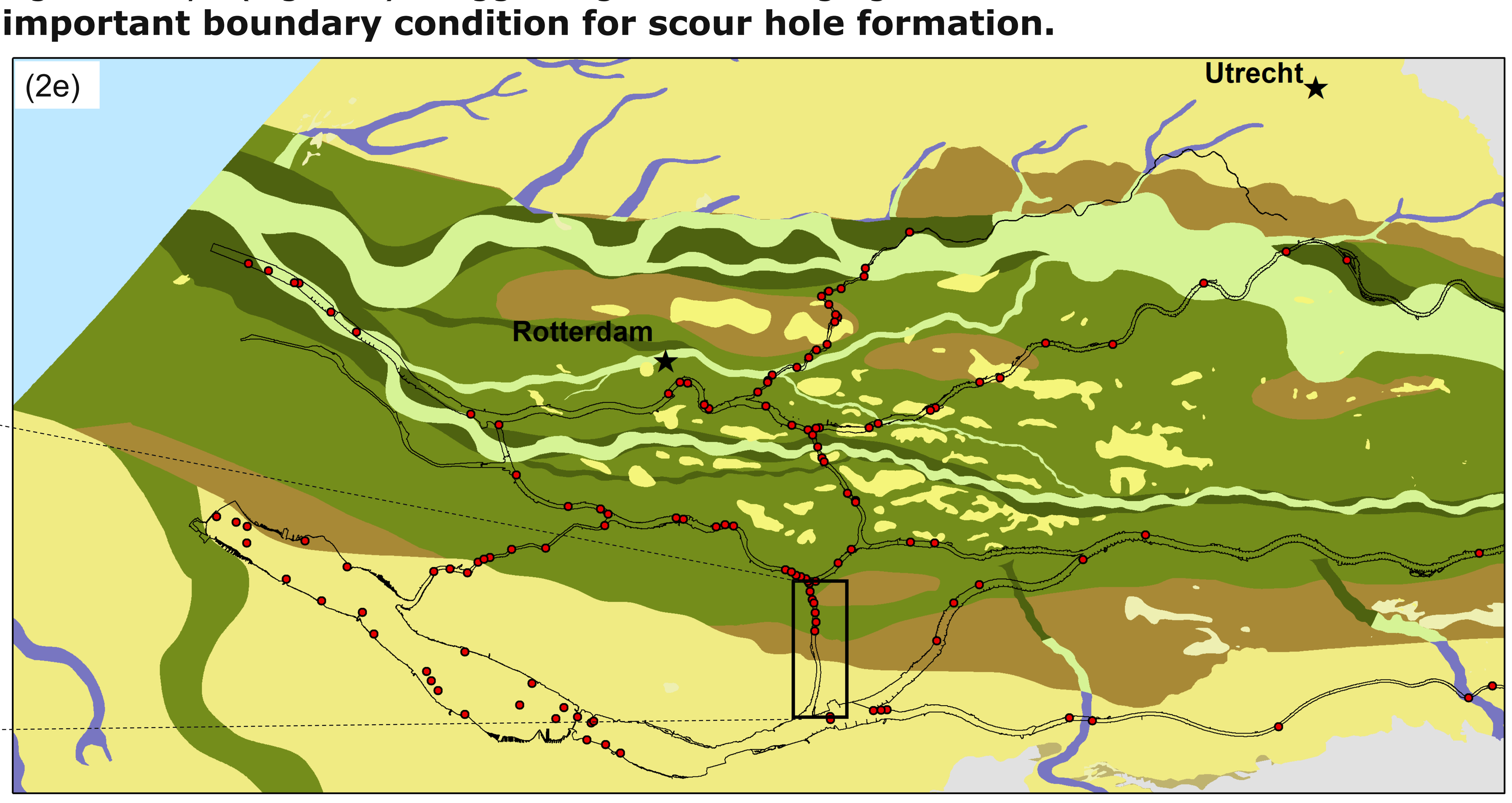
A total of 166 scour holes are found of which approximately **75% are located in the downstream area.** This difference coincides well with regional trends in the subsurface buildup and related depositional history. The **downstream part is more heterogeneous** and generally consists of alternating tidal, fluvial and peat deposits (dark green) whereas upstream is dominated by fluvial deposits (light green). The downstream part of the study area became delta plain in direct response to Holocene sea-level rise; provision of accommodation space was largest and the fluvio-deltaic wedge is thickest here. Repeated avulsions caused and continuous supply of fresh water created isolated channel belt sand bodies that are encased in organic rich, cohesive deposits (Stouthamer et al., 2011a). This trend can be observed in figures 1a and 1b where a gradual trend can be observed from being dominated by Pleistocene and older fluvial deposits, mainly consisting of coarse sands and gravels, towards a mixture of Holocene Fluvial, Marine and Peat deposits generally consisting of non-erodible finer materials such as clays and organics with localized occurrences of erodible sand bodies. Towards downstream, the number of scour holes per kilometer of river increases significantly (Fig. 1c) suggesting the changing **subsurface architecture is an important boundary condition for scour hole formation.**

4. Example of the influence of geology on the depth of the Dordtsche Kil and relation to genesis

Figure 2 shows that the depth profile of the Dordtsche Kil (Fig. 2a) is **strongly influenced by subsurface architecture** and associated depositional history. A clear distinction can be observed between the northern part, characterized by local scour holes, and southern part which is much more homogeneous in depth. The river bed in the northern part consists of a Holocene clay/peat delta substrate whereas the southern part consists of Pleistocene deposits and more homogeneous sands (Figs. 2c and d). This clear distinction is located on the border of the Pleistocene valley of the braided Rhine and Meuse systems (Fig. 2e). Changing conditions led to a shift from a braided river pattern towards a meandering system and deposition of early Holocene clay deposits (Wijchen member) which was restricted to the north part of the Dordtsche Kil. Later dissection by former courses resulted in breaches of this clay layer and deposition thick sand bodies with flanking overbank deposits (Fig. 2b). Therefore the river bed in the northern part of the Dordtsche Kil shows **strong variability in erodibility and subsequently localized deep scour holes**.



(a) Longitudinal depth profile of the Dordtsche Kil, (b) cross-section of the subsurface composition (Wiersma, 2015), (c) lithostratgraphic composition (legend: see figure 1a) with dissecting older channel belts (green) and (d) Lithologic composition (legend: see figure 1b).



Location of the Rhine-Meuse paleovalley (light and dark green), riverdunes (yellow) and terrace remnants (brown) bounded by coversand areas (yellow) to the north and south.

5. Conclusion

Our results indicate that a heterogeneous subsurface composition is an important boundary condition for scour hole formation and that locations can be explained well from a genetic perspective. Subsurface architecture plays an important role in the depth of modern rivers and scour holes generally occur where there is locally strong variability in erodibility of the subsurface. Using this knowledge can also help to identify potential risk areas for new scour holes.

References

Cohen, K.M., Schokker, J., Hijma, M.P., Koster, K., Pierik, H.J., Vos, P.C., Erkens, G., Stafleu, J. (2017). Landschapskaarten en hoogtemodellen naar periode en diepte voor archeologisch gebruik in Holoceen-afgedekte delen van Nederland. Deltares, i.s.m. TNO &UU Report 1210450-000-BGS-0013, doi: 0.17026/dans-zck-y7ww.
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, doi: 10.17026/dans-x7g-sjtw.
Hijma, M.P. (2009).From river valley to estuary. PhD thesis, Utrecht University.
Stafleu, J., Maljers, D., Gunnink, J.L., Menkovic, A., Busschers,F.S. (2011). 3D modelling of the shallow subsurface of Zeeland, the Netherlands.Netherlands Journal of Geosciences - Geologie en Mijnbouw, 90-4:293–310.
Stouthamer, E., Cohen, K.M., and Gouw, M.J.P. (2011a). Avulsion and its Implicationsfor Fluvial-Deltaic Architecture: Insights from the Holocene Rhine–MeuseDelta.SEPM (Society for Sedimentary Geology), pages 215–231. ISBN:978-1-56576-305-0.
Stouthamer, E., Pierik, H.J., Cohen, K.M. (2011b). Erodibiliteit en kans op het ontstaan van zettingsvloeiing als maat voor stabiliteit van oevers,onderwatertaluds en rivierbodem van de Lek. page (49p.). Utrecht: Dept.Fysische Geografie / Universiteit Utrecht.
Wiersma, A. P. (2015). De ondergrond van de Boven Merwede, Dordtsche Kil, Nieuwe Maas en Nieuwe Waterweg. 1208925-000-ZWS-0024. Advies Beheer Rivierbodem RMM. Deltares.