Influence of silt in sand-silt mixtures on dynamic near-equilibrium bedform geometry

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ABSTRACT: Subaqueous geometric bedform properties such as height, length and leeside angle are crucial in determining hydraulic form roughness and interpreting sedimentary records. Traditionally, bedform existence and geometry are predicted with phase diagrams and empirical equations, which are mostly based on uniform, cohesionless sediments. However, mixtures of sand, silt and clay are common in deltas, estuaries, and lowland rivers where bedforms are ubiquitous. Here, we test the influence of silt in sand-silt mixtures on bedform geometry, based on laboratory experiments conducted in a recirculating flume. Sand and silt content were systematically varied for various discharges. The results indicate that both fine (17 µm) and coarse silt (40 µm) do not stabilize the bed. Primary bedform height increases with decreasing sediment size of sandy mixtures, while the bedform height decreases with decreasing sediment size of silty mixtures, but both trends are minor. Additionally, a gradual transition from ripples to dunes is observed, and both scales can co-exist.

1 INTRODUCTION

Estimating bedform geometry is important for hydraulic roughness determination, fairway depth maintenance and sedimentary record interpretation. Bedform geometry and existence in sand-bedded rivers is traditionally predicted with phase diagrams and empirical equations. However, most phase diagrams and empirical equations are based on uniform, cohesionless sediments (Yalin, 1964; van Rijn, 1984; Parsons et al., 2016; Wu et al., 2021), while mixtures of cohesionless sand, physically cohesive mud, and benthic organisms are common in many coastal, deltas, estuaries, and lowland rivers (Manning et al., 2010; Parsons et al., 2016; Schindler et al., 2015). Bedform dimensions may decrease when clay (<4µm) is present (Schindler et al. 2015), and when high suspended sediment concentrations (SSCs) suppress bedform growth (Ma et al., 2020). Non-cohesive silt (~30 - 63µm) is mainly transported in suspension and is therefore expected to limit bedform height and length. Additionally, the experiments of Bartzke et al. (2013) and Yao et al. (2022) demonstrate that silt could stabilize the bed because it fills the space in between the coarse sand particles. Consequently, the silt particles block the flow through the sediment bed and thus decrease the permeability. Weakly-cohesive silt (4-~30µm) is expected to limit bedform development similar to clay. Evidently, it is unknown what the exact influence of silt on bedform dimensions is.

Here, we test the influence of silt in sand-silt mixtures on bedform geometry, based on laboratory experiments conducted in a recirculating, tilted flume, in the Kraijenhoff van de Leur Laboratory for Water and Sediment Dynamics at Wageningen University & Research. We seek a relation between bedform geometry and silt content in the riverbed, bed shear stress and suspended sediment concentration (SSC). We hypothesize that with increasing silt concentration, SSC increases and the hydraulic roughness decreases, resulting in a decrease in bedform height and length. With this analysis we aim to quantify the influence of fine-grained bed sediment on bedform geometry.

2 METHODS

2.1 Experimental setup

The experiments were conducted in a tilting flume with recirculation facilities for both water and sediment in the Kraijenhoff van de Leur Laboratory for Water and Sediment Dynamics from Wageningen University and Research (Figure 1 and 2). The flume has an internal width of 1.20 m, length of 14.4 m, and height of 0.5 m. A diffuser at the upstream part made sure that the inflow was distributed over the entire width of the flume. The diffuser was followed by a stacked pile of PVC tubes that serve as a laminator, suppressing turbulence. At the end of the flume, a funnel was connected to the reservoir to make sure that bed transport was recirculated and did not deposit in front of the weir.

A sediment bed of 10 cm was applied, which consisted of a manually mixed combination of two grain sizes: a base sediment of medium sand (270 µm), mixed with fine sand (180 µm), coarse silt (40 µm) or fine silt (17 µm) (Table 1). Experimental runs were performed for different discharges (45, 80 and 100 L/s), to be able to distinguish the effect of transport stages, corresponding with an average flow velocity of 0.38, 0.67 and 0.83 m/s respectively. The flow depth was set to 15 cm measured from the initial flat sediment bed, and the water depth was kept the same for the different discharges by adjusting the weir height. The slope was set to 0.01 m/m.

Figure 1. Picture of the inflow of the flume.

To ensure equilibrium bedform conditions, experiments were ran for 10, 5 and 3 hours

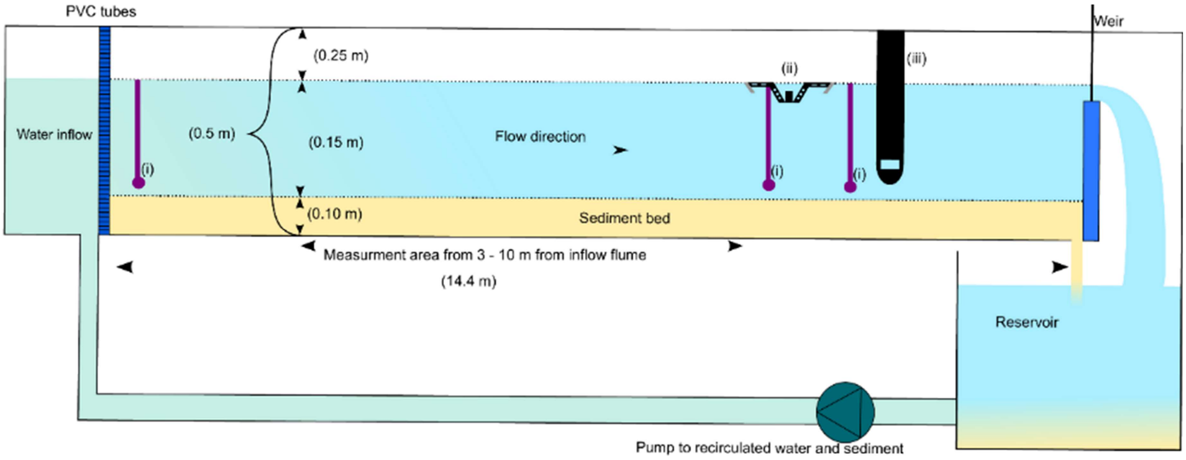

Figure 2. Schematic overview of the experimental set-up indicating with the following measurement instruments i) stilling wells at 2, 11, 12.5 meters from the inflow of the flume, ii) UB-Lab-2C, iii) LISST-200X.

for the discharges of 45, 80 and 100 L/s, respectively.

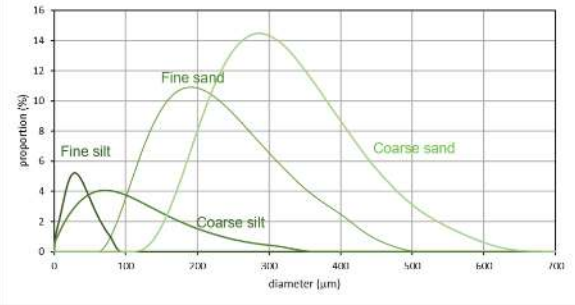

Figure 3. Sediment distribution of the used sediments, measured with a Mastersizer 2000.

2.2 Instrumentation

Table 1: Bed composition (%) of the experimental runs.

Experiment	Medium sand	Fine sand	Coarse silt	Fine silt
Sand_1	0	100	0	0
Sand_2	18	82	0	0
Sand_3	35	65	0	0
Sand_4	49	51	0	0
Sand_5	65	35	0	0
Sand_6	100	0	0	0
CoarseSilt_1	98	0	2	0
CoarseSilt_2	95	0	5	0
CoarseSilt_3	90	0	10	0
CoarseSilt_4	80	0	20	0
CoarseSilt_5	70	0	30	0
CoarseSilt_6	50	0	50	0
FineSilt_1	98	0	0	2
FineSilt_2	96	0	0	4
FineSilt_3	91	0	0	9
FineSilt_4	77	0	0	23
FineSilt_5	70	0	0	30

During the first and last 30 minutes of a run, a LISST-200X measured suspended sediment concentration and grain size, and an UB-Lab-2C measured acoustic velocity profiles. After each experimental run, the flume was drained slowly and a line laser scanner measured the bed topography.

2.3 Data analysis

Based on the topographical data, five transects were constructed with an interval of 200 mm in the crosswise direction through the bed elevation profiles. These profiles served as input for the bedform tracking tool from van der Mark & Blom (2007), which gives bedform height, length and leeside angles based on specific span values used to differentiate between different bedform scales. Three bedform lengths of interest were defined: 150 mm ± 100 (hereafter referred to as secondary bedforms), 500 mm ± 150 (referred to as small primary bedforms) and 1800 mm ± 350 (referred to as large primary bedforms).

3 RESULTS AND DISCUSSION

3.1 General bedform geometry

The general bedform pattern observed during the experiments, could be described as ripples during the 45 L/s experiments, mixed or transitional bedforms during the 80 L/s experiments, and dunes (with ripples super imposed) or upper stage plane bed (USPB) for experiments with 100 L/s (Figure 4).

Those three bedforms scales (ripples, small dunes, and large dunes) can co-exists, and can transition into each other. Traditional bedform stage diagrams do not account for this, and should be adjusted. Furthermore, this observation opposes the theory of Duran Vincent et al. (2019), who’s research showed a scale break between ripples and dune.

Additionally, the definition of the scales differs depending on the chosen type of distinguishing characteristic. Scales can be differentiated on dimension (Schindler & Robert, 2004; Lapotre et al., 2017), steepness (Schindler & Robert, 2004; Robert & Uhlman, 2001), Yalin number (Lapotre et al., 2017) and by comparison with equations predicting bedform dimensions (Soulsby et al., 2012). A comprehensive and all-embracing definition is needed to differentiate bedform scales in different environments.

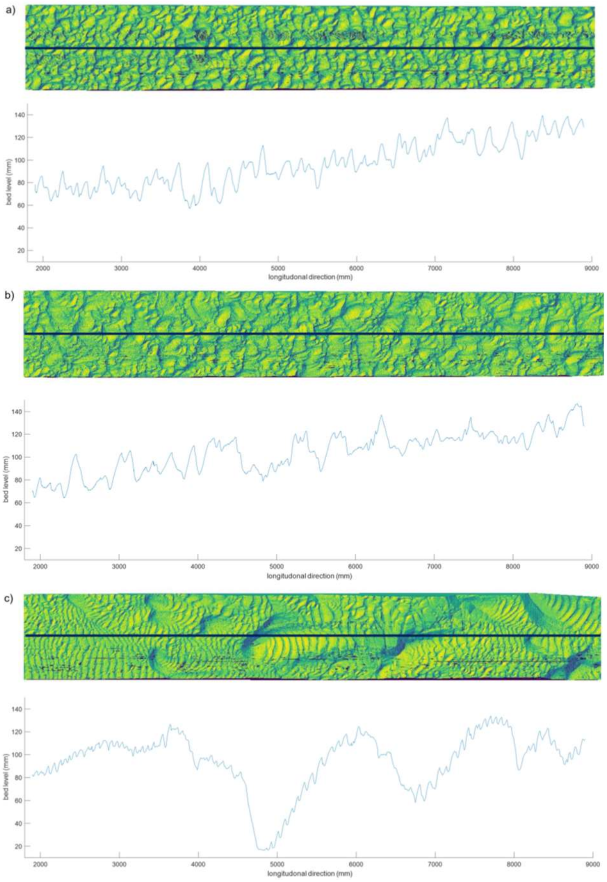

Figure 4. Topography of the bed of the runs with only coarse sand with the corresponding cross-section through the middle of the profile. a) indicates the bed geometry after the run with a discharge of 45 L/s, b) 80 L/s and c) 100 L/s. The dark blue lines indicate the location of the cross-section.

3.2 Influence of sediment composition

3.1.1 Bedform height (H)

Below, we focus on the 80 L/s case. With increasing fine sand content, the bedform height of the secondary (ripples) and small primary bedforms (dunes) decrease, but only minimally. The same observation is made for an increasing coarse silt and fine silt concentration. (Figure 5 A-C). The trend in decreasing ripple height with fining of the bed, can be explained by the fact that ripples are supposed to scale with grainsize. The decrease in height of small dunes cannot be directly explained, and with the current data we can only speculate that this is due to a transition to USPB. Additionally, the observed bedforms seem to be clean sand bedforms (Wu et al., 2021), in which the silt has been washed out. The largest dune scale was observed in the experiments with fine sand and coarse silt, but was absent in the fine silt experiments. We expect that the cohesivity of the fine silt suppresses the growth of larger bedforms. The presence of larger dunes at runs with a high concentration of fine sand, could be due to the higher mobility of the sediment, enabling more transport and therefore larger bedforms to occur. However, during runs with coarse silts, the larger bedforms seem to disappear if the material fines. Either the high suspended sediment concentration, or the increasing stability of the bed due to silt addition, could suppress the development of larger dunes. These hypotheses should be verified by studying the measured suspended sediment and flow velocity data.

3.1.2 Bedform length (L)

In the experiments with fine sand and coarse silt, the bedform length of all bedform scales increases when the bed gets finer. Only during the experiments with fine silt, the bedform length decreases. (Figure 5 D-F). These observations can be contributed due to the higher mobility of the sediment during the fine sand and coarse silt runs, moving the bedforms towards UPSB, and the higher cohesivity of the fine-silt bed, suppressing this transition.

3.1.3 Bedform steepness (H/L) and leeside angle

This increase in bedform length, in combination with decreasing bedform height, results in flatter bedforms (Figure G-I). This corresponds with observations in high SSC environments, suppressing bedform steepness (Ma et al., 2017). Bedforms in the fine silt environment are steeper than in the coarse silt and fine sand experiment, and the steepness remains constant when the bed fines. The same trends are observed for the mean leeside angle of the bedforms (Figure J-L). The increased cohesion could result in less transport, and higher angle of repose.

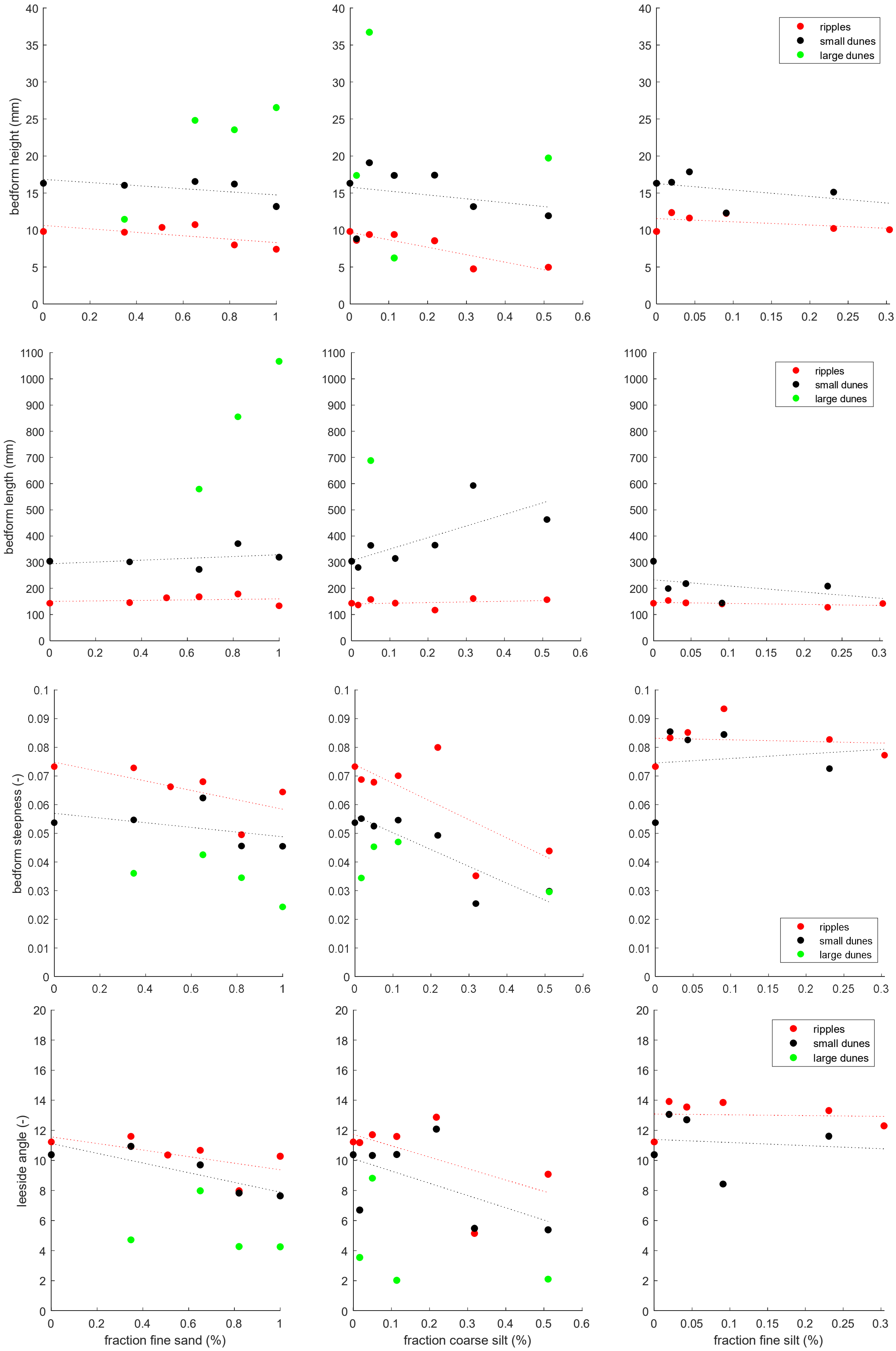

Figure 5. The relation between percentage fine sand (A, D, G), percentage coarse silt (B, E, H) and fine silt (C, F, I) in a medium sand mixture, and bedform height (A-C), length (D-F), steepness (height / length) (G-I) and leeside angle (J-L) of the experiments performed at 80L/s.

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4 CONCLUSIONS

17 experiments were analysed with varying percentages of fine sand or coarse silt in the bed sediment for a discharge of 45, 80, and 100 L/s. Next, bedform height and length of the dunes and ripples were determined.

The addition of coarse silt effects the bedform geometry in the same way as the addition of fine sand does. An increase in transport capacity leads to a decrease in dune height and steepness, while the dune length increases. The addition of coarse silt does therefore not stabilize the bed, since the grains are too large to fill up the pores of the base material. The addition of fine silt results in shorter, steeper dunes, possibly due to the added cohesion of the material.

Finally, multiple scales of bedforms can co-exist and transition into each other, which should be implemented in bedform phase diagrams.

5 ACKNOWLEDGEMENT

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Dune preservation and microplastics distribution over time, River Waal, Netherlands

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ABSTRACT: River valleys are major stores of sediments and plastics, providing archives of their accumulation. However, the temporal storage of sediments in river beds and the mechanisms of deposition and accumulation of microplastics within subsurface sediments remain poorly understood. This study aims to understand the links between dune dynamics, spatio-temporal sediment preservation and the patterns of microplastic accumulation in the subsurface. We collected short time series of bathymetric and sub-bottom profiler data in combination with 18 vibracores in the River Waal, Netherlands. Here, we explore linking the internal sedimentary structures to their formative bedforms, with the aim of establishing the date of formation with bathymetric records collected over the past two decades. Preliminary quantification of microplastics in one core reveals highest concentrations in the active dune, but also an occurrence of microplastics in underlying dune sets. These data will permit unprecedented insight into the development of the sedimentary architecture and its influence on the distribution of microplastics in riverine sediments.

1 INTRODUCTION

The sustainable management of lowland rivers requires a better understanding of spatio-temporal patterns of deposition and erosion of river beds. River dunes are ubiquitous features in sand- and gravel-bed rivers and are key elements in bedload transport (Best, 2005; Zomer et al., 2021). Understanding the links between dune dynamics and the spatio-temporal patterns of sediment preservation (or reactivation) in river beds is important to both system knowledge and the sustainable use of rivers.

Furthermore, river valleys are not only the conduits through which sediments and plastics are transported to the ocean, but also are major stores for plastics. Macroplastics have been found to accumulate in tidal river zones, rather than flowing out to sea (Van Emmerik, 2021) and pollute river banks, beds and water. For microplastics, recent modelling (Drummond et al., 2022) has indicated long residence times of microplastics in river beds (av. 2.5 hrs km^{-1} to max av. 0.15 year km^{-1} for microplastics <100 μm in the main stems of rivers). Through hyporheic exchange (i.e., surface water enters the river bed upstream and re-emerges at some point downstream, while potentially mixing with upwelling groundwater along its flow path, in which dunes also play an important role; e.g. Packman and Brooks, 2001; Frei et al., 2019), microplastics may be incorporated into the bed, re-entered into the water or transported into deeper layers (long-term burial) and into the surrounding floodplains, thereby affecting both riverine ecology and that in the surroundings.

To date, dune dynamics have often been analysed using multibeam echo sounder (MBES) time series, but the spatio-temporal sediment preservation of dune sediments in the subsurface remains poorly understood. Moreover, the mechanisms of deposition and accumulation of microplastics within river sediments are still largely unknown, since present empirical studies merely include water samples and bed (surface) sediments. Vitally, observations must cover the spatial patterns and temporal dynamics of microplastics as related to sedimentary heterogeneity.

This paper presents a preliminary analysis (around selected cores) of dune preservation and microplastics distribution in the bed of the River Waal, a branch of the River Rhine in the Netherlands. The near-3-D dataset that we acquired provides a comprehensive archive of accumulation, in which times of deposition can be dated using bathymetric records. Future quantification and characterisation of microplastics within the preserved sediments will offer a unique opportunity to derive and explain the presence, type and abundance of microplastics in the sedimentary record. These data will permit unprecedented insight into the development of the sedimentary architecture and its influence on the distribution of microplastics in riverine sediments.

2 METHODS AND DATA

In three areas of the River Waal, Netherlands (Figure 1), with varying longer-term bed dynamics (Van Dijk et al., 2015) and varying grain size (Ten Brinke, 1997), we collected simultaneous MBES and sub-bottom profiling data in time series (Table 1). These data were combined with 18 vibracores down to depths of ca. 5 m.

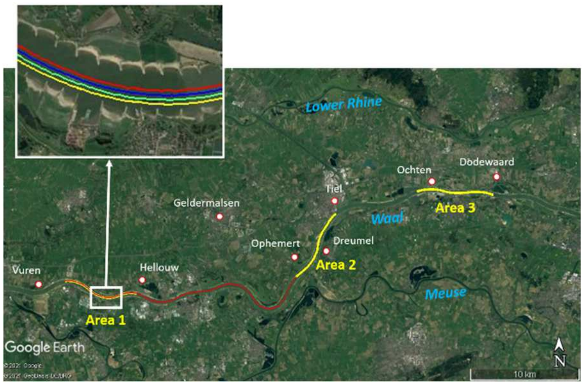

Figure 1: Locations of the three survey areas in the River Waal, Netherlands (yellow). The enlarged inset map of Area 1 shows the four survey lines. In addition, one track line (red in main figure) was surveyed to connect the most western Areas 1 and 2. Flow is from east to west.

2.1 Geophysical surveys

High-resolution MBES (for both bathymetry and backscatter) and sub-bottom profiler data (parametric echo sounder, PES) were recorded simultaneously, as to guarantee their ultimate correspondence in space and time. In each area, four 7 km-long lines were surveyed in the navigation channel (Figure 1), thus creating a near-3-D dataset, sailing in the upstream direction in order to limit the sailing speed to 5 km h^{-1} and provide excellent spatial data resolution.

Surveys were conducted by Van den Herik aboard the ‘Sprinter’, a small survey boat equipped with RTK, GPS and motion sensor. MBES data were recorded using a Teledyne RESON SeaBat T20-P at full swath (512 beams, -70/70°), 400 kHz and 50 pings s^{-1}, resulting in 50-200 observations m^{-2}. Sub-bottom profiling data were recorded with an Innomar Standard SES2000 Parametric Echo Sounder (PES), which was linked to the on-board GPS and motion sensor (Applanix) for optimal processing. The advantages of PES are that the echo sounder emits two primary frequencies, thereby creating two new secondary frequencies (a sum [high] and difference [low] frequency; Sambrook Smith et al., 2013), which results in a good return of the bed whilst preserving a good penetration at ca. 0.10 m vertical resolution. After testing for optimal settings, we used a low and high frequency of 8 and 100 kHz, respectively, ca. 43 pings s^{-1} (system-controlled) and we manually varied the start depth during surveying in order to obtain the optimal subsurface results.

Bathymetric data were gridded into 0.25 m resolution DEMs. PES data were processed to correct for vertical offsets, to convert to horizontal coordinates (i.s.o. $ping^{-1}$) and to suppress noise/to bring out reflectors, using auto-gain, and cleaning the water column.

2.1.1 Data in time series

Repeat surveys were near-exactly overlapping with the navigation lines of the first survey (S1). One repeat survey was conducted after 4 days in Area 1 (S1-R), and 3 weeks after the first survey in all three areas (S2; Table 1). The time in between the surveys was based on previous analyses of dune migration rates (Wilbers & Ten Brinke, 2003; Van Dijk et al., unpublished), so that dune migration between S1 and S2 would have resulted in dune displacement of half a wavelength of a large dune. The period of 4 days was just to be sure, in case dynamics were higher.

2.2 Vibracores

To link PES data to sediment characteristics, 18 vibracores were taken by Marine Sampling Holland (MSH) during survey S2, one day after the MBES and PES data for each of the three areas (Table 1). Core locations were based initially on the PES data from S1, to include clear internal active dune cross-stratification as well as sedimentary structures in the subsurface. Where dune migration dictated, based on inspection of the PES data of S2 (on the same day), core locations were refined. All vibracores penetrated to 5.9 m into the bed (often down into the multiple), but recovery was between 3.9 and 5.5 m, due to rodding.

Table 1: Survey overview

	Area 1	Area 2	Area 3
MBES & PES S1	31 May	1 Jun	2 Jun 2021
S1-R	3 Jun	.	.
S2	21 Jun	22 Jun	23 Jun 2021
VCs (S2)	22 Jun	23 Jun	24 Jun 2021

Sediment cores were split in the laboratory and described (according to NEN 5104 guidelines), whereby grain size was estimated using a comparative microscope. In addition, we made lacquer peels from the cores in order to bring out sedimentary structures, such as fine lamination.

2.3 Microplastics analyses

Cores were subsampled in the laboratory (using the 100 Plastic Rivers project laboratory protocol; UoB, 2019) throughout the depth of the cores and samples were analysed for microplastics (< 5 mm) at the University of Birmingham, using established methods (Nel et al., 2020). First, organic matter was digested (using H_2O_2, below 55°C) and density separation (using $ZnCl_2$ at 1.5 g cm^{-3}) was done to separate microplastics from the sediment and to reduce false positive inclusion. Staining samples with Nile Red enabled fluorescent microscopy (lower size limit here is 64 µm) to count and measure putative plastic particles. µFTIR (micro-Fourier Transform Infrared Spectroscopy) will be performed on select samples (lower size limit is 20 µm) to identify polymer types. Herein, only plastic particles were counted in one core, but future analyses will be extended over the whole area and include particle size and polymer type data. Organic matter content was determined by loss on ignition (LOI).

2.4 Sediment grain-size analyses

Samples were analysed for grain-size distributions, using laser diffraction (Malvern Mastersizer) for the finer sediments and dry-sieving for the coarser sediments.

3 RESULTS

3.1 Morphology and sedimentary structures

Both the bathymetric and PES data show large dunes with superimposed small dunes. The PES data reveal internal sedimentary structures of the active dunes, exhibiting foresets of large dunes and smaller structures where superimposed small dunes descended along the lee slope of large dunes (Figure 2; Galeazzi et al., 2018). In nearly all data, the active large dunes have distinct horizontal reflectors at their base.

As revealed by the PES data, the sedimentary structures immediately below the active dunes and in the deeper subsurface, exhibit foresets of older dune sets (especially Area 1) or display larger-scale horizontal or concave reflectors.

The sediment cores showed large variations, comprising recent dune sediments to Pleistocene deposits. For example, core 2 (Area 1; west) comprised stacked sets of cross-bedded sand and gravel beds, whereas some cores in Area 3 (east) contained an organic clay layer and Pleistocene aeolian sands. In most sediment cores, the recent deposits of the active dunes were clearly distinct units with sharp basal boundaries.

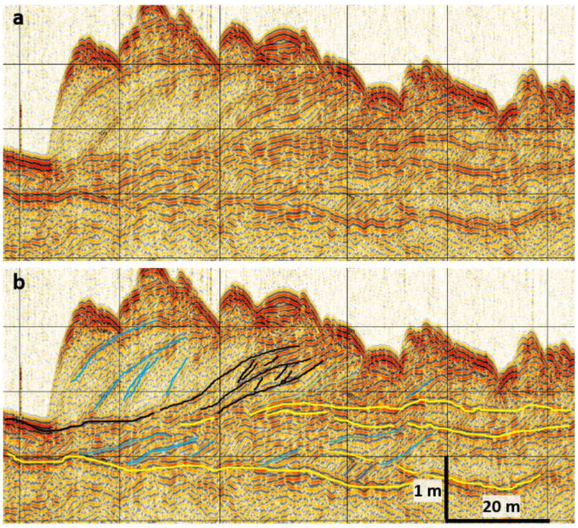

Figure 2: Example of sub-bottom profiler data (parametric echo sounding, PES), showing dune morphology, internal structures of the active dunes and reflections of older dune sets below. **a.** raw data. **b.** preliminary interpretation plotted on raw data.

3.2 Dune dynamics

Both the bathymetric and parametric echo sounding in time series, acquired during these surveys, record dune morphology and dune dynamics. The high-resolution bathymetry data is best used for quantitative morphometric and morphodynamic analyses, such as dune migration celerity. Quantitative analyses still have to be completed, but an initial estimate of average dune celerity based on one dune is 3.6 m day^{-1} in June 2021. Note that the PES data in time series are not only useful for determining sediment reactivation in the subsurface by dune movement, but also for identifying sedimentary structures to larger depths (i.e., where reflectors were within the signal multiple during one survey, they appeared in the other survey, by dune migration).

3.3 Dating of the sedimentary structures

By linking the bathymetry to the PES data, the more recent sedimentary structures can be dated accurately, thereby allowing for the reconstruction of depositional and erosional episodes. Dating the sediments is not only essential for future quantification of the spatio-temporal preservation of sediments in the river bed, but also for the historic record of microplastics within these sediments and understanding the depositional processes and potential distribution of microplastics by hyporheic flow. In addition, a 2-weekly bathymetric time series over the past 16 years (2005-present) and a half-yearly time series (1999-2011) are available from Rijkswaterstaat, which provide a unique opportunity to date the dune structures. However, initial analyses of a selection of bathymetric profiles show a 'spaghetti'-plot, where dune migration causes a rapid and repeated replacement of dune deposits (active dune level). Moreover, a preliminary analysis of dune preservation, (i.e., exploring the riverbed built-up using bathymetric profiles – i.e., 1D – over time; Figure 4), revealed that dune migration has not only caused little preservation since 1999, but in some places the river bed has eroded into the 1999 bed. This implies that at these locations, recent dune deposits will directly overly pre-1999 sediments. This has also led to the finding that older pre-1999 bathymetric datasets (e.g. single-beam data) will be needed to date the sedimentary structures below the active dunes in the PES data.

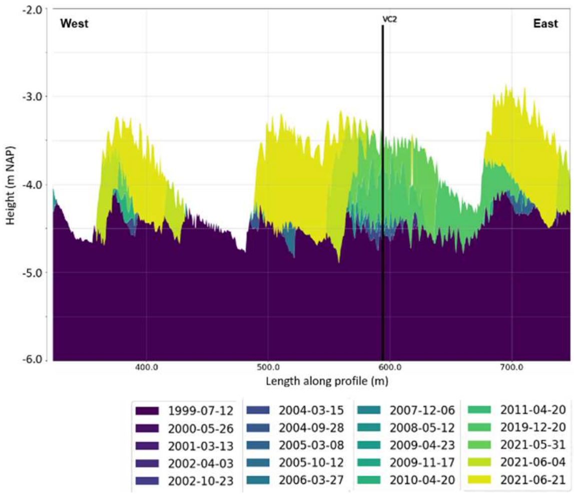

Figure 4: Exploring the analysis of dune preservation (example around core 2) for a small selection of bathymetric profiles between 1999 (purple) and the surveys in this study in 2021 (yellow and yellowish-green).

Additional indicators of the ages of the sediments are the occurrence of *Corbicula fluminea*, an invasive species of freshwater clam that was first recorded in the Rhine system in the Netherlands in 1987 (Den Hartog et al., 2007), and the geological model GeoTop of TNO Geological Survey of the Netherlands.

3.4 Microplastics (core 2)

The concentration of microplastics in core 2 was highest in the top 1 m of the core (see Figure 3, chart on the right). Nevertheless, small amounts of microplastic particles were found down to a depth of 3 m.

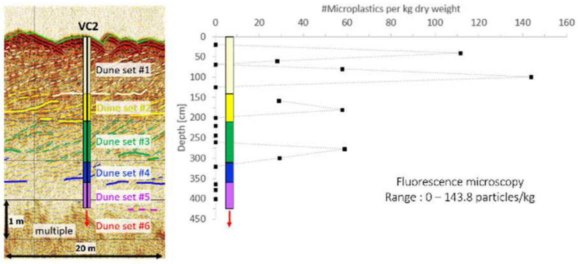

Figure 3: PES raw data with interpreted sedimentary structures around core 2, interpreted dune sets in core 2 and number of microplastics kg^{-1} per sample. The PES data are plotted on a vertically exaggerated scale, so the angles of lee slopes are steeper than in reality.

3.5 Interpretation around core 2

Core 2 is in the western part (lower reach) of the River Waal, where aggradation rates were expected to be largest. On the PES data, six dune sets were identified down to a depth of 5 m. The recovery depth of core 2 of 4.20 m captures five of these dune sets (Figure 3). The high content of microplastics in the top 1 m of the core corresponds to the active dunes (dune set #1). The occurrence of microplastics in the two older dune sets below (yellow and green in Figure 3) suggest active accumulation in older dunes or possible injection within hyporheic exchange.

4 DISCUSSION & FUTURE RESEARCH

The highest abundance of microplastics in the active dune set may confirm their recent deposition, simultaneously with the dune deposits. However, the occurrence of microplastics in the two older dune sets below suggests accumulation during deposition from older dunes (pre-1999) and/or inflow through hyporheic flow.

Although those older dune sets still need to be dated, these may potentially be pre-plastic era in age: if this is the case, hyporheic flow becomes the only mechanism for microplastic introduction into these lower dune sets. For the interpretation of microplastics within the sediments, it is thus crucial to assess the age of the sediments.

Using older (pre-1999) bathymetric data may help in determining the age of the dune sets below the active dune set. However, single-beam echo soundings may not go back in time far enough. In this case, linking the PES data to the Dutch geological model will provide crude depositional epochs of the Late Pleistocene and Early Holocene deposits.

At present, we have analysed the concentration of microplastics in core 2. Although this concentration was small, it is in the order of concentrations found in other rivers (i.e., to date, literature merely reports surface samples of the top 5 cm). Future analyses of all cores will provide the spatial distribution of microplastics (concentration, size and polymer type from FTIR) from surface samples and their vertical distribution in the subsurface of the River Waal.

For the geological context, future interpretation of the full MBES and PES datasets will present a near-3-D record of the sedimentary architecture. In combination with the 2-D bathymetric time series (surfaces rather than profiles) and vibracores, this is a unique 3-D dataset, which will allow quantification of dune dynamics and sediment preservation over time, identifying potential time gaps in the sediment cores and providing insight into the depositional processes of microplastics and hyporheic transport within these sediments. We can then start to link the spatio-temporal sediment storage to depositional events (e.g. floods). To date, creating such a dataset was only possible in flumes, whereas the field record presented herein may contribute to future data-driven morphodynamic modelling.

5 CONCLUSIONS

Dune stratification of active dunes, as revealed on the sub-bottom profiles in the River Waal, Netherlands, comprise foresets of large dunes and occasionally of superimposed small dunes. The combination of high-resolution bathymetry and simultaneously recorded PES data in time series allows for the quantification of spatio-temporal sediment preservation in the last two decades. The dune sets below the active layer may be dated using older bathymetric data.

Microplastics were more abundant in the active dune layer, but were present to a depth of 3 m, corresponding to two older dune sets. Future analyses of microplastics in all cores will provide the 3-D spatial distribution of microplastics in the subsurface. Combining these data with quantification of the sedimentary architecture leads to insights that permit explanation of processes that deposit and redistribute microplastics in river beds.

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