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The effects of sea-level rise on estuary morphology in dredged and undredged systems

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Estuaries are often dredged for navigational access to ports and harbours. Dredging alters the natural dynamics and morphology of estuaries, tending to create deep channels and high intertidal bars and shoals. Estuaries will face many challenges in the future including sea-level rise (SLR) which will influence both estuarine hydrodynamics and morphology. Whilst the effects of SLR have been studied through numerical modelling and have been inferred from empirical relations for natural estuaries, little is known about whether dredged systems will react differently to SLR compared to natural estuary systems. Our objective is to quantify effects of dredging, SLR and the interaction of both processes on estuarine morphology.

We performed scale experiments in a tilting tidal flume (The Metronome)to indicate the proposed effects of SLR on estuarine morphology. Previously, dredging was induced in the flume and the response of morphology compared well with real-world examples such as the Western Scheldt. In the current study, simulated SLR was induced in both a sandy natural (undredged) estuary and a dredged estuary in otherwise the same conditions. These were compared with control experiments without SLR to isolate the effects of SLR in both types of system.

Overall, both maintenance and capital dredging volumes increase with SLR and dredging locations tend to shift upstream. The experiments indicate that channels under SLR tend towards a new equilibrium by changing their hypsometry (width and depth) in response to excess water. This has the overall effect of increasing channel mobility and channel migration speeds. In dredged systems, banks become unstable and collapse into channels which is compounded with rapid erosion of intertidal bars and shoals.

Intertidal areas in non-dredged systems tend to maintain their elevation and extent under SLR, though their locations shift in the upstream direction. In contrast, dredged systems typically show a decrease in total intertidal area, which means the loss of valuable intertidal habitat area and reduction of flood storage.

In the long-term, dredged systems without SLR have an almost fixed morphology, such that the dredged channel persists even after dredging ends. But SLR overwhelms this fixation and remobilizes sediment, enhances channel meandering and migration and induces lateral expansion. If estuaries are constrained by dikes, bank protection or other flood measures, this excess energy, which is not all dissipated in meandering and migration, may have negative effects on infrastructure. In undredged systems, shallower channels have more space to deepen and widen, reducing the braiding index and providing more adaptation capacity. Infrastructure along urban dredged systems (e.g. flood protection measures, dikes) will be at higher risk under SLR than systems with floodplains and intertidal areas which have space to adapt.