Turning the tide: creation of tidal inlet systems and estuaries in experimental scale models.

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Problem definition

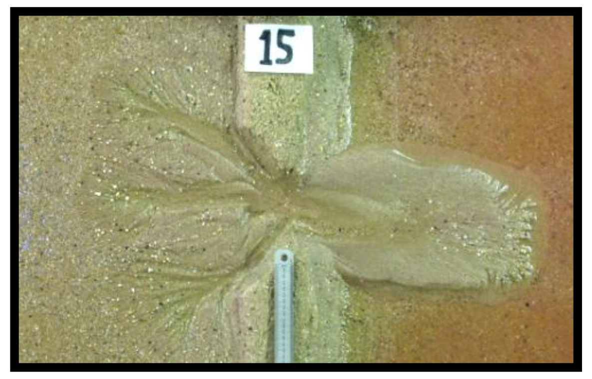
Tidal channel networks, estuaries and ebb deltas usually formed over a period longer than observations cover. Much is known about their characteristics and formation from linear stability analyses, numerical modelling and field observations. However, experiments are rare whilst these provide data-rich descriptions of their evolution in fully controlled boundary and initial conditions.

Objective

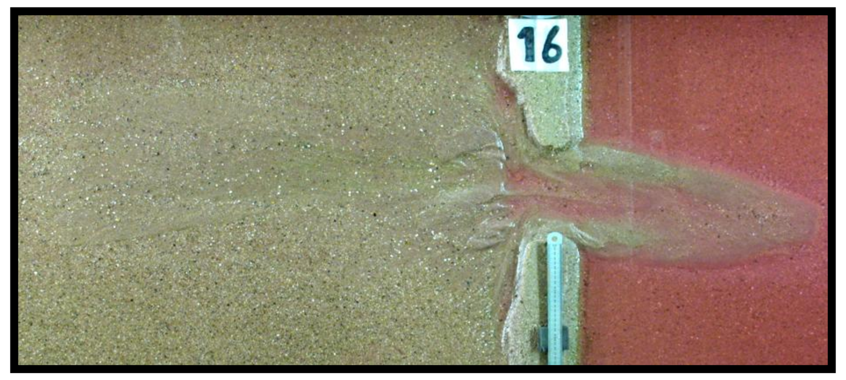
Our objective is to ascertain whether tidal basins and, hereafter, estuaries can be formed in experiments, what possible scale effects are, and whether morphological equilibrium of such systems exist.

Survey of experimental results

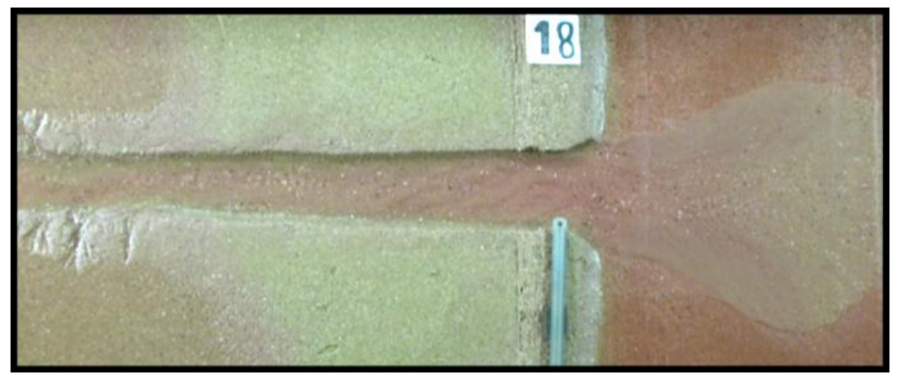
Initially dry, low amplitude ebb-dominated system



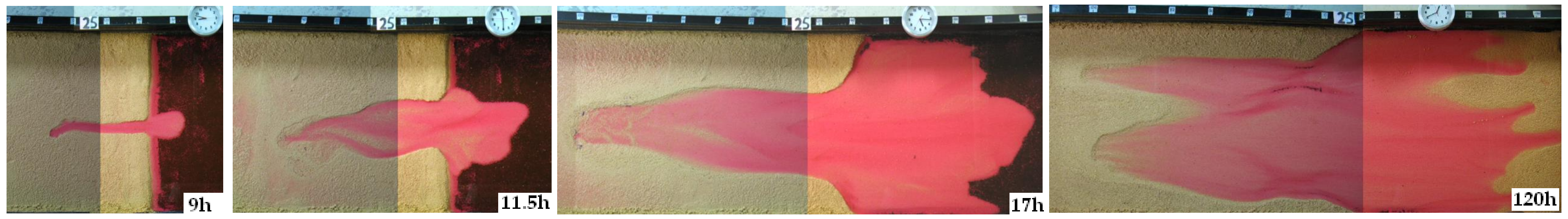
Initially drowned, high amplitude system with transport during the ebb-and flood phase



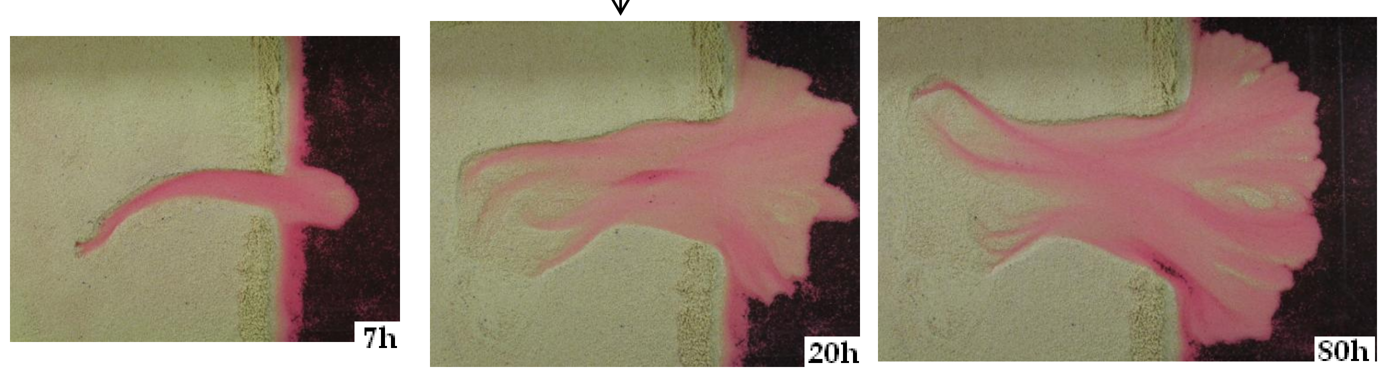
Initially drowned channel that shows bed profile adjustment, funneling and alternating bars



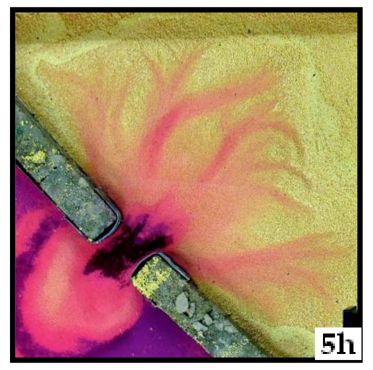
A plain basin bed consisting of lightweight plastic. The system shows sediment rearrangement through both separate ebb- and flood channels and two-way flow channels. The system development is described by periods of little morphological change and periods of sudden, rapid change. Bank formation is an important mechanism.



An upward sloping sediment bed (warping) consisting of lightweight plastic. The system widens by bank erosion. The channel tail-ends sway back and forth over the width of the basin until the proper morphologic equilibrium is reached. The ebb-tidal delta expands through fan-deltaic behavior.



Pilot experiment with lightweight plastic and restricted inlet width shows a branching channel network of two to fourth order.



Method

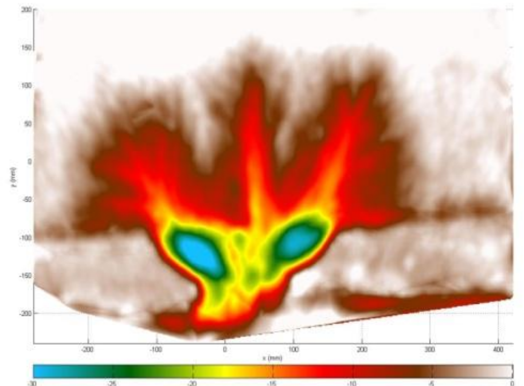
The experimental apparatus is 1.2 x 3.5 meter in size and comprises a sea and a sediment basin (table). Rather than create tides by varying water level, we tilted the entire basin vertically (photo). Hence the tidal channel resembles a river of two-way flow.

EXPERIMENT	number	15	16	18	24	25
total time	hours	2.5	3	7	96	120
jackspeed	mm/min	45	30	50	50	50
tilt from MSL	mm	15	30	15	7	7
duration tidal cycle	sec	88	214	166	67	67
total tidal cycles	nr	102	50	152	5160	6450
Sediment	description	Metsel-zand	Metsel-zand	Metsel-zand	Poly-styreen	Poly-styreen
Sediment level	cm	4	4	4.5	3	3

Photo and table: Experimental apparatus at U.U. and table with experimental settings.

The advantage of this novel method is that the bed surface slopes in downstream direction both during flood and ebb phase, resulting in significant transport and morphological change in the flood phase as well as the ebb phase. The effect of the transport phases is prominent in the photo below.

Photo of experiment 17 with prominent transport during the ebb- and flood phase.



DEM of experiment 15. Starcam tm 3D Camera is old and needs renewal.

Conclusion

Tidal channel networks and ebb deltas were produced in the tilting basin from initial flat bed. The experiments show that equilibrium occurs invariably when net sediment transport is zero for the flood- and ebb phase. Major findings are:

- Channels bifurcated during channel deepening and backward erosion to form a network of up to four orders. Backward erosion is sensitive to details in initial topography.
- The rate of change, the size of the channels and the final length of channels and delta were very sensitive to the tidal amplitude, tidal period and initial water depth in the basin.
- An initial shallow rectangular channel showed bed profile adjustment and funneling. Moreover, the channel bed showed alternating bars.

These processes and morphologies are at least qualitatively the same as in nature indicating that the experimental setup works well. The novel experimental setup for fast formation of tidal systems and estuaries offers the possibility to study long-term evolution and response to, for example, sea level rise.

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