Simulation of hydrodynamics and transport of fine sediments in vegetated polders with a controlled reduced tide: Pilot project Lippenbroek

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The Actualized Sigmaplan aims for satisfying safety and ecological needs along the Scheldt river in a sustainable way. Therefore different measures have been elaborated which combine safety with estuarine restoration, eg. dike strengthening together with more space for the river, flood control areas (FCA), and non-tidal wetlands. As a pilot project, the former Lippenbroek polder has been converted into a 10 ha flood control area (FCA, **Figure 1**) with a controlled reduced tide (CRT) installed. Goal is to obtain inundation characteristics similar to natural tidal marshes. In 2006 Lippenbroek started functioning as freshwater intertidal habitat.

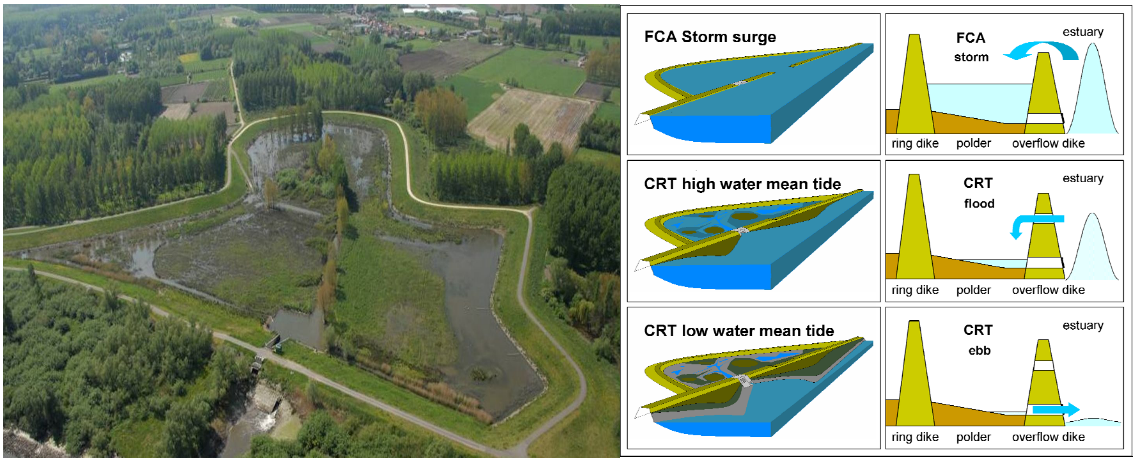

Figure 1: Left: Aerial photograph of the FCA converted Lippenbroek polder (May 2008). Right: Overview of the CRT-principle.

This paper presents results from ongoing multidisciplinary hydromorphological research on the pilot project Lippenbroek. This study at hand aims to determine by means of numerical modeling how much sediment is retained in the polder, what is the spatial distribution, and in particular how this process is influenced by the development of marsh vegetation. The study serves as a test-case and evaluates the possibilities for application of a robust numerical modeling system to assess the morphological evolution of flood control areas with CRT. Several hypothesizes have been put forward that should lead to a better comprehension of the dominant processes and parameters that determine sedimentation in the FCA. In a data analysis aspects of vegetation that influence flow resistance, discharges and water levels, and sediment characteristics have been discussed.

The observed sedimentation is related to the influx of sediments through the inlet structure and to the local erosion of the main creek. Internal factors like vegetation and topography influence where sediment will settle. Outside the creek the rise and fall of the water level is slow, and little turbulent flow can be expected. Also vegetation is known to decelerate the flow and to retain sediments. After the polder is flooded a stagnant water phase up to two hours allow the sediments to settle. The deposition may therefore be related to the sediment concentration at the start of the stagnant phase, the settling velocity of the sediments and the local water depth. As the smaller particles that have been transported into the polder flocculate, the receding (outgoing) flow may not be able to re-suspend these larger particles.

A numerical Delft3D model has been developed to examine the sediment transport in the vegetated polder. Vegetation was modeled using a sub-grid plant flow interaction (trachytope) model based on Baptist (2005). Optimum model parameter settings have been selected and a good representation of the measured water levels and observed inundation pattern was obtained. From the first set of simulations three important parameters have been indicated that determine sedimentation patterns: proximity to the main creek, vegetation and the particle settling velocity.

As the flow velocities on the tidal flats are generally small, the influence of vegetation on the hydrodynamics is limited. The model showed the importance of finding a good representation of the settling velocity and indicated the effect of vegetation on the settlement of the larger particle sizes (**Figure 2a**). As these larger particles represent a smaller fraction, vegetation as such has a limited effect on the overall sedimentation pattern. Since the settling velocity of the predominantly small particles is small, deposition of these particles largely occurs during the stagnant water phase and is therefore correlated to the local water depth (**Figure 2b**). Sediment analysis indicate that during transportation into the polder due to coagulation of the particles the settling velocity increases. Measurements indicate higher sedimentation rates further up into the polder than would be expected based only on the settling velocity of the coagulated particles. Reproduction of the significant sedimentation in the back of the polder with the model is therefore only possible if smaller particle sizes and according settling velocities are applied.

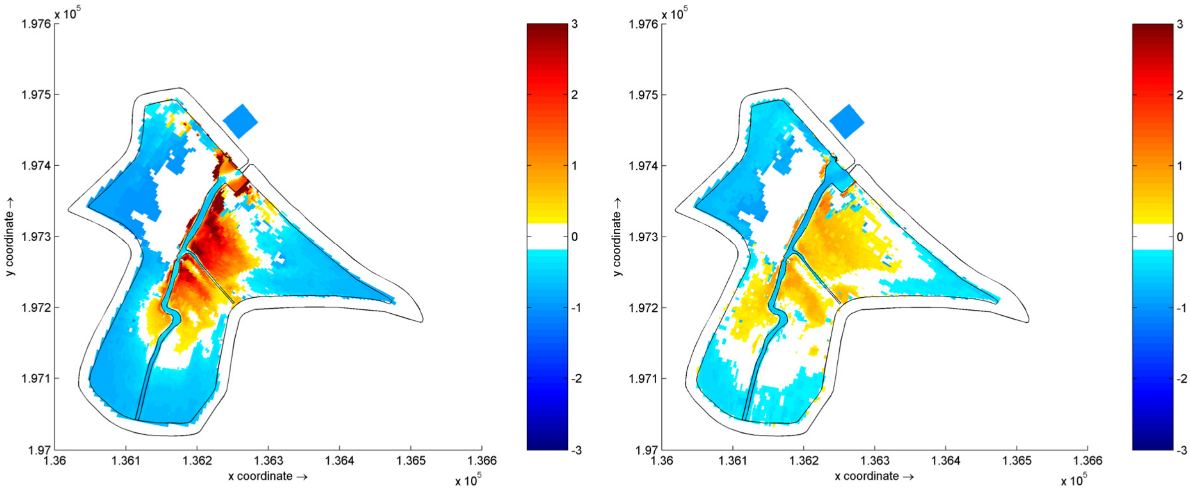

Figure 2: Normalized deposition over normalized maximum water depth. Left: A settling velocity of 0.5 mm/s is used. Right: A settling velocity of 0.1 mm/s is used. Red indicates more sedimentation than can be expected for the local water depth, blue means less sedimentation than can be expected.

The results presented in this paper demonstrate the possibilities for the application of a robust numerical modeling system to assess the morphological evolution of flood control areas with CRT. In addition, a better comprehension of processes and parameters that determine sedimentation in a FCA has been obtained. The knowledge described in this paper will be important for the assessment of other, similar polders that will be converted to flood control areas with CRT. As the model takes into account the various relevant processes that determine sedimentation patterns in the FCA it can be used to determine future maintenance strategies.