Salt accumulation at floodgates and salt-water intrusion in rivers

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Introduction

Salt-water intrusion widely occurs in estuarine areas and can be very problematic to local communities. Worldwide, there is an urgent need for accurate models for salt intrusion predictions since it is one of the most challenging and widespread environmental problems that threaten the quality and sustainability of freshwater resources.

This phenomenon can be aggravated by long-term alterations in weather patterns. On top of this, human activities increased significantly due to heavy urbanization with structural changes to the coastal areas such as deepening of estuaries or construction of gates and locks. Therefore, the understanding of the role of anthropogenic changes on the severity and frequency of salt intrusion events is of high importance in order to get accurate predictions. For example, in Haringvliet inlet in the Rhine-Meuse Delta, the study area of this study, salt intrusion occurs during periods of low flow in the rivers and salt accumulation at floodgates can potentially exacerbate the salinization of freshwater in coastal environments. Hence it is important to understand and quantify how much salt enters freshwater resources through gray-green infrastructures.

Literature review and existing models

Several studies have investigated saltwater intrusion in estuaries. Extensive field data and 3D-hydrostatic (HS) models have been used to study the advection of the salt wedge in the Rotterdam Waterway by De Nijs et al. (2011) and the stratification in the Rhine region of freshwater influence, by Rijnsburger et al. (2016). Schloen et al. (2017) indicated that predictive capabilities of 3D HS models depend on the coupled delta-coastal ocean system, and particularly on the wind and wave forcing and stratification at the mouth of estuaries.

Certain man-made structures such as floodgates that can restrict this free exchange of salt-water and freshwater in an estuary must be managed. Salt can be accumulated in scour pits behind the Haringvliet floodgates and released during every lock cycle towards the inland, resulting in contaminating the freshwater. Flow in a scour hole can be non-hydrostatic (NHS) as Vermeulen et al. (2015) showed for a scour pit in a river bend. NHS models have been used for idealized studies of resonant trapped internal waves generated by sand waves (Labeur and Pietrzak, 2005).

Objective

The final goal of this study is to develop a sophisticated 3D-HS model which will be parameterized by using NHS-3D models and field data from the Haringvliet inlet in the Rhine-Meuse Delta in order to model salt exchange through low dynamic systems such as floodgates.

The model will be able to establish under which conditions salt accumulates in scour pits and under which conditions the salt is released again into the inland freshwater systems. To reach the ultimate objective, a better understanding of the trapping and releasing processes is needed. This insight will be obtained by extensive field measurements to mitigate and control freshwater salinization.

Methodology

Vermeulen et al. (2015) showed that the hydrostatic pressure distribution of flow turns to non-hydrostatic into the scour pits. In order to explore whether the same transition happens to the flow in the scour pits near the floodgates of the Haringvliet system, intensive field data collection will be carried out by using CTD casts and ADCPs (Acoustic Doppler Current Profilers) in the study site which is shown on Fig. 1. Same instrumentation will be used to monitor the inland propagation of the salt wedge.

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Figure 1. Top view of the study site at Haringvliet and the location in the Netherlands. Retrieved from Google Maps

For a better understanding and quantification of the NHS flow, the novel and available measurement techniques developed by Vermeulen et al. (2014) will be adapted and modified accordingly. Additional instruments will be deployed to complement the existing data.

By parameterizing non-hydrostatic effects in scour holes, a 3D-HS model will be developed to simulate the trapping and release process of salt.

Expected result and application

This research strives to deliver an advanced 3D-HS salt intrusion model which is validated and parameterized for the NHS physical processes that occur at floodgates by data retrieved from field measurements.

This model can be applied in estuaries to simulate the salt exchange through low dynamic systems, such as floodgates.

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