The responses of the horizontal salinity front to the Nanhui East Shoal Reclamation Project in the Yangtze River Estuary

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ABSTRACT
A well-validated two dimensional hydrodynamic and salinity transport model was established by MIKE21 to study the responses of the horizontal salinity front to the Nanhui East Shoal Reclamation Project (NESRP) in the Yangtze River Estuary. The results show that: (1) the salinity front in the North Channel (NC) is akin to a single-front pattern, while the salinity fronts in the North Passage (NP), the South Passage (SP) and the North Branch (NB) almost have a double-front pattern. (2) The NESRP make the main salinity fronts of the NP and SP move downstream, and increase main salinity front strength of the NB, NC and SP.

KEY WORDS: salinity front; Yangtze River Estuary; numerical model

INTRODUCTION
The estuary, known as a complex zone of land-ocean interaction, is affected by both the river basin and the ocean. Saltwater intrusion is the common phenomenon in the tidal estuaries. It not only influences on the structure of the estuarine circulation and the characteristics of sediment transport, but also affects the development and use of freshwater resources. For the multiple bifurcations, different types of saltwater intrusion are a natural phenomenon in the Yangtze River Estuary (YRE). The impact of major projects on the hydrodynamic and biological environment and saltwater intrusion in the estuary has been of great concern to the government and society in recent years (Zheng and Cai, 2017; Wang et al., 2021). The YRE is a moderate-tidal-controlled estuary, where freshwater from upstream and saline water from the offshore form a barrier, often referred to as a plume front. The Yangtze River plume has a large range, which can extend nearly 100 km, and the front at its core is called the salinity front. As an important physical phenomenon occurring in the YRE, the salinity front has a significant influence on tidal current, mass transport and sediment deposition process.

In recent years, a series of large engineering projects, such as the Hengsha East Shoal Reclamation Project (HESRP), the Nanhui East Shoal Reclamation Project (NESRP) and the North Passage Deepwater Channel Project (NPDCP) etc., have significantly changed the estuary’s morphology. The HESRP enlarged the land area of Hengsha Island. The NPDCP was built along the North Passage (NP) to eliminate the river shoal in the NP and increase the navigation depth. These projects alter the original dynamic conditions of the estuary, and then affect the salinity front at the mouth, which has a direct impact on sediment deposition and water quality (Zhu et al., 2006; Luan et al., 2018; Li et al., 2020; Wu et al. 2020).

Many tidal flat reclamation projects occur in estuaries or bays all over the world, and they have shown that they have significant influences on hydrodynamic processes. For example, the reclamation of portions of the Tokyo Bay, Japan, decreased the residence time of seawater by 35% (Okada et al., 2011). Reclamation on the west coast of Korea generated the far-field effects on the Chinese coast and could result in a rise of tidal amplitude and onshore sediment transport. The former may enhance the coastal hazards such as storm surge, and the latter may result in severe siltation (Song et al., 2013). The reclamation and other anthropogenic projects in the San Francisco Estuary have impacted saltwater intrusion and outflow due to the changes in estuary geometry, bathymetry, and tidal trapping (Andrews et al., 2017). The HESRP lead to a net transsection water flux increase in the North Channel (NC) and decreases in the South Channel (SC), NP, and South Passage (SP), which weaken the saltwater intrusion in the NC and enhance the saltwater intrusion in the SC, NP, and SP (Lyu et al.,2019). Song et al. (2013) indicates that the amount of coastal area annually reclaimed in China has been increasing as its Gross Domestic Product grown with double digit rate since 2002, in order to satisfy the demand for land-use and to pursue economic profits and wealth accumulation. For instance, between 2004 and 2020, the Caofeidian Reclamation Project in the city of Tangshan, Hebei Province, northern Bohai Bay, planned to reclaim a total of 129.7 km² of tidal flats from the Bohai Sea (SOAPRC, 2009).

The NESRP, with a total area of 147 km², is the largest beach reclamation project in the Yangtze estuary in recent years. The project has changed the local topography of the lower and middle sections of the SP, which will inevitably affect the local dynamics of the estuary and saltwater intrusion, but there is a lack of in-depth research on the effects...