Marine Geology 343 (2013) 47–61

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

Shifts in depositional environments as a natural response to anthropogenic alterations: Nakdong Estuary, South Korea

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ARTICLE INFO

Article history:
Received 4 October 2012
Received in revised form 27 May 2013
Accepted 28 May 2013
Available online 4 June 2013

Communicated by J.T. Wells

Keywords:
estuarine dam
Korea
trapping efficiency
^{210}Pb ^{137}Cs accumulation rate
facies models

ABSTRACT

The Nakdong Estuary, located within the coastal zone of Busan, South Korea, has been subjected to a series of engineered alterations typical of many eastern Asian estuaries. The construction of two estuarine dams (1934 and 1983) and numerous seawalls associated with land reclamation projects has altered the timing and flux of sediment, and resulted in three contrasting discharge energy regimes. Additionally, the impoundments have appreciably reduced the tidal prism by at least 50%. Consequently, vast geomorphologic changes have occurred including the development of five new barrier islands. In order to assess the impacts of these modifications, 19 vibracores were obtained throughout the estuary. The dispersal and accumulation of sediment was evaluated utilizing ^{210}Pb and ^{137}Cs radioisotope geochronology of 6 cores. Average sediment accumulation rates range from 2.19 cm yr^{-1} adjacent to the first constructed dam to as high as 6.55 cm yr^{-1} in the middle region of the estuary. These high rates are further supported by comparison of bathymetric survey data from 1985 to 2009. Laser diffraction grain size analyses and X-radiographs revealed distinctive changes associated with dam construction, and correlation of events between cores conveys the episodic sedimentation corresponding to floodgate releases. Ultimately, anthropogenic alterations have resulted in a shift from a tide-dominated to a wave-dominated estuary. The increase in sediment trapping efficiency that has ensued resulting from extensive coastal construction provides the basis for reevaluating traditional facies models for estuaries. A conceptual model is developed here to characterize the alterations in sediment depositional patterns according to relative discharge energy of the adjacent floodgate.

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1. Introduction

Historically throughout much of the world, estuaries have been hubs for human settlement. This is due to their protection from and access to the open sea, high rates of biological productivity providing sustenance, and being the confluence point of rivers allowing access to inland navigation. Today, this remains evident with many of the largest shipping ports, industrial, and metropolitan centers being located adjacent to estuaries. However, in combination with vast drainage basin characteristic changes, this has ultimately resulted in extensive alteration of natural systems.

On the Korean Peninsula and throughout much of East Asia, traditional agricultural practices include terraced upland agricultural fields and rice farming, which utilize local water resources through irrigation and drainage canals (Crawford and Lee, 2003). Additionally, coastal construction of estuarine dams to impede saltwater intrusion, and extensive seawalls in land reclamation and river divergence projects has considerably modified the shoreline within the last century (Yoon et al., 2007). Together, this has resulted in significant engineering of the drainage system in most watersheds, altering both net transport of sediment and freshwater from these systems and modulating the timing of the discharge (Yoon and Woo, 2000; Choi et al., 2005). As a result, the sediment dynamics and ecosystems within the estuaries into which these rivers flow have been significantly altered.

Several studies have demonstrated the impacts on estuarine sedimentation after the emplacement of dams and/or reservoirs near the coast. The impoundment of the Senegal River on the West coast of Africa has increased the influence of marine forcing factors (i.e. wave reworking) in the outer estuary, resulting in vast and rapid morphological changes of sand bars. Subsequent to the construction of the dam, the mouth of the estuary narrowed and several mouth bars accumulated (Barusseau et al., 1998). The reduction of water discharge and sediment supply within the Yalu Estuary, located on the border of N. Korea and China, due to dam and reservoir construction within the last century was investigated with hydrodynamic calculations, heavy mineral and grain size analyses, and comparison of historical records. A decrease in the bedload transport flux and an increase in the amount of sediment

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0025-3227/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.margeo.2013.05.010

transported landward due to extensive decreases in discharge, coupled with recent dredging activities have significantly altered the estuarine geomorphology, including migration of barrier islands (Gao et al., 2012). After the construction of a dam in the Keum Estuary on the West coast of S. Korea, the sedimentation rate increased by a factor of 1.9, and an increase in accumulation of fine-grained sediments occurred due to a stronger flood dominated tide and a decrease in overall current velocity (Kim et al., 2006). Coastal engineering projects and dam construction within the Haringvliet Estuary in the Netherlands also resulted in a decreased tidal prism, an increase in the relative influence of waves on morphology, and an increased sediment volume within the estuary (Tönis et al., 2002).

The Nakdong Estuary is a prevalent example of an anthropogenically engineered estuary. Within the last century, two large estuarine dams have been emplaced preventing natural flow conditions and the intrusion of saltwater. The Noksan Dam was the first constructed in 1934, and eliminated the flow from the West Nakdong River

Fig. 1. Detailed study area map showing location of the Nakdong Estuary within South Korea and all core sampling locations and cross sections shown in Figs. 8 and 9. Noksan, Nakdong, and Daejeh Dam locations, channel names, barrier islands, and industrial (ID) and residential districts (RD) are indicated (WG = Western Floodgate, CG = Control Floodgate, MG = Main Floodgate, JN = Jinudo, DM = Daemadeung, JA = Jangjado, BH = Bakhabdeung, SN = Sinjado, DY = Doyodeung, NM = Namutsitdeung, and MG = Maenggeummeorideung).