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Effects of in-channel sand excavation on the hydrology of the Pearl River Delta, China

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Summary The hydrology and morphology of the Pearl River Delta (PRD; South China) water system has been predominantly dictated by human activities over the last 20 years. Uncontrolled sand excavation occurred in all 324 tributaries, largely to meet the construction needs arising from the rapid economic growth and urbanization in the region. It was estimated that $>8.7 \times 10^8$ m^3 of sand were excavated from 1986 to 2003 based on field surveys of excavating activities and the river hypsography, resulting in average downcutting depths of 0.59–1.73 m, 0.34–4.43 m, and 1.77–6.48 m in the main channels of the West River, North River, and East River (three major water networks in the PRD), respectively. Consequently, the water levels in upstream of the PRD were decreased by 1.59–3.12 m (Sanshui Station). Uneven sand dredging also caused changes in the divided flow ratio (DFR) between various water courses. For example, the DFR increased by 8.8% at the Sanshui Station on the upper part of the North River network from the early 1980s to 1999. DFRs also increased almost 7.7% at the four major runoff outlets in the eastern side of the PRD. As a result, present brackish-water has intruded upward 10–20 km more than in the 1980s. Apparently, there are two sides to the effects of sand excavation. The positive effects are decreased chances of flooding damages, improved navigating conditions, and more water inputs to rapid economically growing regions. The negative effects include increased grade slope and instability of the riverbank, disruption of navigation in upstream dredging pits during dry seasons, and brackish-water intrusion.

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Introduction

The Pearl River Delta (PRD), located in South China and adjacent to the South China Sea (Fig. 1), has become one of the fastest economically growing and urbanizing regions in China and around the world during the last 20 years. Extensive anthropogenic activities have brought about numerous environmental concerns within the PRD. In particular, river water contamination has been a subject of many research efforts (Ho and Hui, 2001; Mai et al., 2002). However, an important issue that has been largely neglected is the large-scale dredging and excavation of river sand, which in turn would affect the morphology of river channels within the PRD and related geomorphic processes. Consequently, it would result in substantial hydrological deformation (Luo et al., 2002).

As reported by Lagasse and Winkley (1980), more than 4.26×10^7 metric tons of sand and gravel were removed from the upper Mississippi River basin in 1950, and by 1960 the production had almost doubled to 8.35×10^7 metric tons. These authors underscored the importance of the coarser fractions of the bed material as a bed surface armor layer to the stability of river systems. They also concluded that gravel dredging in the lower Mississippi River could cause major changes in bed degradation, resistance to flow, flood heights, groundwater tables, and aquatic habitats.

Some researchers applied mathematical models to evaluate river channel changes and the responses of fluvial processes to in-stream mining (Chang and Stow, 1989; Cotton and Ottozawa-Chatupron, 1990). Other researchers studied the behavior of mining pits (Gill, 1994; Lee et al., 1993; Li and Simons, 1979). Through hydraulic model tests and field investigations along the Danube River in Hungary, Kornis and Laczay (1988) suggested that a dredging pit must not be made shorter than the channel width nor wider than about half the channel width to avoid undesirable flow disturbance and bed erosion. Mas-Pla et al. (1999) examined the effects of gravel mining on the aquifer-river system in the coast of the Baix Fluvià area (NE Spain) and showed that in-stream mining caused a decline of the water-table head resulting in salty-water intrusion from the river into the aquifer. Han et al. (2005) scrutinized the impact of sand excavation on the hydrological regime in the East River network of the PRD, and the results showed that changes in the river regime parameters, such as lowering of water levels, alteration of surface water and groundwater recharge,

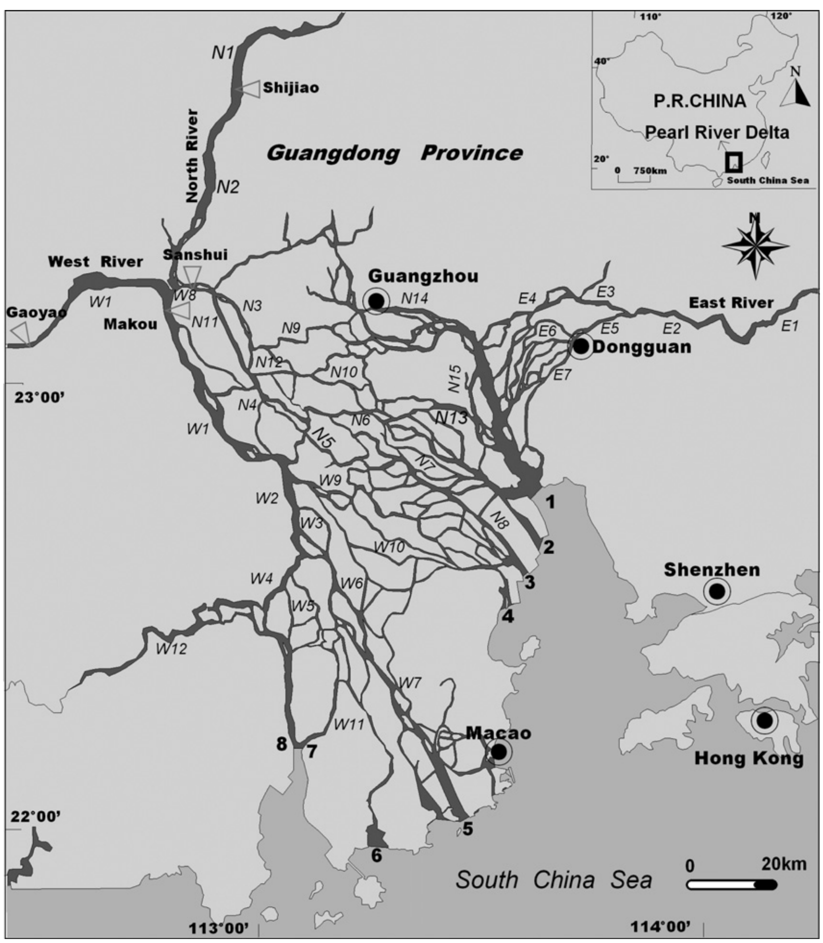

Figure 1 Map of the Pearl River Delta and its river network. N1—N15, W1—W12, and E1—E7 are the channels or reaches of the North River network, West River network, and East River network, respectively; Numbers 1—8 indicate the eight river runoff outlets connecting the Pearl River Delta to the South China Sea, include Humen, Jiaomen, Hongqimen, Hengmen, Modaomen, Jitimen, Hutiaomen, and Yamen going from east to west. The triangle symbols represent the locations of the hydrologic stations.