Estuarine, Coastal and Shelf Science xxx (2016) 1–13

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Field studies of estuarine turbidity under different freshwater flow conditions, Kaipara River, New Zealand

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ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form
15 April 2016
Accepted 19 June 2016
Available online xxx

Keywords:
Estuarine sediments
Turbidity
Tides
Salinity gradients

ABSTRACT

We present a first interpretation of three days of measurements made in 2013 from the tidal reaches of the Kaipara River (New Zealand) under both low and high freshwater inputs and a neap tidal cycle. During the first day, we occupied two stations that were approximately 6 km apart in a tidal reach that runs for 25 km from the river mouth to the upstream limit of tidal influence. During the second day, longitudinal surveys were conducted over a distance of 6 km centred on the upstream station. The data reveal a turbidity maximum in the form of a high-concentration 'plug' of suspended mud that was advected downstream on the ebbing tide past the upper (HB) measurement station and which exchanged sediment with the seabed by settling at low slack water and by resuspension in the early flooding tide. The data suggest that fine sediment is transported landwards and trapped in the upper part of the tidal reach under these low-flow conditions. On the third day of measurements we repeated the experiments of the first day but later in the year, for a much higher freshwater flow. This interpretation of our data set highlights the potential contribution of a range of processes to the generation of the observed suspended-sediment signals, including resuspension of local bed sediment, advection by the tidal current, settling of suspended sediment over a long timescale compared to the advection timescale, advection of longitudinal gradients in suspended sediment, and suppression of vertical mixing by density stratification of the water column. The level of temporal and spatial detail afforded by these measurements allows a much clearer understanding of the timing and importance of vertical stratification on the transport of suspended particulate matter than is generally possible using fixed-point sensors.

1. Introduction

Estuaries are commonly centres of population and commerce. The availability of water, access to trade routes and to points further inland, and sources of food and materials mean that the careful management of estuaries is central to economic growth and development. Of particular concern are the effects of human activities on the natural functioning of estuaries and the services that they provide. The dredging of channels and the management of muddy intertidal regions both require an understanding of the physical processes that govern the transport of fine sediments in regions that can be some distance away from the open sea where the adjacent coastline is subject to a high tidal range (Wu et al., 2004; Schuttelaars et al., 2013; de Jonge et al., 2014). In some cases, canalisation and land reclamation over several centuries have forced estuaries to form within long tidal rivers, subject to the influences of the processes that occur at the fresh–saltwater interface (Uncles and Stephens, 1993). When such systems are subject to stressors such as increased sediment loading, drought, and freshwater abstraction, this can affect the balance of processes controlling sediment erosion, transport and deposition, all of which need careful management. The presence of high concentrations of suspended material can also adversely affect primary production via reduced light penetration (Obrador and Pretus, 2008; Pedersen et al., 2012). Here, we focus on the response of the turbidity maximum in a narrow, shallow system subject to the influences of the fresh–saltwater interface and increased inputs of fine sediment from the landward side. As with all such studies, the provision of good quality data is essential for calibrating numerical models that underpin the decisions made by managers on the long-term sustainability of estuarine systems under rapidly changing environmental conditions.

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http://dx.doi.org/10.1016/j.ecss.2016.06.009
0272-7714/

Please cite this article in press as: Mitchell, S.B., et al., Field studies of estuarine turbidity under different freshwater flow conditions, Kaipara River, New Zealand, Estuarine, Coastal and Shelf Science (2016), http://dx.doi.org/10.1016/j.ecss.2016.06.009

We present a preliminary interpretation of measurements of a turbidity maximum (TM) from the tidal reach of the Kaipara River, which drains an area to the west of the city of Auckland, on the North Island of New Zealand (Fig. 1(a)). To our knowledge this is the first report of its kind on the TM-related sediment dynamics of this or any nearby tidal system. The system has much in common with other estuarine systems in New Zealand in that since European colonisation there has been a considerable increase in the amount of sediment it receives from terrestrial sources, which has been primarily due to large-scale catchment deforestation (e.g., McGlone, 1983; Page and Trustrum, 1997), with concomitant increases in estuarine sedimentation rates (e.g., Hume and McGlone, 1986; Goff, 1997; Addington et al., 2007). This data set from the Kaipara river was obtained in early 2013 during a period of prolonged low rainfall, which caused a migration of saline water inland under certain tidal conditions. Apart from the lack of data on this or similar systems, the novelty of this work lies in considering the temporally and spatially varying details of the structure of the salinity and concentrations of suspended material together with the velocity, over depth, in a system subject to the sudden arrival of relatively newly eroded material.

In more general terms it is well known that turbidity maxima are usually highly mobile, both over individual tides and over longer time scales in response to changing patterns of freshwater flow (Doxaran et al., 2009) and sediment input (Jiang et al., 2013). It is also known that the nature and location of the fresh–saltwater interface in a tidal river can influence the transport of fine sediment which then dictates where the TM will be and what form it will take. The magnitude, location and persistence of vertical, saline-induced density gradients affect both the vertical velocity gradient and the net tidal transport of fine material (Geyer, 1993; Liu et al., 2009; Burchard and Hetland, 2010). Both of these can be measured with some precision provided the conditions allow it, and both are affected by the twin drivers – sediment inputs and freshwater runoff – of interest here.

Our aim is to understand the extent to which the TM becomes trapped in the tidal reach of the Kaipara River under conditions of low freshwater runoff, and to provide a preliminary assessment of the relative importance of the mechanisms involved in its entrapment and subsequent migration downstream. The data were obtained on three days in 2013, on 19 February, 5 March, and 4 July, when we measured velocity, suspended sediment concentration and salinity in mid-channel over the whole depth of flow at 15-min intervals through the tidal cycle. On all three days the tide was neap; on the first two days the freshwater runoff was very low, but on the third day the freshwater flow was much higher. Clearly, a numerical model of the type used by many previous authors would be useful in isolating the mechanisms involved, but by using high-resolution spatial and temporal measurements it is possible to visualise the processes involved more clearly than would be

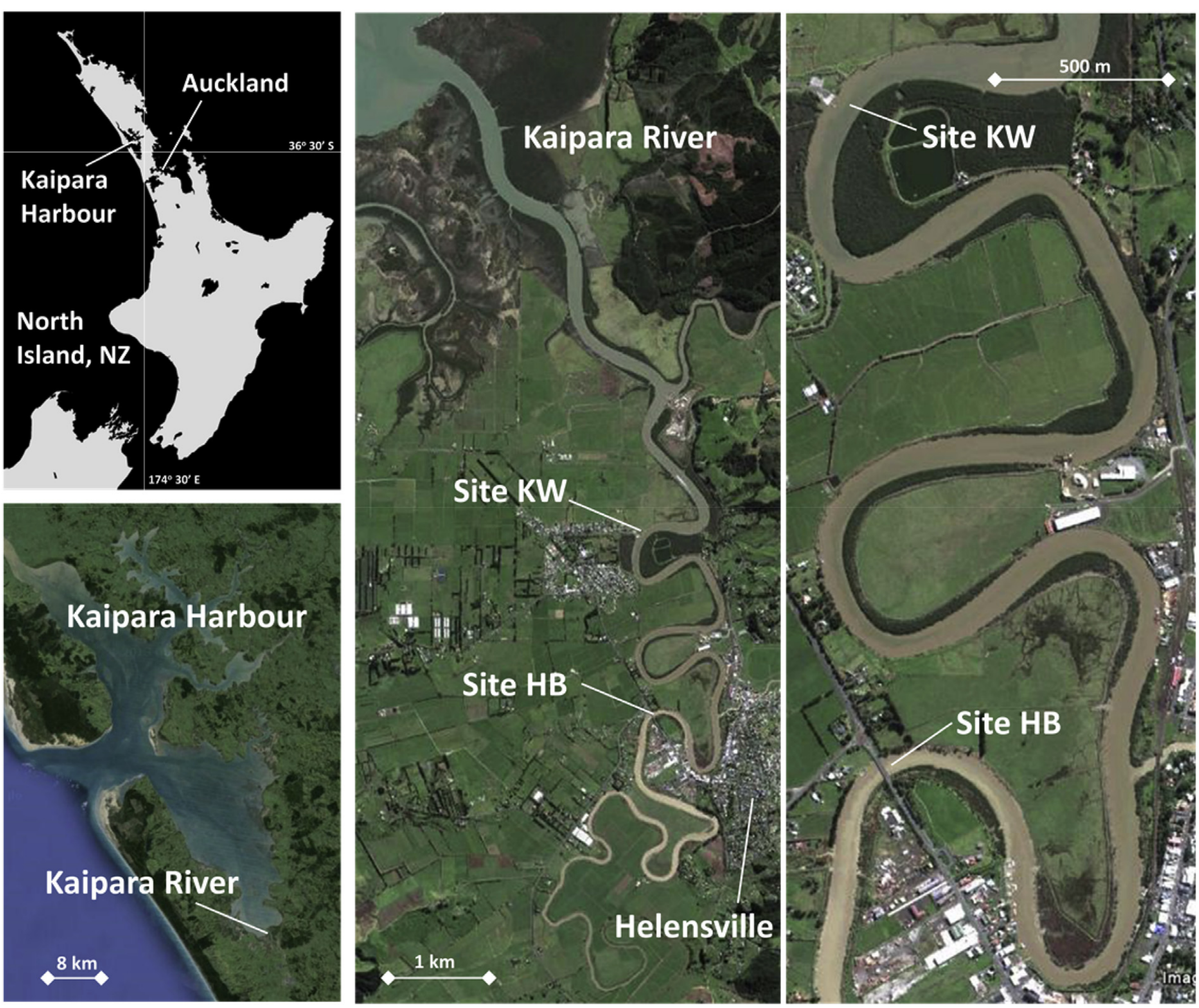

Fig. 1. Map of study site.

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