Chapter 9

CONTROLS ON ESTUARINE SEDIMENT DYNAMICS IN MERRYMEEETING BAY, KENNEBEC RIVER ESTUARY, MAINE, U.S.A.

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1. INTRODUCTION

Over the past several decades, estuaries have earned a reputation as sediment sinks through the theoretical and empirical works of many scientists (e.g. Postma, 1967; Pritchard, 1967; Meade, 1969, 1972, 1982; Biggs, 1970; Biggs and Howell, 1984; Schubel, 1984; Knebel, 1989; Dalrymple et al., 1990). These studies have documented the combined roles of sediment influx rates, sea-level rise, climate, and estuarine circulation as the dominant controls on estuarine infilling (Schubel, 1984). However, aspects of most of these models (e.g. distance-velocity asymmetry and settling lag and scour lag) only consider the movement of fine-grained sediments (<100 μm) capable of suspension or transport-limited systems in which estuarine sediment supply is greater than the transport capacity (Milliman and Meade, 1983). Much less is known about the dynamics (i.e. estuarine processes and time scales responsible for sediment fluxes) within fluvial-estuarine transition zones with respect to bedload sediment transport (Milliman and Meade, 1983).
Moreover, studies of bedload sediment transport near the mouths and entrances to the large estuaries have revealed a net landward bottom transport direction of coarse-grained sediments (Meade, 1969; Sherwood et al., 1984; Knebel, 1989; Nichols et al., 1991; Fenster, 1995), sand circulation cells (Ludwick, 1970, 1972), and/or mutually exclusive ebb-flood transport paths (Harris, 1988). Some studies conducted within estuary-flood channels have indicated that even freshwater floods cannot provide enough energy to deliver sand to coastal or inner shelf environments (Bryce et al., 1998).

Fewer studies have provided evidence that estuaries can serve as sand sources for mainland and barrier beaches (Horne and Patton, 1989; Cooper, 1993, 2002; Fenster et al., 2001; FitzGerald et al., 2004). Fenster et al. (2001) pointed out that variations in estuarine geometries and dynamics produce differences in bedload sediment transport regimes. In particular, ebb-dominance occurs primarily through spring snowmelt floods (freshets) in mesotidal, high-latitude, narrow, rock-bound estuaries (e.g. Fenster et al., 2001). Similar results have been observed during extreme floods in microtidal, tide-dominated estuaries (Cooper, 2002). On the other hand, flood-dominance occurs within long, coastal plain estuaries where sea-level rise and bi-directional transport dominate (e.g. Knebel, 1989).

Empirical data from the lower 27 km of the Kennebec River estuary, Maine, USA, have shown that the estuary provides coarse-grained sediment to the nearshore and coastal region of south-central Maine (Fenster and FitzGerald, 1996; FitzGerald et al., 2000; Fenster et al., 2001). These studies showed that the relationship between freshwater discharge and tidal range could predict annual bedload transport fluxes through the Kennebec River estuary. In particular, for the Kennebec River estuary, seaward transport occurs when discharge values exceed the threshold range of 225-325 m$^3$ s$^{-1}$, independent of tidal range. These conditions occur during spring freshets which produce an ebb-dominated velocity asymmetry that flushes sediment from the Kennebec River estuary to the nearshore, and contributes to the formation and maintenance of barrier complexes (FitzGerald et al., 2000). Other New England estuaries, such as the Saco, Merrimack, and Connecticut River estuaries, function similarly (Horne and Patton, 1989; FitzGerald et al., 2004). Consequently, these findings provide empirical evidence that could augment existing conceptual and morphological models that are based on, but do not fully account for, net seaward sand transport in the relative contributions of marine and fluvial processes (Dalrymple et al., 1992; Fenster and FitzGerald, 1996; Fenster et al., 2001).

Less is known about sediment transport processes in the relatively low-energy central zone of net ebb-dominated estuaries. If net landward transport occurs in the marine-dominated, outer estuary and net seaward transport takes place in the river-dominated, inner estuary, then the mixed-energy, central zone should serve as an area of net convergence for sediment in the