Estuarine, Coastal and Shelf Science 150 (2014) 196–214

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

The geomorphology of UK estuaries: The role of geological controls, antecedent conditions and human activities

Kenneth Pye [a, b, *], Simon J. Blott [a]

[a] Kenneth Pye Associates Ltd, Blythe Valley Enterprise Centre, Central Boulevard, Blythe Valley Park, Solihull, West Midlands B90 8AJ, UK
[b] Ocean and Earth Sciences, University of Southampton Waterfront Campus, European Way, Southampton SO14 3ZH, UK

ARTICLE INFO

Article history:
Accepted 23 May 2014
Available online 2 June 2014

Keywords:
geomorphology
morphometry
estuaries
geological controls
human activities

ABSTRACT

This paper provides an overview of the geomorphological characteristics of UK estuaries and the factors which control them. Many of the features included in previous classifications of UK estuaries are not true estuaries since they do not possess significant river influence. The features considered in this paper to be 'true' estuaries are divided into 'restricted entrance' and 'unrestricted entrance' types on the grounds that the size and geometry of the estuary mouth exerts a critical influence on water levels, tidal currents, wave action, sediment transport and morphological evolution. An estuary which has a wide mouth, narrows and becomes shallower towards the head is likely to be flood dominated, especially if it has a large tidal range, whereas an estuary which has a narrow mouth and widens and/or becomes deeper towards the head is more likely to display ebb dominance, especially if it has a relatively small tidal range. Wide-mouthed estuaries are influenced to a greater degree by wave processes than estuaries with a narrow mouth. Previous authors have hypothesised that estuaries may maintain a state of dynamic equilibrium through alternating periods of flood and ebb dominance, but it is concluded that there is presently no substantive evidence to support this hypothesis. UK estuaries have been affected to varying degrees by embanking, land claim, dredging, sea wall breaching and managed realignment. Some estuaries have adjusted quickly to such perturbations, but others continue to show progressive change, either sedimentary infilling or erosion and sediment loss. The quantification of estuary morphometry, identification of change over time, and testing of hypotheses regarding the morphodynamics and stability of estuaries requires adequate bathymetric/topographic, hydrodynamic and sediment data. At present, such data are available for relatively few UK estuaries.

1. Introduction

The principal aim of this paper is to provide an overview of the current state of understanding of the geomorphology of UK estuaries, including small estuaries which are defined here as those which have an active tidal area (at HAT level) above the mouth of <50 km^2. Subsidiary objectives are to review the definition and classification of estuaries, to summarise the geomorphological characteristics of UK estuaries, to highlight the importance of geological controls, antecedent history, postglacial sea-level rise, tidal characteristics, sediment availability and human activities on their morphological development, and to highlight the inadequate nature of currently available morphometric, process and sediment data which acts as a severe constraint on estuary modelling and management.

Confusion remains regarding the physical nature, and even the definition, of estuaries, and there is no agreement regarding the physical features of estuaries which should be measured and monitored in order to allow assessment of their present 'condition', or the potential effects of future climate change and human activities.

2. The definition of estuaries and estuary types

There have been many previous attempts to define and classify estuaries from differing points of view (e.g. Cameron and Pritchard, 1963; Pritchard, 1967; Caspers, 1967; Fairbridge, 1980a,b; Dalrymple et al., 1992; Cooper, 1993; Dyer, 1997; Perillo, 1995; Healy, 2005; Townend, 2005) but all suggested schemes have their limitations. Some authors have considered the term "estuary" to be synonymous with "inlet", "bay", "sound" or "lagoon", and the term

* Corresponding author.
E-mail addresses: k.pye@kpal.co.uk (K. Pye), s.blott@kpal.co.uk (S.J. Blott).

http://dx.doi.org/10.1016/j.ecss.2014.05.014
0272-7714/

"freshwater estuary" has been used, notably in the Great Lakes region of North America, to describe the transition zone where a river enters a lake, and where mixing of freshwaters with slightly differing chemical characteristics takes place (e.g. Sapper, 2008). However, the term 'estuary' derives from the Latin *aestuarium* for tidal channel (Pearsall and Trumble, 1996), and many geomorphologists view estuaries essentially as the tidal mouths of rivers (e.g. Pethick, 1984).

Cameron and Pritchard (1963) defined an estuary as "a semi-enclosed body of water which has a free connection with the open sea and within which sea water is measurably diluted by freshwater from land drainage". This definition does not include the lower tidal reaches of rivers where water levels are influenced by tidal forcing but the water is fresh, except during storm surges (e.g. Schuchardt et al., 1993), and most geomorphologists, sedimentologists and oceanographers would place the landward boundary of an estuary at the normal limit of tidal influence, regardless of salinity (e.g. Dyer, 1997).

One of the earliest classifications (Pritchard, 1952) recognised four principal estuary types: (1) *coastal plain*; (2) *fjords*; (3) *bar-built*; and (4) *tectonic* estuaries. The classification was developed in relation to 'estuaries' in the United States (US), but has since been applied more widely. *Coastal plain* estuaries are essentially drowned river valleys set within a wide coastal plain, for example Chesapeake Bay and Delaware Bay in the eastern US (Valle-Levinson, 2010). *Fjords* result from marine flooding of glacially over-deepened troughs, and there are numerous examples in the north-western US, Alaska, Canada and northern Europe. *Bar-built* estuaries represent situations where submerged valleys or bays have been partially enclosed by the development of a bar or spit across the entrance. *Tectonic* estuaries result from faulting and land subsidence; examples cited by Valle-Levinson (2010) include San Francisco Bay, Manukau Harbour in New Zealand and the rias of northwest Spain. However, many of the features included within the Pritchard (1952) 'estuary' classification, and its derivatives, are not estuaries according the strict definition adopted in this paper which requires significant river influence, not only in terms of salinity but also sedimentary processes and morphological development. Tidal inlets, bays, lagoons straits and sounds, which receive little or no freshwater, are regarded here as separate types of water body (Fig. 1). However, a clear distinction between estuaries and tidal inlets, bays, lagoons and deltas is not always possible since a continuum of process domains and landforms exists (Davies, 1977; Dalrymple et al., 1992).

In this paper, the term *inlet* is used to describe an indentation of the coastline, often narrow relative to its length, which receives little or no freshwater input, but which may possess intertidal and subtidal morphological features, including marshes, tidal flats, banks and channel systems, which are also found in estuaries (Fig. 1a and b). Coastal indentations which are wide relative to their length are referred to here as *bays*. Some previous authors have preferred to use the term 'inlet' to describe tidal passages between, or within, coastal sedimentary barriers (e.g. Fitzgerald, 2005). However, many large coastal indentations around the world bear the name 'inlet', including Cook Inlet in Alaska and the Hunt, Surf and Knight Inlets in British Columbia. Dionne (1963) stated that "an estuary is an inlet of the sea, reaching into the river valley as far as the upper limit of tidal rise, usually being divisible into three sectors: (a) a marine or lower estuary, in free connection with the open sea; (b) a middle estuary, subject to strong salt and freshwater mixing; and (c) an upper of fluvial estuary, characterised by freshwater but subject to daily tidal action". Allen (1992) also defined an estuary as "a generally narrowing elongated inlet reaching across a coastal plain or inward along a river valley as far as the upper limit of tidal rise". An estuary can therefore be regarded as a type of inlet which has a river at its head or on its margins. Coastline inlets without rivers are readily distinguishable from smaller-scale tidal passages between barrier islands or spits, which are referred to here as *barrier inlets*.

The presence of waters with a range of salinities is an essential qualifying feature of an estuary. However, the range of salinities and degree of mixing vary greatly, even within a single estuary,

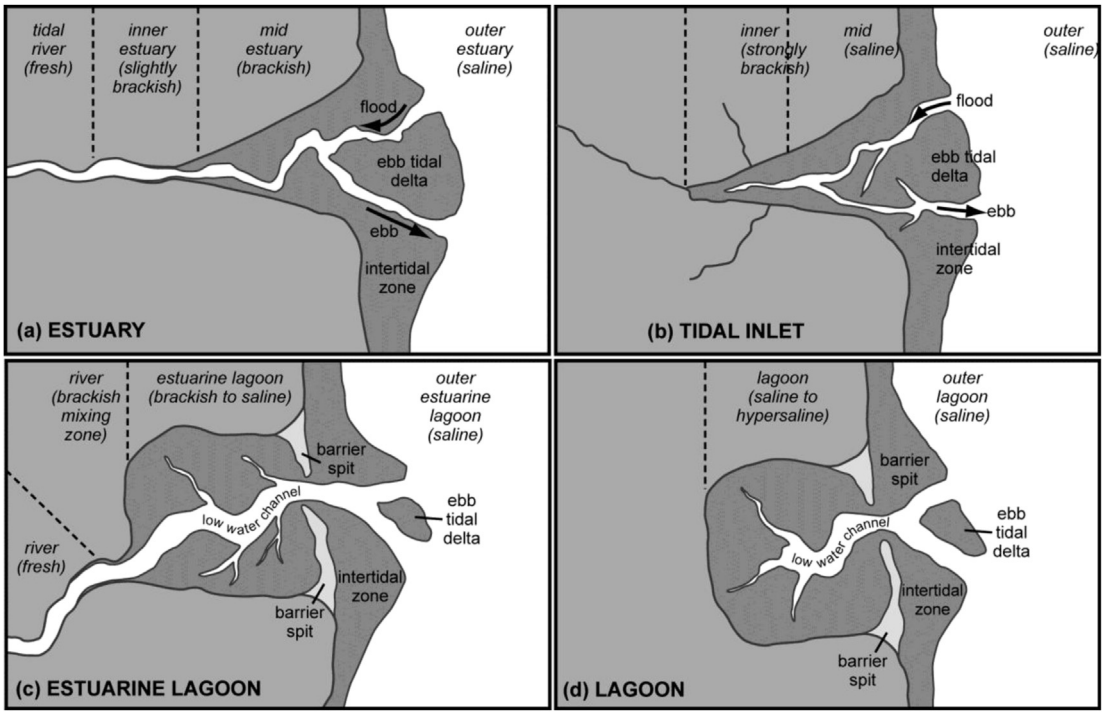

Fig. 1. Schematic diagrams showing the principal features of (a) an idealised funnel-shaped estuary, (b) an idealised tidal inlet, (c) and idealised estuarine lagoon, and (d) an idealised lagoon.