ESTUARIES

How estuaries grow old

Terry Hume
Andrew Swales

Have you ever wondered how estuaries have formed and if they will eventually fill up with sediment and die?

Estuaries in New Zealand have not always looked like they do today. These semi-enclosed coastal water bodies, where land drainage mixes with the sea, began life about 6500 years ago, when climatic warming caused sea level to rise some 150 m to its present level. The sea level rise drowned an ancient and varied landscape. So, in the Auckland region, the seabed of present-day Hauraki Gulf was once a broad alluvial plain with meandering river channels incised into it and the coast was out beyond Great Barrier Island. In south-west New Zealand, the landscape was dominated by deep U-shaped valleys cut by glaciers. The "proto-estuaries" that formed as sea-level rose were very different from those we see today because since that time they have filled with sediment and grown old.

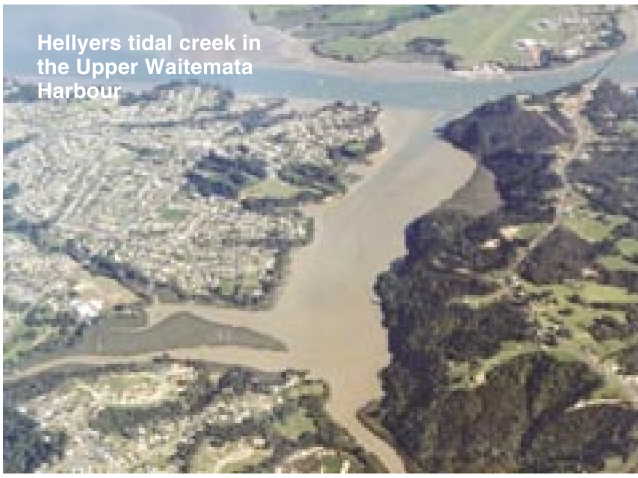
The aging process

The geomorphology of today's estuaries depends on the shape of the landscape that was flooded by the sea, and on how estuaries have been subsequently modified by sediment infilling. First, the shape and size of the flooded basin determine how much sediment can accumulate. Second, the pattern of infilling is controlled by the interaction of stream/river processes, tidal exchange and waves. An important point is that estuaries infill with sediment derived from both the land and the sea.

Map showing locations of estuaries mentioned in the text.

The variety of landscapes that were flooded by the sea and the many paths the aging process can take are the primary reasons we have so many different types of estuaries in New Zealand, as the following examples show.

- There will have been rapid aging where the sea drowned deeply incised landscapes and there has been abundant soil runoff from the land. Examples are drowned valleys such as the Mahurangi, Waitemata and Otago harbours. Here, thick sequences of sediments have accumulated rapidly in deep basins to develop into low-gradient intertidal flats. Tidal creeks in the upper reaches of such estuaries have infilled with many metres of mud.
- In contrast, the drowned valleys of the Marlborough Sounds have aged more slowly despite runoff from large catchments. Infilling has been most visible in the headwaters, where marshes have developed. But the steep-sided, deep Sounds provide copious storage space for sediment. Furthermore, estuarine flow and stratification of the water (layering according to temperature and salinity) help to ensure that sediment-laden river water is transported as a surface layer and dispersed well down the estuary.



Hellyers tidal creek in the Upper Waitemata Harbour

- Where drowned valley estuaries emerge onto a sheltered coastline with little sediment drift (for example, Auckland's Waitemata and Mahurangi harbours) there is little infilling from the sea and sandy shoals (tidal deltas) don't form at the mouth.
- In contrast, on the exposed west coast, ocean swells and sediment drift build shoals of marine sands at the mouths of large harbours such as the Hokianga.
- Tides and infilling from the sea play a major role in the growth and aging of shallow tidal lagoons such as Tauranga Harbour, Whangarae Estuary and the Avon Heathcote Estuary. In these systems, river inputs are small relative to tidal flows. Here, sand driven along the open coast by

Mahurangi Harbour, a drowned-valley estuary.

Terry Hume and Andrew Swales are based at NIWA in Hamilton.

waves is captured by the tidal flows at the entrance to build sand bodies outside the entrance and inside the bay. A quasi-equilibrium develops between sand being captured and stored in the shoals and sand being released back to the open coast. The middle parts of the lagoons contain a mixture of marine and catchment-derived material, the thickness of which depends on the topography of the original landscape that was drowned. Many of these landscapes were originally shallow embayments and today they have largely infilled so that when the tide goes out extensive areas of intertidal flats are exposed. Interestingly, sedimentation can slow down late in the infilling process because there is no opportunity for deposition when the tide is out, and when wind-generated waves stir the seabed, sand is remobilised and transported out to sea.

- River-mouth estuaries age differently. These systems, such as the Mokau River (right), are short and narrow and have little space for sediment. So it is surprising that these estuaries age slowly, in spite of having large catchments. The reason is that floodwaters and suspended sediment are quickly jetted though the system to the sea, bypassing the estuary. Little sediment enters river mouth estuaries from the sea because the flows in the estuary are directed seawards for most of the time. Floodwaters also scour the bed, prolonging the life of river mouth estuaries.
- Some estuaries don't show their age. The fiords of Fiordland, for instance, have changed little since the "great flood" because sediment build-up is insignificant in these very deep (200–300 m) and steep-sided water bodies. Furthermore, there is relatively little sediment runoff from the heavily forest-clad catchments, despite the very large rainfall and runoff.

Factors that accelerate aging

The aging process can be dramatically accelerated by biological and anthropogenic factors. The colonisation of intertidal areas by fringing vegetation, such as mangroves or salt-marsh rush (*Juncus*, for example), speeds up infilling. Fringing vegetation reduces local currents, which encourages sedimentation. Therefore, fine sediment becomes trapped on the intertidal areas. Fortunately, the infilling slows down in the final stages of this process, prolonging estuary longevity.

Human activities, in particular catchment deforestation and rapid urbanisation in the last 150 years, have had pronounced effect on the aging of some estuaries. Some effects are obvious, such as reclamation of estuary margins for farmland or ports, or construction of causeways for roading and rail. Some anthropogenic effects are more subtle, such as increases in catchment sediment runoff associated with land-use change.

We know that increased runoff from catchment clearance associated with logging, agriculture and urban development has greatly increased sedimentation rates and infilling in estuaries, especially during floods (see pages 11–13 in this issue for more details). However, wise land-use practices such as avoiding large-scale land clearance and maintaining riparian vegetation may help minimise these effects.

Whangarae estuary, a small tidal lagoon near Nelson.

You can watch the daily changes at the Mokau River mouth on NIWA's Cam-Era system (www.niwa.co.nz/services/cam-era/sites/mokaua/)

What does the future hold?

For some very deep estuaries such as fiords there will be little observable change in the next few centuries or millennia. Other small, shallow systems, such as Hot Water Beach and Waikawau (eastern Coromandel Peninsula) will infill with sediment and die. In these situations the upper reaches of the former estuary are now farmland and the lower reaches are so choked with marine sands that the sea only enters at high tide. We expect estuary infilling to be partly offset by sea-level rise associated with climatic warming, which will deepen estuaries by about 2 mm/yr, and by the sea flooding low-lying margins which will evolve to marsh and then tidal flats. However, in many places this will not be allowed to happen as the shores of farmland are stopbanked to prevent flooding and property loss. Thus, anthropogenic processes and climate change make the future for estuaries rather uncertain and human activities mean that some estuaries will not be able to grow old gracefully. ■

Teachers: this article can be used for Biology L7 A.O. 7.3(a) and NCEA AS 2.5, 2.9, 3.2, 3.4. See other curriculum connections at www.niwa.co.nz/pubs/wa/resources

Further reading

Bell, R.G.; Hume, T.M.; Hicks, D.M. (2001). Planning for climate change effects on coastal margins. A report prepared for the Ministry for the Environment as part of the NZ Climate Change Programme. MfE, Wellington. 73 p.