# The future of the estuaries of south-western Australia

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## Introduction

Professor Arthur McComb who preceded me on the occasion of this talk [acceptance of the "Kelvin" Medal of the Royal Society of Western Australia, July 1997] discussed his investigations of nutrient enrichment in the Peel-Harvey estuarine system. I recognise that eutrophication is still the immediate problem for estuarine management in Peel-Harvey, the Swan and a few other estuaries; however the sources of nutrients are now well known and I hope that eutrophication will soon prove to be a short-term problem for management, scientifically at least. My talk addressed some long-term management problems for the estuaries of southwestern Australia in the context of their history; their Holocene history and their history since 1829. It is a subject that has been rumbling round in my head since 1970 when I spoke about the history of the estuaries at an EPA seminar and Bruce Hamilton asked "How does this help us to manage the estuaries?" I had no answer then and am not sure what *practical* suggestions I can make now.

It is reasonable to assume that the future is likely to be a continuation of the past but only until something happens to change the rules. That is just what happened here with the arrival of "civilised" people whose traditional attitude to the environment was the Old Testament injunction to Noah: be ye fruitful, and multiply; bring forth abundantly in the earth, and multiply therein (Genesis 9-7) [King James version of 1611]. The estuaries of 1997 are no longer the estuaries that European settlers found in 1829, let alone the estuaries where Aborigines fished only 6000 years ago.

## Holocene History

All estuaries have been greatly changed by natural processes since they were flooded by the world-wide post-glacial rise in sea level about 6500 years ago, many of them much more than have ours in Western Australia. At that time the estuaries of the south west were 'textbook' estuaries where river water and sea water mixed tidally within the coastline; there was a salinity gradient up their length, and they had a diverse marine-estuarine benthic fauna. By about 3500 BP, catchment sediment had narrowed the riverine reaches, built river deltas, and shallowed the lagoon basins, and longshore drift of coastal sand had built the bars and flood-tide deltas that obstruct tidal exchange to the estuaries today.

The Swan-Canning, Peel-Harvey, Leschenault, Hardy and Nornalup Inlets, and Oyster Harbour are still open to the sea and tidal all the time (Fig 1). Physically they are permanently open (PO) estuaries, but hydrologically they are seasonal, river-flow-dominated estuaries with almost stagnant marine salinity water (36 ppt) for half the year, then are flushed with fresh (< 3 ppt) river water for the other half year (Fig 2). Ecologically, these long-term salinity extremes restrict the diversity of the benthic biota to the few euryhaline species that now flourish in them.

The Holocene transformation of estuaries resulted from a unique complex of physical features (Fig 3):

- sea level was initially at least 1 m higher than its present level;
- the estuaries were already enclosed by coastal barrier dunes (most lithified), with narrow entrances;
- the entrances were sheltered from the prevailing SW winds and swell by headlands or reefs;
- the astronomic tides are microtidal (0.5 m MHHW—MLLW); and
- river flow is highly seasonal (the climate is of Mediterranean-type).

Bar formation is a battle between river flow and the ocean process of littoral drift, and most of the 50 estuaries of the south west are now intermittent estuaries where the bars close periodically;

- seasonally — seasonally open closed estuaries (SO);
- for 3 to 5 years — normally closed estuaries (NC); or
- now permanently — permanently closed coastal lagoons (PC);

and the hydrological extremes are greater than in PO estuaries and the biota are less diverse, especially in NC and PC estuaries. Most purely riverine estuaries are SO.

This series of permanently open to permanently closed estuaries appears to be a natural sequence related principally to differences in the volume and pattern of river flow (see below). River flow to PO and SO lagoonal estuaries comes mainly from the high rainfall area (> 700 mm pa) of the south west where it is large and relatively reliable (except the Murchison River); the catchments of NC and PC estuaries receive < 700 mm mean annual rainfall and river flow is episodic. But the sequence is also related to differences in a) the degree of shelter to the entrances from the SW winds sand swell, b) the



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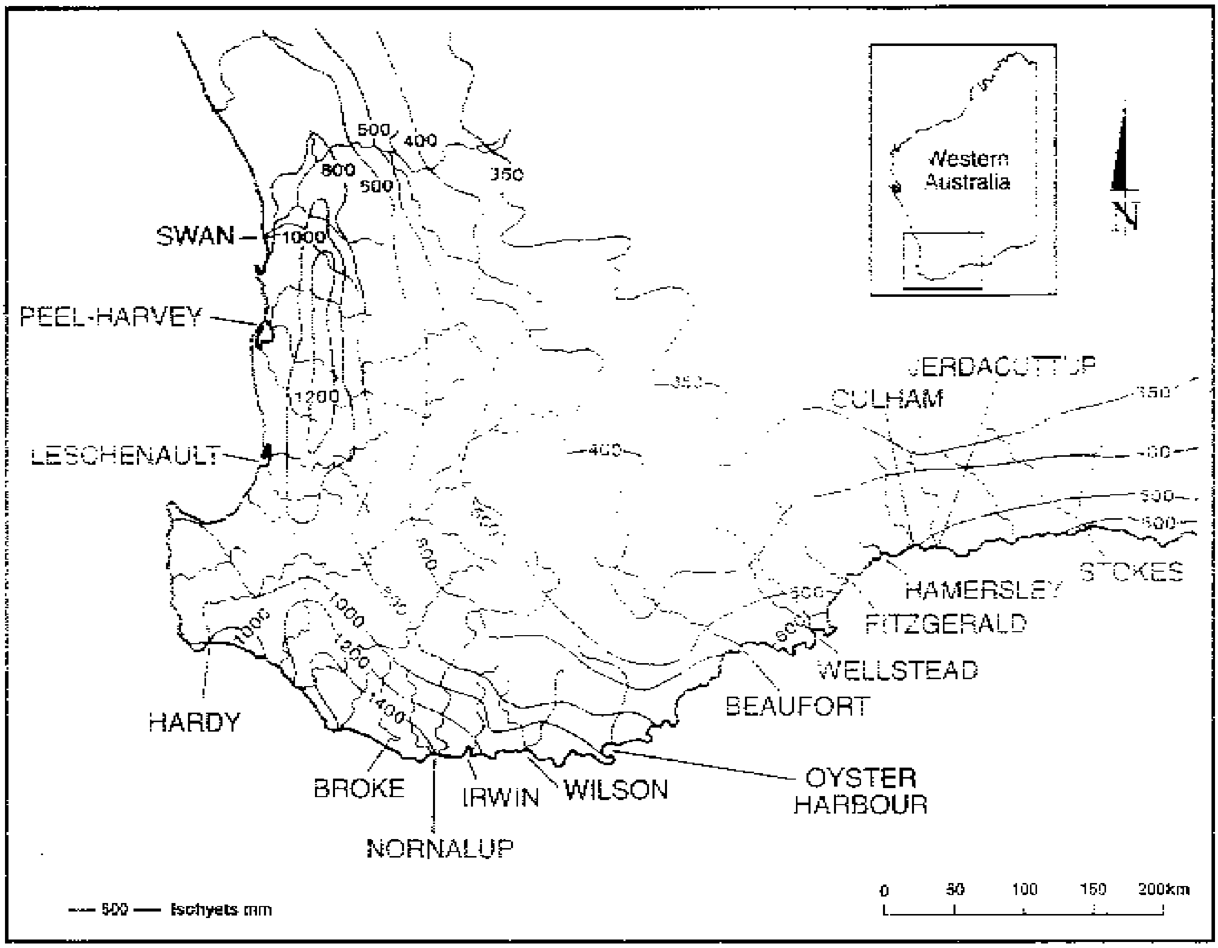


Figure 1. The principal estuaries of south-western Australia.

volume of flood flow relative to the available volume in the estuaries, and c) the volume of catchment sediment transported to the estuaries.

The Holocene history of the estuarine ecosystems of the south west is the subject of a paper by Hodgkin & Hesp (1998).

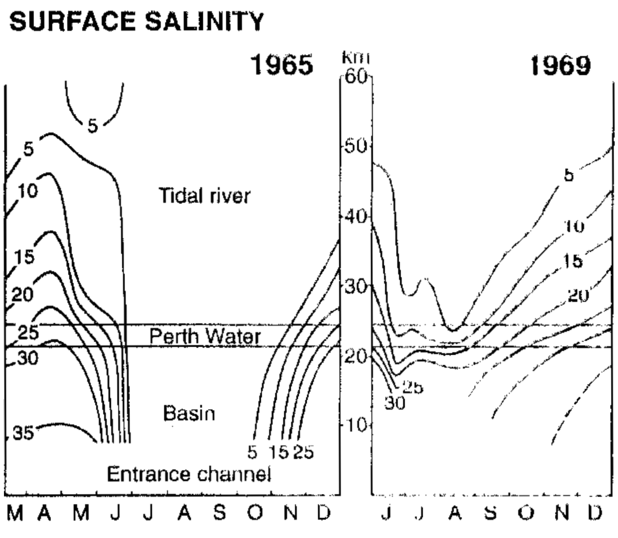


Figure 2. Surface salinity in the Swan Estuary.

**1827 to 1997**

In 1827 Captain Stirling's crew had to push their boats over the reef at the mouth of the Swan River, along a narrow channel through the flood-tide delta, and drag them through mud laced with fossil oyster shells in Perth Water. They then sailed the 35 km to Ellen Brook, where recently we had to drag our flat bottomed dinghy over sand bars for the last 5 km.

Last century, Perth's sewage poured into the Swan River via Claise Brook; this cannot have done much good for this seasonal estuary. But when C Y O'Connor constructed Fremantle Harbour in the 1890's, he not only greatly increased the tide range in the estuary from < 20% of the ocean tide to now 80% in Perth water, but also increased tidal exchange and tidal flushing of pollutants from the estuary and made it hydrologically a more marine environment .

Peel-Harvey is now a permanently open estuary, but until 1958 the Mandurah bar occasionally closed to water flow. For example, in May 1915, "the water was 20 inches below zero... very discoloured and there is a disagreeable smell along the western portion waters edge caused by stagnation and all floating matter is carried onto this shore by the prevailing winds" (Fisheries and Wildlife Department files). The Dawesville Channel has increased the tide range in the Harvey Inlet from 8% to 63% of the ocean tide, and in Peel from 12% to 45%; it

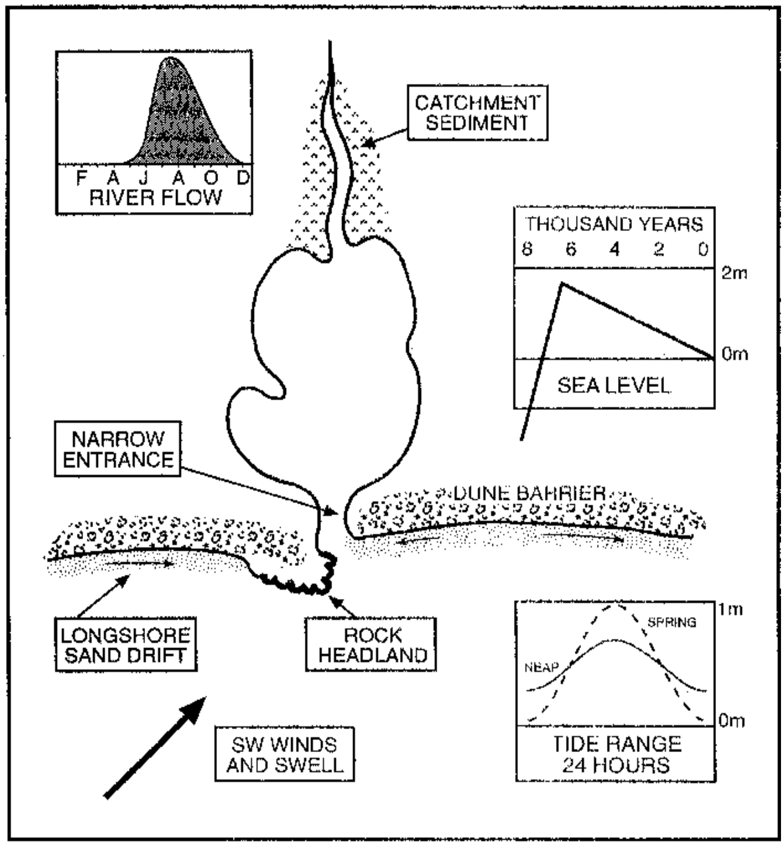


Figure 3. Environmental factors which have combined to transform lagoonal estuaries of south-western Australia during the Holocene.

has greatly improved tidal exchange and flushing and decreased mean residence time from 50 days to 17 days in the Harvey and from 30 days to 10 days in the Peel Inlet (Hart 1995). Bradby (1997) gives a fascinating story of the 'algal problem' in Peel-Harvey and the social and environmental history of the catchment, but it is still too soon to say what changes there have been to the ecology of the estuary.

It was probably not O'Connor's intention to increase tidal exchange in the Swan, and it was only to Bruce Hamilton I dared say in 1970 that if the 130 km$^2$ Peel-Harvey Estuary was to accommodate the rapidly increasing urban population around its shores and be a healthy estuary again, then it had to have a second channel to the sea. The Swan Estuary is now better flushed than it was last century and the Peel-Harvey Inlet is no longer on the road to being a seasonally closed estuary. I believe that the reversal of the natural process of bar building has made both estuaries now more ecologically sustainable environments.

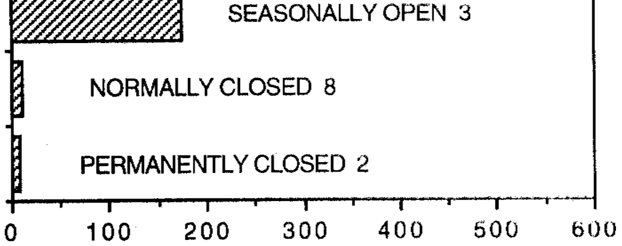


Figure 4. Mean river flow (x10$^6$ m$^3$ pa) to the different kinds and number of estuaries.

### Sedimentation

All estuaries are 'sediment traps' and are continually being filled with sediment, although that seems to have been a much slower process in our south west estuaries than in estuaries on the NSW coast where sediment has filled estuarine lagoons and left riverine channels winding through their deltas to the sea (Roy 1984). Nevertheless sedimentation is now probably the principal long-term process threatening our estuaries and their tributary rivers.

River flow now averages 570 M m$^3$ pa to the permanently open estuaries and 170 M m$^3$ pa to the seasonally open estuaries of the high rainall area (Fig 4). Most of the increased bed load from their low rainfall, now cleared, upper catchments is probably still in the river beds and has yet to reach the estuaries. However the suspended particulate matter is a nutrient-rich organic mud that drops out in the estuaries (and may be resuspended and go out to sea). It has enriched the estuarine ecosystems naturally, but with the application of artificial fertilizers to the catchments it has caused hyper-eutrophication. Within the lagoons, wave action resuspends marginal sediment and reshapes the contours, a slow natural process which extends the shallows that are probably the most productive areas. Several estuaries are being segmented in this way *e.g.* Harvey and Broke Inlets.

Normally closed estuaries of the low rainfall areas (< 700 mm pa) present a very different picture. Mean river flow is small (< 15 M $m^3$ pa), the bars break from flood flow once in every three to five years, and only remain open briefly. Sediment has already filled most of them almost to sea level. Some always hold water and are productive until the water becomes too hypersaline (*ca* 75 ppt) and the fish die (Beaufort, Wellstead and Stokes Inlets), but others dry up periodically (Gordon, Fitzgerald, Dempster and Hamersley Inlets). What is the long-term future for these normally closed estuaries? What should/can be done about them? Their future looked bleak even before there was clearing in their catchments and now appears to depend on the above environmental factors; degree of shelter to the entrances, volume of the estuaries relative to the volume of flood flow, volume and pattern of river flow, and the volume of catchment sediment transported to them.

There is probably little we can now do about the Beaufort and Wellstead Estuaries, but both the volume of river flow and the volume of catchment sediment to many estuaries have increased dramatically in proportion to the area cleared in the catchments. Clearing is estimated to have increased river flow to the Beaufort Estuary by more than ten times (Surface Water Branch, Water and Rivers Commission, unpublished data). That may have made the bars break more frequently, but not often enough to prevent the lagoons becoming hypersaline, and other estuaries drying up.

Clearing has increased sediment loss from the catchments, although there are few hard data on the rate of sedimentation in the estuaries. The Stokes catchment was cleared in the 1960s and 50-60 cm of wet sediment (20-25 cm dry) had settled in it in the 30 years to 1987; this is probably ten times the natural rate of sedimentation. The 1982 flood was estimated to have taken 100,000 $m^3$ of sediment from the Pallinup River to Beaufort Estuary. Such sedimentation rates foretell a rapid decline for these estuaries.

The now permanently closed estuaries (Culham and Jerdacuttup) are probably a lost cause as estuaries, but they could continue to be productive coastal lagoons were it not for human activities, as illustrated by the recent history of Culham (Hodgkin 1998).

### Management

Each estuary presents its own complex of management problems and decisions must be made in the historical context both of the long term natural processes that have slowly transformed them, and also in the context of the short term effects of human interference on them, and unfortunately in the context of conflicting social and economic pressures. So when were any of our estuaries last 'natural' ecosystems; was it in 1829, or 3000 years or 6500 years ago; and what should their future be? The decision to make the Dawesville Channel was made to reduce the load of plant nutrients in the Peel-Harvey Inlet by increasing tidal exchange to pre-1829 levels in a judgement that did not conflict with what we thought to have been the physical condition of the estuary at that time. However, the Swan-Canning estuary has been so greatly changed by Perth's burgeoning human population that its previous history is now largely irrelevant to management.

The three seasonally closed estuaries, Broke, Irwin and Wilson Inlets, present different management problems related principally to differences in volume of river flow, area of water, nutrient input and human demands on them.

As yet the normally closed Wellstead Estuary (sic) has been little affected by human activities, but the bar only breaks infrequently following episodic river flow from the low rainfall catchment; between breaks, evaporation lowers the water level to expose weed and mud, and the water becomes hypersaline. The residents of Bremer Bay town want to salvage their lovely estuary, although of course it hasn't really been an open estuary for about 3000 years. The easy answer is to "keep the bar open", but that could only be achieved at enormous cost because coastal sand drift fills channels almost as fast as bulldozers can dredge them.

### Conclusions

In recent years more consideration has been given to the welfare of the estuarine ecosystems of south-western Western Australia than in the past, but too often political and economic pressures still seem to be the primary considerations on which management decisions are made. The long-term future of these estuaries, and of the river systems of which they are a part, now lies largely with catchment management. What effect has catchment clearing had on them and in particular on sediment transport? Much can be learnt from the sediment record, both about the long-term and the short-term history of the rivers and estuaries. Sediments encode estuarine history and it only awaits decoding from sediment cores taken in the estuaries and on their floodplains to decipher both the Holocene and recent history of the estuaries.

The main message I would like to leave here is: please look beyond the problem of eutrophication when deciding how to manage these estuarine ecosystems and see the primary consideration for decision making as their future welfare.

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