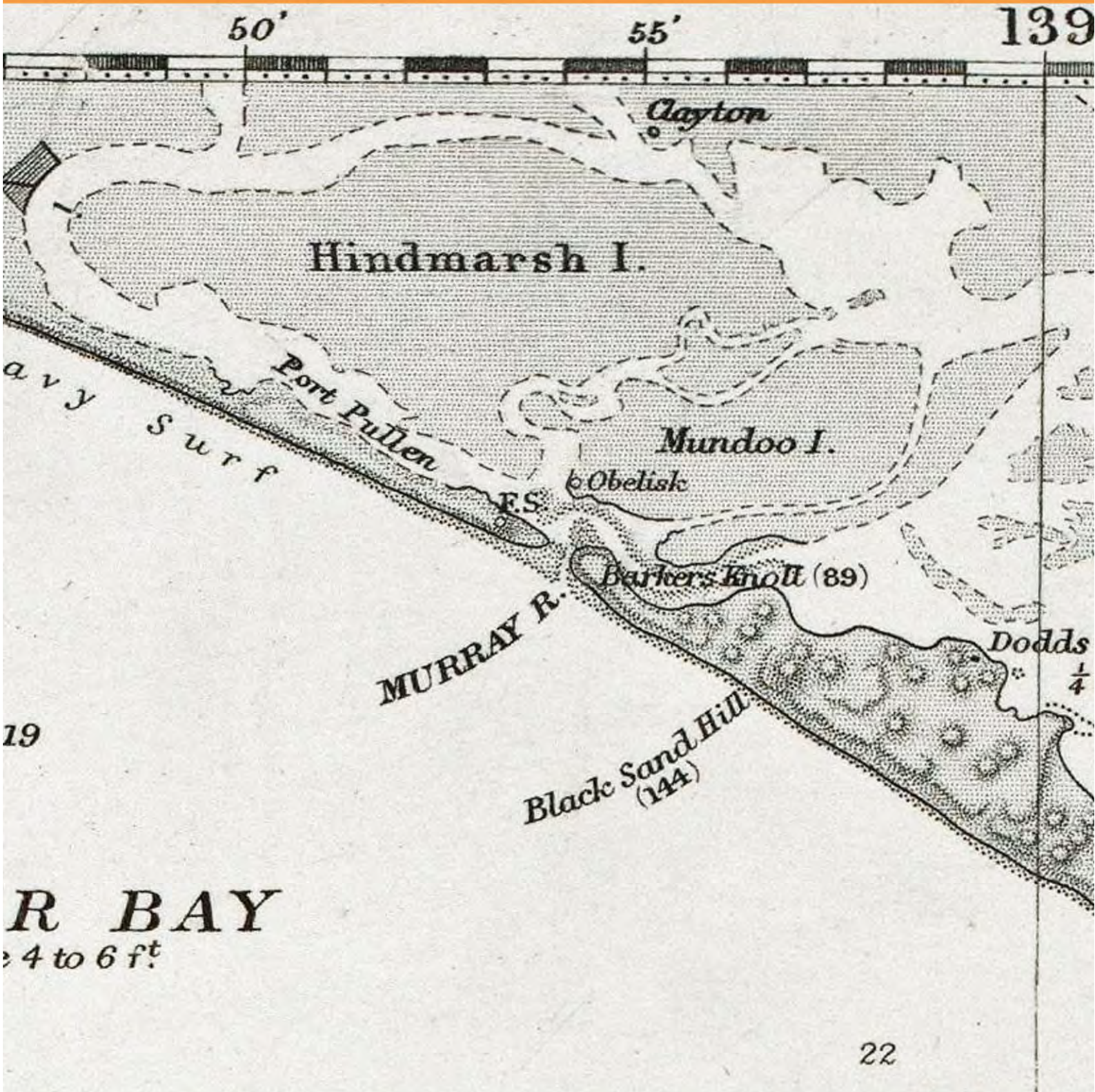


Plugging the Murray River's Mouth: The Interrupted Evolution of a Barrier Estuary

By Jennifer Marohasy BSc PhD



This report is presented to inform discussion and to highlight the state of the science used to underpin policy decisions and the distribution of \$10 billion dollars of government funding under the proposed Murray Darling basin water plan.

Illustrations (including covers, map of Lower Murray and all photographs) by Susan Myers,
www.lakesneedwater.org

The back and front cover is from a hydrographic map: South coast of Australia (Colony of South Australia): Cape Jervis to Guichen Bay/ surveyed by Navg. Lieutenant F. Howard, R.N. assisted by Navg. Sub Lieutenant W. N. Goalen, R.N. 1870-1.

National Library of Australia. <http://nla.gov.au/nla.map-rm4071>

The front cover shows the Murray River's mouth in 1870-1871. Immediately behind the mouth is sand shoaling and then Mundoo Island. Bird Island did not form until the Mundoo channel was blocked first by a wooden barrage and later by a concrete sea dyke built in the 1930s.

For further information contact:

The Australian Environment Foundation

PO Box 274

Deakin West ACT 2600

Telephone: 03 5762 6883

Fax: 03 5762 3069

Website www.aefweb.info

ISBN

Copyright Jennifer Marohasy

Contents

Map of the Lower Murray.....	4
Summary.....	5
A Short History	7
Intermittently Closed and Open Lakes and Lagoons	8
Murray River Flows 1956-2010	9
An Artificial Drought for an Artificial Lake	10
Junk Science versus Real Science	10
Seven Thousand Years Ago	12
Barrier Estuaries Evolve and Change	13
Losing the Fight Against the Southern Ocean	14
The Solution	16
Bibliography	17
Acknowledgements	19

Map of the Lower Murray



Summary

The Australian Government's \$10 billion plan to save the Murray-Darling by reconfiguring upstream irrigation so that more water is sent to the Lower Lakes, Murray's mouth and Coorong, is based on a false premise; a misunderstanding of the fundamental nature of the Murray River's estuary and the coastal processes that continue to shape it.

Like many southern Australian estuaries, the Murray River's estuary was formed 7,000 years ago during a period of rapid sea level rise. It consisted of a central lagoon, known as Lake Alexandrina, and a sand barrier, the Younghusband Peninsula. It was in an intermediate stage of evolution with the central lagoon developing from intermittently closed to fully tidal, when in the 1930s, sea dykes¹ were built across the bottom blocking all five channels that converged on the Murray's mouth.

These sea dykes dammed the estuary, stopping the tides, and made Lake Alexandrina totally dependent on Murray River flows.

After the Mundoo channel was blocked, sand that shoaled around the Murray's mouth consolidated creating a new island, Bird Island.

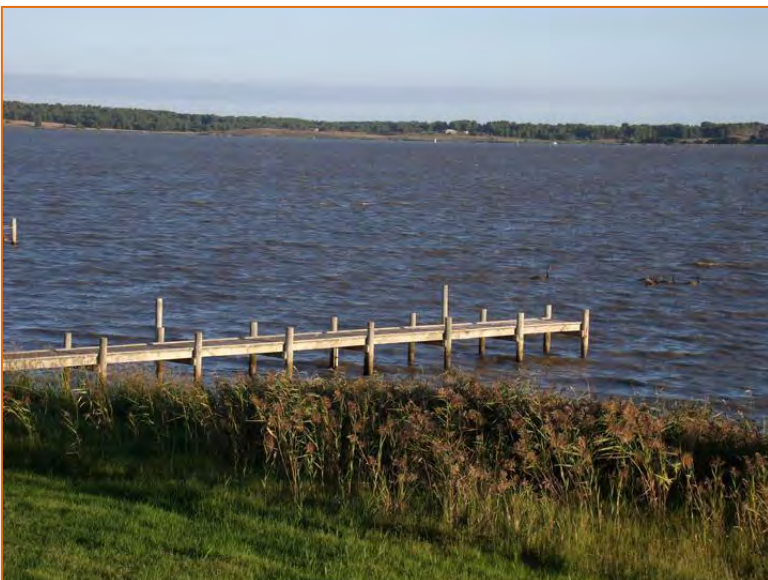
Long-standing government policy and vested interests preclude discussion of the coastal processes that are growing Bird Island that may one day permanently block the Murray's mouth. Instead there has developed a false narrative based on junk science and misguided expectations that the buy-back of large volumes of irrigation water and federal monies for the dredging of the river's mouth will solve the problem.

But this \$10 billion plan is inconsistent with everything real science tells us about how to best work with high-energy coastal processes including how to avoid Lake Alexandrina ever drying-up again, or catastrophic flooding of the new marina and housing estates on Hindmarsh Island.

Back in 1856, South Australia's Surveyor General George Woodroffe Goyder recognised the potential of the Mundoo channel to scour the Murray's mouth. He suggested the natural process of deepening and widening of the Murray's sea mouth be enhanced by cutting through the rock bar across this channel thus further concentrating tidal water inflow and river water outflow. Instead, over the last 156 years government policy has worked to stop the tide and block the channel – but it's not too late to change direction and restore the estuary and bring back the tide.

¹ The dykes are known locally, and within Murray Darling Basin Authority publications, as the barrages, however, the correct term for an embankment restraining the waters of a river or the sea is a dyke (Macquarie Australian encyclopedic dictionary 2006). The dykes hold back the Southern Ocean and created a freshwater reservoir with a storage capacity of 1,974 GL. The dykes are variously built of earthen embankment, concrete sluices, concrete piers and stop-logs. The Goolwa and Tauwichee dykes include a lock.

Clayton Bay, Lake Alexandrina



Clayton Bay on the Goolwa Channel in 2006, then 2009 during the drought when the lake waters receded because the sea dykes blocked inflows from the Southern Ocean, and then in 2011 after flooding rains in the catchment.

A Short History

For thousands of years before the European settlement of Australia, when there was good snowmelt in the Australian Alps, the Murray River would tumble down from the mountains, then spread west over the vast black soils of the Riverina, wind its way south through the limestone gorges of the Riverland, before flooding into Lake Alexandrina. Lake Alexandrina is still a vast body of water covering an area of 570 square kilometres; so vast that looking back across the lake from Point Sturt, shorelines recede into the distance and it's impossible to see Pomanda Point near where the river enters the lake.

While the lake is vast, its outlet to the sea is a narrow and shallow channel between the sand dunes of Encounter Bay – an outlet that sometimes closes over.

In April 1802 Matthew Flinders, while circumnavigating Australia, described the shoreline as low and sandy topped with hummocks of almost bare sand. There was no river mouth on his map. Historians have written that this acclaimed navigator and cartographer “missed” the Murray’s mouth.² It is much more likely that the inlet had closed-over.

Twenty-eight years later, in February 1830, another famous British explorer, Charles Sturt, visited the region but from the inland, travelling-down the Murray in a whaleboat. Captain Sturt described the place where the river enters the lake, which is about 60 kilometres from the Southern Ocean, as the end of the river. He wrote in his journal that:

“We had, at length, arrived at the termination of the Murray. Immediately below me was a beautiful lake, which appeared to be a fitting reservoir for the noble stream that had led us to it; and which was now ruffled by the breeze that swept over it.”

On the third day, Captain Sturt attempted to manoeuvre his whaleboat from the lake to the Southern Ocean but was blocked by sandbars. He wrote:

“Shoals again closed in upon us on every side. We dragged the boat over several, and at last got amongst quicksands.”

It was not until the fourth day that Sturt conceded that it would be impossible for his men to drag the whaleboat any further over the sand bars and sand flats. So, again in February 1830 the Murray’s sea mouth was closed-over.

When Captain Sturt’s diary was later published it included comment that:

“Australian rivers fall rapidly from the mountains in which they originate into a level and extremely depressed country; having weak and inconsiderable sources, and being almost wholly unaided by tributaries of any kind; they naturally fail before they reach the coast, and exhaust themselves in marshes or

² Linn 2001. See page 5.

lakes; or reach it so weakened as to be unable to preserve clear or navigable mouths, or to remove the sand banks that the tide throws up before them."

In fact, the Murray River often ran strong in spring and summer, but by autumn had slowed and then a south westerly wind would pick up and the sea would pour in.³

Since European settlement there have been many attempts to widen and deepen the Murray River's sea mouth to make it more permanently navigable including through blasting and dredging.⁴ More recently, a national consensus has formed around the idea that if there were less irrigation upstream, the Murray's mouth could be restored to its former glory.⁵ But it's a myth that the Murray's mouth was ever deep and wide.

Intermittently Closed and Open Lakes and Lagoons

A single narrow and shallow inlet between sand dunes is a characteristic of many southern Australian estuaries with their central basins known as Intermittently Closed and Open Lakes and Lagoons (ICOLLs). For example, from Sydney to the Victorian border there are 70 ICOLLs with local governments regularly making decisions about whether or not to open them to the sea.⁶

The greatest risk from a closed ICOLL is flooding.⁷ In South Australia the state government insists the Murray's mouth be kept open.⁸ In contrast NSW state government policy does not support the artificial opening of ICOLLs unless local councils can demonstrate that the social, environmental and economic benefits greatly outweigh any potential adverse impacts. In NSW there is a specific policy against the development of flood prone land on the margins of ICOLLs. In contrast,

³ Wood 2007. See page 121: "In those days a number of things happened. After good winter rains and plenty of snowmelt, that old river would flog down, wide as hell, from September til maybe Christmas. There was nothing to stop it, no levees, weirs or barrages to bugger it up, so it flooded into the lake, then straight out the Mouth. As soon as the flood had gone, the river dropped right down real quick. By New Year's Eve most years the old cockies around Paringa fancied their chances of wading across it. But down here the sea breeze had kicked in. We'd get burst of hot weather and she'd blow from the north for a day or so, then a change would come in through and she'd blow hard from the southwest. The sea would pour in through the Mouth and work its way up into the lake, maintaining its level. As I said, in those days the channels around the Mouth were bloody good; and the water was clean, not full of silt like today."

⁴ Linn 1988. See especially page 78: "Between 1856 and 1876, the South Australian Government, ever anxious to prove the Mouth navigable and therefore the river trade secured for the colony, commissioned numerous surveys of the Murray Mouth. Moreover, schemes were devised for dredging sandbars, blasting through channels, changing the flow of water and setting up new outports – both within and without the Mouth."

⁵ For example, Four Corners: Interview with Peter Cullen. June 24, 2003. Peter Cullen in reply to Ticky Fullerton: "We have a tiny dredge trying to keep the mouth of the Murray open at the moment and it's not succeeding and what we should be doing is addressing the cause of the problem and putting enough water down the river to let the river function naturally."

⁶ Management of coastal lakes and lagoons in NSW. Department of Primary Industries, NSW Government. <http://www.dpi.nsw.gov.au/fisheries/habitat/aquatic-habitats/wetland/coastal-wetlands/management-of-coastal-lakes-and-lagoons-in-nsw> (Accessed online January 8, 2011).

⁷ Ibid. Harvey 1988.

⁸ Murray Futures: Lower Lakes and Coorong Recovery. South Australian Government, May 2009. This plan details how the \$610 million Murray Futures program funded by the Australian Government will include dredging of the Murray's mouth.

the South Australian government has actively promoted the subdivision of farmland on the shores of Lake Alexandrina and the development of this land into new housing estates, resorts and marinas.⁹

Murray River Flows 1956-2010

These new developments will flood. In 1956, when the Hume Dam was already in place, Lake Victoria and Yarrawonga already developed, and levees already built along much of the lower Murray River, there was still extensive flooding including of the townships of Milang and Goolwa on the shores of Lake Alexandrina. Flooding has never been as bad as 1956¹⁰, but very large volumes of water still regularly empty into Lake Alexandrina in most years.¹¹ Average flow over Lock 1 from 1968 to 2010 was 5,920 GL.¹² Putting this in some perspective, Port Jackson, that includes Sydney Harbour, holds about 560 GL at high tide: so enough water has been flowing into Lake Alexandrina on average each year for the last 42 years to fill about eleven Sydney Harbours each and every year. In 1974, despite river regulation 31,879 GL flowed over Lock 1: that's 57 Sydney Harbours full of freshwater.

It is generally assumed, however, that the most significant issue facing the Lower Murray, including Lake Alexandrina and the Murray's mouth, is a reduction in flows because of upstream extractions and diversions for irrigation – not flooding. It's true that the building of upstream water storages has reduced both the magnitude and frequency of major floods. Some of the water that once flowed out to the Southern Ocean during flood events is now restrained by the large storages in the upper catchment and also the development of Lakes Victoria and Menindee as water storages.

River regulation was designed to “drought proof” the Murray Darling and because of the upstream dams and weirs, drought impacts are not as severe. The main channel of the river no longer dries up as it did, for example, in 1915.¹³ But, because of the

⁹ For example, the website of Hughes Public Relations explains: “The Marina Hindmarsh Island (TMHI) is a \$330 million residential development on the doorstep of the Lower Murray and the Coorong, where Australia's biggest river meets a coastal playground and the Southern Ocean” <http://www.hughespr.com.au/news/newsreleases/79-marinahindmarshisland> (Accessed online January 18, 2012)

¹⁰ The Murray and Darling were both in flood at the same time in 1956. The 1956 flood is often referred to as “the greatest natural catastrophe in South Australia's history”. See, for example, The State Library of South Australia, Water in South Australia. <http://guides.slsa.sa.gov.au/content.php?pid=175671&sid=1510120> (Accessed January 25, 2012).

¹¹ Jacobs 1990. See especially page 57: “Flow in the Murray is not highly regulated compare with many other large rivers in the world... Flow records along the Murray show that it is usually fully regulated for less than half the time. The high natural variability and flow in the Murray and the high economic cost of building large storages has restricted the extent that flow has been regulated. In most years, large volumes of water pass down the Murray to the sea.”

¹² Values calculated from daily flow data as measured at Lock 1 near Morgan in South Australia. Data sourced from the Murray Darling Basin Authority. Lock 1 is at the top of the pool that includes Lake Alexandrina. Inflows are highly variable despite river regulation with 31,879 GL flowing over Lock 1 in 1974 and only 499 GL in 2009.

¹³ Photographs show families picnicking in the dry riverbed at Easter in 1915 and according to Russell McDonald from Riversdale, Central Murray Valley: “Water was never more than two feet deep while

construction of the Murray mouth sea dykes that dammed the Murray River's estuary, Lake Alexandrina is particularly susceptible to low flows because it is now totally dependent on the upstream dams to feed this end-of-system freshwater reservoir.

An Artificial Drought for an Artificial Lake

In 2006 water levels in Lake Alexandrina fell precipitously from 0.85 metres above sea level to -1.10 metres below. There was simply not enough water in upstream dams to keep both Lake Alexandrina and the adjacent smaller Lake Albert supplied with adequate water. In earlier times, for example, during the Federation drought (1895-1902), as flows from upstream slowed, the seawater pushed in taking over the entire lake and extending many kilometres up the main channel of the river.¹⁴ But during the Millennium drought (2002 to 2009), the 7.6 kilometres of concrete sea dyke engineered and built in the 1930s, held back the Southern Ocean.

The South Australian government could have opened the 593 gates within the five sea dykes to let the Southern Ocean in, but instead it kept the gates shut tight. That the South Australian government chose not to open the gates during the drought and let the Southern Ocean flood in, was not generally reported in the national media which instead focused its television cameras on either the receding lake waters or the sand dredge working to keep the Murray's mouth open conveniently avoiding images of the massive sea dykes in between.

As soon as the floodwaters arrived in the spring of 2010, the government opened the gates to let excess water out.

According to the website of the South Australia Department of Water the sea dykes were not opened during the drought because: "The State Government is committed to maintaining the Lower Lakes as a freshwater system." Interestingly, at the website, this is not justified on the importance of the lake as a supply of freshwater for irrigation or for Adelaide, but on the false claim that the lake has always been a freshwater lake and that letting in seawater would spoil its ecological character.¹⁵

Junk Science versus Real Science

This claim, that the lake has always been fresh, is never juxtaposed, for example, against the observations in the diary of Charles Sturt that the waters of Lake Alexandrina were salty in February 1830¹⁶ or the presence of a thriving mullocky¹⁷

we carted timber, and for a long time in autumn 1915 was perfectly dry, the river having stopped running in February or March." For a general technical assessment of regulation see Wen (2009).

¹⁴ Jenkin 1985. See page 206.

¹⁵ See the 'Environmental Issues. Frequently Asked Questions' webpage of the Department of Water, Government of South Australia. <http://www.waterforgood.sa.gov.au/rivers-reservoirs-aquifers/murray-darling-basin-plan/faqs/environmental-issues/> (Accessed January 22, 2011).

¹⁶ Charles Sturt wrote in his journal that as he approached Pomanda Point, Lake Alexandrina, in 1829: "Thus far, the waters of the lake had continued sweet; but on filling a can when we were abreast of this point, it was found that they were quite unpalatable, to say the least of them. The transition from fresh to salt water was almost immediate, and it was fortunate we made the discovery in sufficient time to

fishery in Lake Alexandrina, until construction of the sea dykes.¹⁸

It would be difficult for a rational person, familiar with the available evidence, to come to the conclusion that Lake Alexandrina has been a predominately freshwater lake for 7,000 years. Yet this is the advice in a recent report by CSIRO scientists¹⁹ and also the advice from scientists at the Australian Wetlands and Rivers Centre.²⁰ And this popular claim has been bolstered recently by a prominent statement in the executive summary of a report commissioned by the South Australian Department of Environment and Heritage prepared by Jennie Fluin, Deborah Haynes and John Tibby.²¹ These scientists are recognised experts at reconstructing the past history of lakes and wetlands based on the presence or absence of particular species of diatom in sediment cores. Diatoms are unicellular algae.

The scientists incorrectly state in the report that:

"There is no evidence in the 7,000 year record of substantial marine incursions into Lake Alexandrina."

This claim, while consistent with South Australian government policy, is at odds with not only what we know about how Southern Australian estuaries evolved and now function, but also many studies published in reputable scientific journals including research papers authored by the same scientist, Drs Fluin, Haynes and Tibby.²² Indeed the claim is inconsistent with the specific diatom assemblage described in their published papers and also in their report to the South Australian government.²³

Research by other scientists into diatoms²⁴ and also another group of microfossils known as foraminifera²⁵, and more generally into the sedimentology and geomorphology of the region²⁶, provides evidence for three distinct phases in the evolution of Lake Alexandrina and the Murray River's estuary: a period of maximum marine influence when the estuary was starting to form, then a period of maximum freshwater influence after a sand barrier formed across the estuary, followed by a

prevent our losing ground. But, as it was, we filled our casks, and stood on, without for a moment altering our course."

¹⁷ Mulloway are not a freshwater fish species. Mulloway are common in Southern Australian estuaries, oceans, gulfs, and also offshore reefs.

¹⁸ Olsen 1991.

¹⁹ Aldridge K.T. *et al.* 2009. See page 2.

²⁰ Kingsford *et al.* 2009. See page 9

²¹ Fluin *et al.* 2009.

²² For example in Gell *et al.* (2005), which included Drs Tibby and Fluin as authors, the waters of Lake Alexandrina were particularly salty 1,000 to 2,000 years ago. Somewhat at variance with this conclusion, in Fluin *et al.* (2007), co-authored by Haynes and Tibby, it is concluded that between 7,000 years and 2,300 years ago, a strong marine influence was present in Lake Alexandrina.

²³ For example, in their report to government, Drs Fluin, Haynes and Tibby list the species *Staurosirella pinnata* as a dominant species from the bottom of a Lake Alexandrina sediment core taken near where the river enters the lake and therefore indicative of the lake being "fresh to brackish" for 7,000 years. But in a more recent paper also published by Drs Fluin, Haynes and Tibby, this same diatom species is listed as common in the very salty Coorong with mention that it has a broad salinity tolerance (see Hayne *et al.* 2011).

²⁴ Barnett 1994.

²⁵ Cann *et al.* 2000.

²⁶ Bourman *et al.* 2000.

third phase with conflicting evidence as to whether Lake Alexandrina was becoming generally fresher or saltier at the time the sea dykes were built. It is agreed that this third phase was interrupted by construction of the sea dykes that have fundamentally changed water quality in Lake Alexandrina and converted the water body from a wave dominated estuary to a freshwater reservoir.²⁷ That there have been three distinct phases in the evolution of the Murray River estuary is consistent with what is generally known about the evolution of wave dominated, hydrostatically positive estuaries in Southern Australia.²⁸ But let's start at the beginning and place the natural history of Lake Alexandrina in a geological context.

Seven Thousand Years Ago

Very different coastal processes are at work depending on whether sea levels are falling, static or rising. Rivers cut downwards into the underlying substrate when sea levels are falling, so, for example, about 900,000 years ago the Murray River cut down forming a trench about 65 metres deep where the river now meets Lake Alexandrina.²⁹ Fast-forward from 900,000 to 120,000 thousand years ago and the earth's climate had warmed. Very significant polar icecap melt meant sea levels rose to above present sea-level.³⁰ Then the earth cooled again, and the Southern Ocean again retreated.

For tens of thousands of years conditions were much colder, windier and drier than they are today. Then, about 18,000 years ago, the climate changed yet again. The earth started to warm somewhat abruptly and sea levels started to rise again by on average 130 metres around the world.³¹ About 10,000 years ago sea levels dipped, then rose again. During the last 6,000 years sea levels and climate have been relatively stable.³²

It was during the last period of significant sea level rise, which was about 7,000 years ago, that the Southern Ocean flooded in to the area we now refer to as Lake Alexandrina. As the sea pushed in, the Murray River was pushed back, and the seawaters spread out across an area of natural subsidence.³³ A new estuary began to form with the Southern Ocean regularly washing in to the entire area through a wide opening.³⁴

²⁷ Barnett (1994) includes comment that: "barrage construction across the Murray mouth since the late 1930s has fundamentally altered the natural processes in the lake". Bourman *et al.* (2000) states: "Originally a vibrant, highly productive estuarine ecosystem of 75,000 ha, characterized by mixing of brackish and fresh water with highly variable flows, barrage construction has transformed the lakes into freshwater bodies with permanently raised water levels".

²⁸ Digby *et al.* 2004.

²⁹ Rutherford 1990. See page 29

³⁰ Bourman *et al.* 2000. See page 146.

³¹ Lambeck 2004.

³² The general consensus is that by 6,000 years ago, sea levels had dropped 1-2 metres to present levels including as a consequence of hinged hydroisostatic uplift. However, according to Lewis (2008) sea level did not fall to present levels until 5,000 years before present.

³³ Bourman *et al.* 2000 and also Barnett 1994.

³⁴ Barnett 1994.

From the beginning, localised wave action would have deposited sand at the margins of the seaward opening of the young estuary slowly building sand flats, then beaches. Beaches build as sand from wave action is deposited higher and higher. When dry sand from the beach is blown beyond the reach of the waves, and then a bit further, sand dunes start to form. The shoreline across the Murray River estuary has accumulated so much sand over the last six thousand years that 5,000 tonnes of sand may be in motion at any one time along just 10 kilometres of beach.³⁵

In 1802 Matthew Flinders named the coastline in front of the sand barrier, hiding Lake Alexandrina, Encounter Bay. Later the sand barrier was named the Younghusband Peninsula after a prominent South Australian. The sand peninsula formed from water currents running along the early beach face dropping sand across the top of the estuary forming shoals. Typically shoals will consolidate into a sand-spit. Then through beach building processes a sand-spit develops into a beach, then a sand dune, that eventually extends across the entire estuary. Studies of the deposition of sand and sediments within Lake Alexandrina suggesting sand pit formation was complete by 2,300 years ago.³⁶ Other studies suggest the sand barrier was already in place about 3,600 years ago and that at this time Lake Alexandrina was predominately a freshwater lake.³⁷ This period is thought to have corresponded with a period of climatic aridity within the Murray Darling Basin when there were no big floods to break open the sand barrier and so it consolidated.

Provided there is adequate freshwater inflow, lakes and lagoons protected by sand barriers, even without a sea inlet, can remain healthy functioning freshwater ecosystems. Paradoxically it is when freshwater inflows are too high that overtopping of the sand barrier will typically occur, followed by “lagoon breakout”, and then a rise in salinity levels as the lagoon is reconnected with the ocean.³⁸

The dynamic high-energy coastal processes of beach and dune formation across the Murray River’s estuary would have occasionally been interrupted when there was significant flooding in the Murray Darling. Then large volumes of water would have rushed across Lake Alexandrina and pushed over and eventually eroded through the developing Younghusband Peninsula: chopping it into pieces. Thus in the early stages of development of the modern Murray River estuary there was more than one outlet to the Southern Ocean and many discrete sand islands.³⁹

Barrier Estuaries Evolve and Change

Southern Australian barrier estuaries in their early stages of development are dependent on flood events to open their sea entrance.⁴⁰ But the Murray River estuary had moved beyond this stage of evolution at the time of European settlement. The position and opening of the River Murray’s sea mouth was becoming fixed and

³⁵ Bourman 2000.

³⁶ Barnett 1994. See page 266.

³⁷ Cann *et al.* 2000. See especially page 387.

³⁸ Pollard 1994.

³⁹ Bourman *et al.* 2000. See page 145.

⁴⁰ Digby *et al.* 2004. See page 16. Dakin 1952.

increasingly dependent on the ocean as explained by South Australian historian J. C. Tolley:⁴¹

“The position of the channel at the mouth is governed principally by the ocean... During the great 1956 flood, the highest ever recorded on the lower Murray, the river outlet, although wider and deeper than normal, was situated in the easterly section of the overall movement pattern and was in a similar position as the situation of the mouth during the dry year of 1914.

However in April 1938, during a violet storm the mouth doubled its width in a few days and a great deal of sand at the western extremity was washed away. Within two months the channel had narrowed and when surveys were carried out 12 months later the position of the outlet was in almost the same situation as before the storm. During this period there was no great fluctuation in the volume of fresh water coming down the river.”

Working from the barrier estuary conceptual model endorsed by the National River Health Program, the Murray River’s estuary was probably at an intermediate stage of development at the time the sea dykes were built. From the beginning the Murray River would have brought sediment to the newly forming estuary. However, the high-energy action of the waves would have meant that mud flats could not properly develop until after the sand barrier started to form, reducing tidal scouring. After the barrier formed, sediment carried down the Murray River started to fill the central lagoon behind the sand barrier. Infilling of this area, known as Lake Alexandrina, had been occurring for at least 2,300 years and the sea entrance had become channelized. Typically as a barrier estuary matures many channels will coalesce into a single channel.

Left alone to develop into a mature, and fully tidal system, the Mundoo channel may have come to dominate the Murray River’s estuary as the other channels and margins of the lake infilled with sand and sediment.

The Goolwa channel generally carries more water, but this water has less energy as it elbows around Hindmarsh Island following the old riverbed. In contrast, the Mundoo channel has the steepest gradient to the sea and is immediately behind the Murray’s sea mouth. Back in 1856, South Australia’s Surveyor General George Woodroffe Goyder recognised the potential of the Mundoo channel to scour the Murray’s mouth. He suggested the natural process of deepening and widening of the Murray’s sea mouth by this channel be enhanced by cutting through a natural calcareous sandstone bar across the channel thus further concentrating tidal water inflow and river water outflow.⁴²

Losing the Fight Against the Southern Ocean

Instead, early settlers worked hard to block off the Mundoo channel because they wanted to keep the lake fresh, they did not want the tidal force concentrated through

⁴¹ Tolley 1997.

⁴² The Advertiser, 1903. The Murray Barrages: Report by Experts, June 29, Page 8.

the mouth, then along Mundoo channel and into Lake Alexandrina. A wooden barrage with sluice gates was built across the Mundoo channel in 1915.⁴³ The current sea dyke, built in the late 1930s, is 800 metres long, partly earthen embankment protected with heavy stone pitching and partly concrete stop-logs. Even when fully open to allow floodwaters out, flow is still restricted to about 20 per cent of the natural channel width.⁴⁴ In short, inflow along the Mundoo channel has been stopped and outflow has been significantly curtailed.

Without a channel for the tide to scour, shoaling, which had always been common at the seaward side of the Mundoo channel immediately behind the Murray River's sea mouth, consolidated into a permanent sand island. This sand island had four metre high sand dunes in 1988⁴⁵ and was a kilometre in diameter by 2000.⁴⁶ The development, growth and consolidation of Bird Island are a direct consequence of blocking the Mundoo channel.⁴⁷ Bird Island has not only changed the geomorphology of the region and interrupted the estuaries evolution to a fully tidal system, but Bird Island also blocks water released through the gates of the Goolwa sea dyke purported for the Coorong.

Geoscience Australia classifies the Murray River's estuary as a wave-dominated estuary with positive annual hydrodynamics.⁴⁸ It is wave dominated because coastal processes rather than river flow, has most influenced its evolution. It has annual positive hydrodynamics because it receives a relatively large and constant freshwater supply throughout the year that exceeds evaporation. Many South Australian estuaries that close over become hypersaline and eventually turn into salt marshes because they have a negative hydrodynamics. This is a real possibility for both Lake Albert and the Coorong but not Lake Alexandrina.⁴⁹ Many freshwater lakes in South Australia become saltpans.⁵⁰ There is a real fear in South Australia that Lake Alexandrina could become a saltpan, but this fear is misplaced. Upstream river regulation has not affected the positive hydrodynamic status of Lake Alexandrina. Annual evaporation from the lake system is between 878 and 1,083 gigalitres,⁵¹

⁴³ The Register, 1919. Keeping the lakes fresh. February 27. Page 6.

⁴⁴ Bourman 2000. See page 28: "The volume of water discharged through the Mundoo Barrage has become negligible. Mundoo Barrage is operated infrequently, as the gates are cumbersome to operate, making it extremely difficult to respond to rapid changes in conditions induced by the wind. The structure consists mostly of causeway with a small number of discharge gates. Even when the gates are fully open, there is a restriction of flow at the barrage gates only cover 20 per cent of the natural channel width. As a result, flows through the Mundoo Channel are greatly reduced in volume and frequency from pre-barrage flows."

⁴⁵ Harvey 1988.

⁴⁶ Bourman 2000.

⁴⁷ Bourman 2000. See page 25: "The most important geomorphic impact of river regulation has been the growth and consolidation of the flood tidal delta (Bird Island) landward of the Murray Mouth."

⁴⁸ Ryan *et al.* 2003. See Appendix D

⁴⁹ While the Coorong shares a sea mouth with Lake Alexandrina it has a distinct hydrology, geological and natural history: it is not obviously part of the Murray River's estuary. Lake Albert is an appendage of Lake Alexandrina joined by a narrow entrance that was blocked off during the recent drought. Detailed discussion of matters concerning the Coorong and Lake Albert are important, but beyond the scope of this article.

⁵⁰ For example, early South Australian settlers established farms around Lake Torrens when it was full of freshwater, then Lake Torrens reverted to salt plan.

⁵¹ In July 2008, Australian of the Year, Professor Tim Flannery is quoted suggesting that opening the sea dykes and letting the area flood with seawater would save 1,300 GL of freshwater that would

which is a very large volume of water, but significantly less than average inflows of nearly 6,000 gigalitres.⁵²

The biggest issue for Lake Alexandrina and all the new surrounding land developments and subdivisions, including on Hindmarsh Island, is flooding from a blocked river mouth. The Murray's sea mouth is choking, and it is principally the fault of the Mundoo sea dyke – not upstream irrigators.

The Solution

Everything science tells us about coastal processes would suggest that an inevitable consequence of blocking the Mundoo channel would be the eventual permanent blocking of the Murray's sea mouth. Unfortunately discussion of these coastal processes has been omitted from planning and policy documents developed under the Commonwealth government's \$10 billion water reform program. There is a budget for the ongoing dredging of the Murray's mouth on the basis that large volumes of freshwater have been taken by upstream irrigators. The Water Minister Tony Burke has suggested that if some of this water is returned the problem will be alleviated.⁵³

But damming the estuary has changed the hydrology of the region, and subsequently its geomorphology. The process will inevitably be one of growth and consolidation of Bird Island until it eventually blocks the Murray's mouth irrespective of how many sand dredges the government tries to fit into the shrinking space or how much water is returned as environmental flow.

Rather than using the \$10 billion budgeted under the Water Act 2007 to reduce the size of upstream irrigation based on an invented narrative about a lake that would always be brimming with freshwater if it weren't for greedy irrigators, a better way would be to spend the money working to enhance the coastal processes that would have once acted to deepen and widen the Murray River's sea mouth. In particular the 800 metres of sea dyke needs to be removed from across the Mundoo channel.

otherwise be lost to evaporation. Evaporation rates vary with temperature, humidity, solar radiation and wind velocity. Pan evaporation has historically been used as a proxy for actual evaporation with a coefficient of 0.75 applied when calculating for natural water bodies. Nowadays relatively simple computer models that import relevant meteorological data are increasingly used and give a more accurate measure of evaporation. Output from a CSIRO model and also three earlier studies of evaporation from the Lower Lakes that used different techniques including pan evaporation indicate evaporation rates from the Lower Lakes are in the order of 1,171 to 1,445 mm per annum. This rate can be converted to gigalitres per year by multiplying the rate by the surface area of both lakes (750 kilometres squared) and then dividing by one thousand. These published studies which take into account meteorological variable and lake characteristics are in reasonable agreement and give an annual volume evaporated of between 878 and 1083 GL.

⁵² Values calculated from daily flow rates at Lock 1, data supplied by Murray Darling Basin Authority.

⁵³ The Minister Tony Burke interviewed by Fran Kelly, ABC Radio National, November 28, 2011, said: "The draft plan that's in front of us does exactly what the Water Act calls on it to do... So if you take the numbers that are released today compared to one of the high figures, say a 4000 figure, and look at the environmental outcome of the mouth of the Murray. The numbers released today would have the mouth of the Murray open 89% of the time. Four thousand gigalitres would only get that open 92% of the time." <http://www.environment.gov.au/minister/burke/2011/tr20111128.html>. (Accessed online January 30, 2012.)

If the calcareous sandstone bar across the channel, which is a relic of sea level rise 125,000 years ago, were also removed, then Bird Island would quickly be eroded away. And so the Murray River's estuary could continue to evolve to eventually become fully tidal and so more independent, resilient and over time more biologically diverse.

A fully tidal Lake Alexandrina could support a rich fishery and even grow mangroves⁵⁴ and seagrass. Importantly the Lake would be resilient to drought in the basin and water quality could be maintained by regular flushing with the tides of the Southern Ocean at no cost to Australian taxpayers.

Bibliography

Aldridge K.T., B.M. Deegan, S. Lamontage, A. Bissett, J.D. Brookes. 2009. Spatial and Temporal Changes in Water Quality in Lake Alexandrina and Lake Albert During a Period of Rapid Water Level Drawdown. Water for a Healthy Country Flagship Report, CSIRO, Commonwealth of Australia

Barnett, E.J. 1994. A Holocene paleoenvironmental history of Lake Alexandrina, South Australia. *Journal of Paleolimnology* 12:259-268

Bourman R.P., C.V. Murray-Wallace, A.P. Belperio, N. Harvey, 2000. Rapid coastal geomorphic change in the River Murray estuary of Australia. *Marine Geology* 170: 141-168

Bourman, R.P. 2000. Geomorphology of the Lower Murray Lakes and Coorong. *In* River Murray Barrages. *Eds.* Jensen, A., M. Good, P. Tucker, M. Long. pages 23-29

Cann, J.H., R.P. Bourman, E.J. Barnett, 2000. Holocene foraminifera as indicators of relative estuarine-lagoonal and oceanic influences in estuarine sediments of the River Murray, South Australia. *Quaternary Research* 53: 378-391

Dakin, W.J. 1952. Australian Seashores, Angus and Robertson, pp. 372

Digby, M.J., P. Saenger, M.B. Whelan, D. McConchie, B. Eyre, N. Holmes, D. Butcher, 2004. A Physical Classification of Australian Estuaries, The National River Health Program, LWRRDC Occasional Paper 16/99

Fluin, J., P. Gell, D. Haynes, J. Tibby, G. Hancock, 2007. Palaeolimnological evidence for the independent evolution of neighbouring terminal lakes, the Murray Darling Basin, Australia. *Hydrobiologia* 591:117-134

⁵⁴ Mangroves grow where there are tides, mostly in tropical and subtropical parts of the world. But there are also mangroves along South Australia's coastline including in the Gulf of Saint Vincent, Spencer Gulf and some protected bays on the Eyre Peninsula.

Fluin, J., D. Haynes, J. Tibby. 2009. An environmental history of the Lower Lakes and Coorong. Report Commissioned by the South Australian Department of Environment and Heritage

Gell, P., J. Tibby, J. Fluin, P. Leahy, M. Reid, K. Adamson, S. Bulpin, A. MacGregor, P. Wallbrink, G. Hancock, B. Walsh. 2005. Accessing limnological changes and variability using fossil diatom assemblages, South-east Australia. *River Research and Applications* 21:257-269

Harvey, N. 1988. Coastal management issues for the mouth of the River Murray, South Australia. *Coastal Management* 16: 139-149

Haynes, D., R. Skinner, J. Tibby, J. Cann, J. Fluin, 2011. Diatom and foraminifera relationships to water quality in The Coorong, South Australia, and the development of a diatom-based salinity transfer function. *Journal of Paleolimnology* 46:543-560

Jacobs, T. 1990. Regulation and management of the River Murray. *In The Murray*. Murray Darling Basin Commission, Eds. Mackay N., D. Eastburn. pages 39-60

Jenkin, G. 1985. Conquest of the Ngarrindjeri: The Story of the Lower Murray Tribes. Rigby Publishers Adelaide. pp. 300

Kingsford, R.T., P.G. Fairweather, M.C. Geddes, R.E. Lester, J. Sammut, K. F. Walker, 2009. Engineering a Crisis in a Ramsar Wetland: The Coorong, Lower Lakes and Murray Mouth, Australia. Australian Wetlands and Rivers Centre

Lambeck, K. 2004. Sea-level change through the last glacial cycle: geophysical, glaciological and palaeogeographic consequences, *C.R.Geoscience* 336: 677-689

Lewis, S. E., R. A. J. Wust, J.M. Webster, G. A. Shields, 2008. Mid-late Holocene sea-level variability in Eastern Australia. *Terra Nova* 20:74-81

Linn, R. 2001. A Land Abounding: A History of the Port Elliot and Goolwa Region, South Australia. Alexandrina Council. pp. 262

Linn, R. 1988. A Diverse Land: A History of the Lower Murray, Lakes and Coorong. Meningie Historical Society Inc., pp. 288

Martin, W. 2005. Water Policy History on the Murray River. Southern Riverina Irrigators, pp. 356

Olsen, A. M. 1991. The Coorong: A Multi-species Fishery. Part 1, History and Development, Fisheries Research Papers No. 22. Department of Fisheries, South Australia

Pollard, D. A. 1994. Opening regimes and salinity characteristics of intermittently opening and permanently open coastal lagoons on the south coast of New South Wales. *Wetlands (Australia)* 13: 16-35

Rutherford, I. 1990. Ancient River Young Nation, *In The Murray*, Eds. N. Mackay, D. Eastburn. Murray Darling Basin Commission, Canberra, Australia, pages 17-38

Ryan, D.A., A.D. Heap, L. Radke, D.T. Heggie, 2003. Conceptual Models of Australia's Estuaries and Coastal Waterways: Application for Coastal Resource Management, Geoscience Australia Record 2003/09

Tolley, J.C. 1997. South Coast Story: A History of Goolwa, Port Elliot, Middleton and the Murray Mouth. Rowett Print, Mt Compass, South Australia. pp. 78

Wen, L. 2009. Reconstruction natural flow in a regulated system, the Murrumbidgee River, Australia, using time series analysis, *Journal of Hydrology* 364: 216-226

Wood, A. 2007. Poor Man River: Memoirs from the River Murray Estuary. Digital Print, Adelaide. pp. 163

Acknowledgements

This is the first report of the Rivers Need Estuaries Campaign of the Australian Environment Foundation.

The report has been peer-reviewed by Professor Peter Ridd, James Cook University.

Dr John Abbot, Central Queensland University, helped with analysis of the diatom information.

I've been helped and inspired by many people, but especially Susan Myers from Adelaide, Louise Burge from Deniliquin, and Catherine Jane who grew-up on a dairy farm with a view of the full moon lighting-up the vast coastal lagoon we know as Lake Alexandrina.

Aerial photograph showing Pomanda Point and where the Murray River enters Lake Alexandrina, taken in 2012.



Photograph of the Goolwa sea dykes taken in 2009 from upstream and also downstream.

