Appendix B

MOURYA ESTUARY BANK EROSION STUDY

BY

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1 INTRODUCTION

1.1 OBJECTIVES

The objectives of the geomorphological component of the study are to provide:

- An assessment of the nature and extent of bank erosion in the Moruya River estuary; and
- Advice on sediment inputs to the estuary from the upstream river system.

1.2 METHODOLOGY

The geomorphological component is based on the following investigations:

- Site inspections of the Moruya River estuary by boat and from land to provide a field assessment of the extent and type of bank erosion in the estuary;
- Inspections of selected sites on the Deua River upstream of the estuary to provide information on the nature of sediment deposits in the river system that are likely to provide a source of sediments to the estuary;
- Analysis of recent and historical aerial photographs (the historical aerial photographs date from 1940 and are generally confined to the lower part of the estuary);
- Review of previous reports and information; and
- Assessment of the implications of the outputs of hydraulic modelling carried out by AMOG.

2 EVOLUTIONARY HISTORY OF ESTUARY

The Moruya River catchment is formed of Palaeozoic granitic, sedimentary and metamorphic rocks (Warner 1981, O'Brien 2001) and the published 1:250,000 geological map shows that the valley of the Moruya River estuary is also carved into these formations. The estuary valley contains Quaternary alluvial and swamp deposits, which are particularly extensive in the middle section of the estuary. Quaternary sediments, including dune and beach deposits, occur along the coast.

The long term evolution of NSW South Coast estuarine inlets (including the Moruya) was examined by Bird (1967), who proposed the following sequence of events:

- The river and stream courses became deeply incised during phases of lower sea level in the Pleistocene;
- The rise to the present sea level about 6000 years ago submerged the lower sections of the incised river valleys, forming estuarine inlets;
- Coastal barrier systems (consisting of beaches, dunes and sand spits) were formed at mouths of the inlets by coastal processes;
- In the case of the Moruya and other major South Coast rivers (Shoalhaven, Bega and Towamba), the area behind the coastal barrier has been largely infilled by the deposition of sediment derived from the upstream catchment (the estuaries with smaller catchments remain as partly infilled estuarine inlets) (observations by GHD [1981] and the present author indicate that Malabar Lagoon is an area within the Moruya River estuary that has been only partly infilled); and
- The Moruya (and the other major rivers) now discharge fluvial sand into the sea during floods.

3 BANK EROSION

3.1 NATURE AND EXTENT

3.1.1 Downstream of Princes Highway

The banks of the Moruya River downstream of the Princes Highway have been extensively lined with rock riprap. Some of the rock walls along the river were constructed to facilitate navigation by coastal steamers, others for bank protection. Training walls for navigational purposes date back to the mid nineteenth century – the earliest known works were commenced in 1861 to provide a permanent channel at the river mouth (DPW 1978). More recently, the southern bank of the river opposite Malabar Creek confluence was rock lined to mitigate bank erosion as recommended by GHD (1981).

The stability of the rock-lined banks is a key issue in the Moruya River estuary downstream of the Princes Highway. Problems observed during the course of the site inspections include the collapse and slumping of sections of rock riprap due to loss of toe support, erosion of the banks above and behind the rock lining, and the existence of large voids in the rock matrix which reduce the effectiveness of the rock lining and increase its susceptibility to failure. At the Moruya Caravan Park, there are a number of substantial embayments behind the rock wall that may possibly be caused by instream flood scours or inflows of overland runoff or floodplain return flows. The collapse or slumping of rock walls causes rocks to fall into the river, posing a hazard to navigation. An engineering audit of the rock lining and a remedial strategy to address problems with the rock lining are required.

Unlined banks occur in a few sections of the Moruya River estuary downstream of the Princes Highway:

- Banks formed of unconsolidated sediments at the downstream end of Racecourse Creek and on the inside of the bend opposite Garlandtown – these banks are affected by natural erosion processes that are likely to have been exacerbated in places by reductions in riparian vegetation and stock damage;
- Banks formed in bedrock, such as at the wharf near the Moruya Quarry – some bank erosion is evident in the sandy soils associated with granitic bedrock, but rates and extent of erosion are limited by the presence of hard bedrock; and
- The lagoon behind the training wall in the vicinity of Quandolo Island, where the natural river banks are separated from the main channel by a training wall which now effectively functions as the river bank under low and medium flow conditions– no erosion of the natural river banks was observed in the lagoon behind the training wall.

Comparison of an orthophotomap based on 1999 aerial photography with available historical aerial photography does not show evidence of any major bank retreat due to erosion. However, it needs to be noted that the earliest photography, from 1940, 1962, 1966 and 1971, covers only the lower 2 km of the river; the 1977 aerial photographs extend as far upstream as Racecourse Creek; and only the 1984 aerial photographs cover the whole reach to the Princes Highway). Slow rates of bank retreat are also indicated by GHD (1981) who noted that bank erosion at Mynora Flats has occurred over a long period but the continued presence of car bodies in one area indicated that not much change had occurred in recent years. All the aerial photographs show extensive shoaling in the river channel, and changes in the position of sand shoals are apparent from comparisons of photographs for different dates. The most significant changes apparent from the comparisons of aerial photographs are accretionary changes in the lagoon behind the breakwater at Moruya Heads since 1940, including the development of a barrier across the seaward end of the lagoon, extending from the pre-existing barrier to the breakwater.

3.1.2 Upstream of Princes Highway

Rock lining of the river banks upstream of the Princes Highway is limited to area adjacent to, and immediately upstream of, Moruya. Like the rock lining in the lower estuary, there are problems with the stability and effectiveness of sections of rock lining in this reach.

Bank erosion in the unlined areas is widespread, particularly where the banks are formed of unconsolidated alluvial sediments. Erosion occurs on both sides of the river, not just the outer banks of bends, although it may be more severe on outer banks. Bank slumps, collapse and tree falls apparently related to undercutting at high tide level were observed, and notching at high tide level was evident in some places. Localised damage to banks resulting from uncontrolled stock access was evident.

3.1.3 Malabar Lagoon

The only bank erosion observed along the shoreline of Malabar Lagoon was localised erosion adjacent to the western end of the road crossing. Local advice indicates that the area affected by erosion is reclaimed land and the erosion is occurring in the fill rather than natural bank materials. No reports of erosion in Malabar Lagoon were found in the literature. Clarke and Pressey (1981) reported that anecdotal evidence from local residents indicated significant sedimentation of Malabar Creek and Malabar Lagoon took place in the period 1950-1980 (Clarke and Pressey 1981), which they attributed to receipt of sediment from erodible agricultural land.

3.2 CONTRIBUTORY FACTORS

3.2.1 Tidal Processes and Wave Action

Much of the bank erosion in the estuary was observed to be associated with water levels within the tidal range. Features include the existence of a notch in the bank at high tide level and slumping or collapse of the banks (with or without trees) above the notch area. Processes contributing to erosion include wave action and frequent wetting of the banks.

3.2.2 Meander Process

In any meandering river channel, flow velocities are unevenly distributed across the river cross-section so that higher velocities at outer banks of bends lead to higher rates of erosion in these areas. The Moruya River estuary would not be an exception to this general rule, although the results of hydraulic modelling by AMOG for the 1 and 20 year ARI floods do not show large differences in velocities between inside and outside bank locations at bends. Bank erosion in the Moruya River estuary is not limited to the outside banks of bends.

3.2.3 Floods

None of the reports on flooding of the Moruya River reviewed for this study make any special mention of bank damage associated with floods; however, this may just reflect the focus of these reports on overbank issues – flooding depth and sedimentation problems – rather than a lack of accelerated erosion associated with floods. Floods can cause bank erosion in a number of ways, including saturation of the upper bank areas resulting in slumps when water levels recede at the end of the flood, by removing sediment from the toe of the banks and causing or renewing undercutting, and by direct attrition of the banks by flowing water and flood debris. Hydraulic modelling by AMOG shows that in the 1 year ARI flood, velocities in the Moruya River estuary are typically in the order of 0.5 to 1.5 m/s, while in the 20 year ARI flood they are typically in the order of 0.5 to 2.5 m/s. These velocities are in the range that is capable of removing the sandy bed material in the bank toe areas, and of eroding soils and unconsolidated sediments exposed in the banks.

3.2.4 Bank Properties

Three main types of bank materials occur naturally in the estuary, depending on the geology of the material exposed in the banks:

- Quaternary alluvium – associated with erodible banks in unconsolidated sediments. Deposits were observed to be sandy and uncohesive, with little structural strength, vulnerable to slumping and erosion;
- Palaeozoic granite – associated with sandy soils and rock outcrops – the sandy soils are erodible but the outcrops limit the extent of erosion; and
- Palaeozoic sedimentary rock – associated with relatively stable banks compared to the Quaternary alluvium and Palaeozoic granite.

The banks of the river have been extensively rock-lined downstream of Yarragee. Problems with the stability of the lined banks were observed during the course of the site inspections as discussed above.

The river banks are steep and high in some places, particularly upstream of Moruya. This is likely to be a contributory factor to erosion, with the erosion process being part of a natural adjustment to a more stable bank slope.

3.2.5 Riparian Zone Management

Riparian vegetation can play an important role in maintaining bank stability as a result of the binding of bank materials by roots, coverage of bare surfaces, and increased hydraulic roughness leading to reduced flow velocities in the near-bank zone. Riparian vegetation loss has occurred on some sections of bank in the Moruya River estuary, and is likely to be contributing to bank erosion processes in these areas. However, bank erosion was also evident at sites where the banks were fully vegetated, where collapse or slumping of the banks had led to downslope displacement of riparian vegetation or tree falls into the water.

Uncontrolled stock access occurs in localised areas, where bank erosion is exacerbated by damage caused by stock trampling.

3.2.6 Powerboats

Powerboats, particularly when they travel fast such as for waterskiing, can contribute to bank erosion as a result of increased wave action caused by their wake. Young and Thoms (2000) noted concerns about powerboat wakes being a contributory factor in the bank erosion in the Yarragee reach of the estuary, which is used for waterskiing.

3.2.7 Sea level change

Sea levels along the South Coast of NSW are thought to have been stable for the past 6500 years (O’Brien 2001). If sea levels rise in the future, this will shift the zone affected by tidal wetting and wave action up-bank, which in turn may lead to an increase in bank erosion, at least during the adjustment phase. This is indicated by experience in the upper section of the Mary River estuary, Queensland, where the raising of high tide levels as a result of tidal amplification in response to the installation of a tidal barrage exacerbated bank erosion (Cameron McNamara 1984).

4 SEDIMENT INPUTS TO MORUYA RIVER ESTUARY

The evolutionary model of estuary development proposed by Bird (1967) implies that the sediments in the lower estuary associated with the coastal barrier system would be coastal or marine in origin, while the sediments in the estuary further upstream would be predominantly fluvial.

This has been confirmed by O'Brien (2001), who carried out studies of sediment character (including grain size, roundness, and sediment composition) which showed that sediments in the lower estuary (lower 2 km) are similar to marine sediments, while sediments in other parts of the estuary are similar to fluvial sediments. In particular, the lower estuary has finer sand, higher proportions of rounded and well rounded grains and higher shell content than the sections of the estuary further upstream. O'Brien (2001) also examined major element geochemistry, which indicated that most of the sediment in the estuary is of fluvial origin. Mineral particle magnetics analysis shows that fluvial sediments derived from the middle reaches of the Deua River and the lower parts of Araluen Creek are likely to be the major contributors of sand to the Moruya River estuary.

Scott Nichol's PhD thesis (cited in O'Brien 2001) also argues that the Moruya River estuary is dominated by sediment sourced from the catchment, based on stratigraphic evidence. Nichol's thesis was not available for review at the time of preparation of this report.

Sediments within the Moruya River estuary are reworked by tidal processes. Some sediment influx from the coast occurs under low flow conditions, rates of input being dependent on hydraulic factors (the net difference between sediment transport rates on the flood and ebb tides). There was a natural tendency for the river mouth to be impeded by the buildup of bars at the entrance, which was periodically opened and enlarged by floods (DPW 1978). Training walls constructed in the mid nineteenth century keep the entrance permanently open (DPW 1978) and the entrance was dredged from the late 1880s to the 1950s to maintain navigability of the river to the town wharf (Young and Thoms 2000). These modifications altered the regime of tidal processes within the estuary. The permanent entrance may allow coastal sediments to be carried further up the estuary than would have naturally been the case.

Bank erosion in the Moruya River estuary provides a local source of sediment input. The mobility of bed sediments in the estuary is affected by seagrasses. Seagrass beds stabilise bed sediments and induce deposition. Loss or reduction of seagrass beds would be associated with increased sediment mobilization. The seagrass beds in the Moruya River estuary are susceptible to natural changes in extent (seasonal and cyclical) due to factors such as turbidity, nutrient levels, sediment build up and disturbance by fauna such as swans (Clarke and Pressey 1981, Young and Thoms 2000) as well a changes due to the effects of human activities. An overall decrease in the total area covered by seagrasses in the estuaries of NSW has been reported (West et al. 1989). Recent trends in the extent of seagrasses in the Moruya River estuary have not been assessed (Young and Thoms 2000). Substantial beds were observed during the fieldwork for the present study.

The sources of sediment in the estuary are likely to be temporally as well as spatially variable. For example, immediately after large floods, when fluvial sediment is delivered to coast, fluvial sediment would dominate the entire estuary, but under low flow conditions, tidal processes would bring coastal sediment upstream, leading to greater dominance of coastal sediments in lower estuary after a prolonged period of low flow conditions.

4.1 FLUVIAL SEDIMENT SUPPLY

The Moruya River has a large catchment compared to many other NSW South Coast estuaries (about 1,500 km^2 – Warner 1981, Young and Thoms 2000). The catchment geology is dominated by Palaeozoic sedimentary and metamorphic rocks but significant areas of granitic rocks are also present (Warner 1981). The granites are particularly significant because they weather to sand and produce sandy alluvium. Sand is also produced from the sandstones (O'Brien 2001). The Deua River contains large sand/gravel bars that would be a source of sediment supply to the estuary under flood conditions. Sediment transport capacity (as determined by channel and valley hydraulics) would be a key determinant of sediment input rates.

Human activities in the Moruya River catchment, including forestry, agriculture and historical gold mining, may have led to increased sand inputs to the estuary. Other human activities with potential implications for sediment supply include river management works and sand/gravel extraction.

A relatively high frequency of bushfires in the Moruya River catchment over the period 1938–73 (Clarke and Pressey 1981) may have contributed to increased sediment availability in recent years.

The connectivity between various parts of the catchment and the Moruya River estuary is determined by sediment transport processes. The Deua Valley is of variable width, some parts being narrow and gorge-like and others being broader and containing minor floodplains and alluvial terraces. Studies elsewhere have shown that such variations in valley morphology and topography are associated with variations in sediment transport, the narrow reaches having higher transport efficiencies than the wider floodplain reaches, which may be net sediment accumulation zones (e.g. Craigie et al. 2000).

Significant influxes of fluvial sediment to Moruya River estuary occur during floods. For example, DPW (1978) noted that the low level bridge at Kiora is often untrafficable after floods due to sediment deposits – for example, in the 1945 flood, 12' (about 4 m) of sand needed to be removed. They also drew attention to overbank deposition of sediments during floods (which may have been sourced from the upstream catchment or the estuarine channel). For example, they noted that in the 1925 flood (record flood) many properties at Kiora and Yarragee were covered with sand 6-12' (2-4 m) deep as well as large amounts of timber.

Warner (1981) drew attention to the role of natural climatic variability in relation to the stability of the Moruya/Deua River system and rates of catchment sediment supply. He distinguished between flood-dominated regimes (FDRs) characterised by above average streamflows and flooding and high degrees of channel instability versus drought-dominated regimes (DDRs) characterised by smaller flows and more stable channel conditions. He identified the period 1900 to 1949 as a DDR and the period since 1949 as an FDR. Changes he noted in the Deua Valley (upstream of the Wamban gauging station) in the recent FDR include channel widening, destabilisation of formerly stable alluvial benches and reductions in channel depths associated with the infill of pools resulting from increased quantities of sediment being in transit.

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