

Appendix 1 Wave action

Michael Hunn—John Meidecke and Partners Pty Ltd

Estimation of the probable effect of wave action on the King River delta

These calculations are based on the following information:

- the delta is composed of a non-cohesive sediment with a specific gravity estimated as 2.65, and a mean grain size of 0.18mm, obtained from sieve results from DELM
- the maximum water level is about 2.2 m above chart datum, or about 1 m above AHD
- there is a fetch of 13 km from the southwestern end of the harbour to the delta, based on the strongest prevailing wind being from that direction
- hydrographic survey information from the HEC, shown on drawings G310587 and G310709

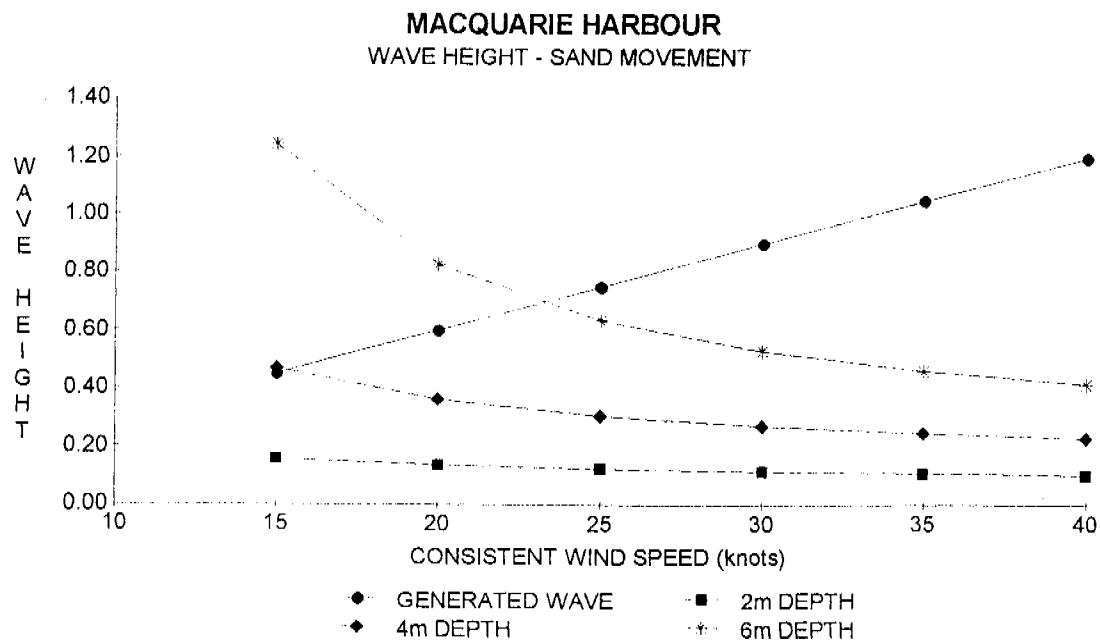
Based on this information, a preliminary estimate of the wave height (H_m) and period (T_m) can be made. The minimum duration of each storm required to generate the waves (t) can be compared with meteorological data to determine the probability for each event.

The wavelength (L) of the generated wave is determined from the period and water depth.

An estimate of the threshold water velocity required to initiate sand movement is determined from the mean grain size (D_{50}) and the specific gravity of the sediment.

The water velocity at the required depth is then compared with the threshold velocity to determine the minimum wave height (H_{min}) which will initiate sand movement.

This information is shown on the following graph.



It can be seen from this graph that in shallow water of depth 2 m the sand can commence to move with very small wave heights of less than 0.25 m, which would represent the conditions with a high tide over the delta, and virtually any wave action.

The required threshold wave height increases with depth, however even at a depth of 6 m the sand movement can be initiated by waves of about 0.75 m.

The minimum time required to develop the wave heights in the graph is shown below.

Wind speed		Fetch (km)	Hm (m)	Tm (sec)	t (hr)	L (m)
(knots)	(m/s)					
15	7.7	13	0.45	2.90	2.50	13.11
20	10.3	13	0.60	3.19	2.27	15.88
25	12.9	13	0.75	3.44	2.11	18.43
30	15.4	13	0.90	3.65	1.98	20.81
35	18.0	13	1.05	3.84	1.88	23.07
40	20.6	13	1.20	4.02	1.80	25.21

The maximum significant wave height of 1.20 m would be generated by a 40 knot wind blowing for at least 1.8 hours, although a storm of this intensity would be rare, and it can be assumed that the maximum wave height would normally be around 1 m.

The outflowing current from the King River would alter the wave directions and heights in the vicinity of the river mouth, although an accurate assessment of the extent of this would require more detail on the direction and intensity of the current. In any case, the configuration of the river mouth presumably alters with time, making such an assessment problematical.

Long-term effect of wave action

In general the equilibrium state of a beach, assuming that the sediment comprising the delta can be considered as such, depends on the interplay of wave forces and currents but can often be characterised by the grain size of the particles making up the beach. In this case the equilibrium slope is approximately 1:40.

It is considered that given sufficient time and wave action of a reasonable magnitude, the sediment would eventually take up this slope from high water down into the harbour, since the replenishment from the tailings in the King River has now ceased. This effect would be modified by movement of the river mouth, and possibly by long-shore movement of sediment to the north.

Slope protection

If the existing profile is reconstructed to provide a steep bank of, say, 1V:3H, the face of the bank would need to be protected by armour rock to prevent erosion by wave action.

Taking the maximum wave height as 1 m, the armour rock would be approximately 750 kg, or about 0.28 cubic metres taking a specific gravity of 2.65. This equates approximately to a rock of 0.65 cubic metres.

The extent of the rock protection would be approximately 2 m vertically above high water down to 2 m vertically below low water, as shown in the diagram below.



Appendix 2 Revegetation Trials, Phase 3

Tim Duckett and Christina Giudici

Introduction

Trials were established on the banks and Delta of the King River to assess various revegetation techniques as Phase 3 of the MLRRDP project 6. The aim of these trials was to gain as much information as possible about the likely success of various means for revegetating the sites.

Timing for the trials was limited, with a maximum of 10 months between establishment and final observations for the longest running trials. This is a short time for monitoring of a revegetation trial, since it is less than one complete growing season. Some of the trials were only run for 3 months before writing of this report. Therefore, the observations and conclusions documented here are preliminary only, and further monitoring which extends over several growing seasons is highly recommended.

Treatments

The range of treatments trialed in this project were determined following observations of the natural revegetation processes on the King River tailings and other tailings sites on the West Coast of Tasmania. The natural revegetation processes on the dry banks often followed a succession from mosses which stabilised the surface material to rushes which provided shelter and a nursery environment for rainforest tree species. In places where the natural forest canopy was close by, a fallen branch could provide shelter, organic material from its leaves and protection from browsing. Several sites were observed where this had happened with dramatic growth of mosses, rushes and rainforest trees in the branch shelter.

These observations indicated those conditions which may limit revegetation. These conditions are outlined below:

Physical constraints

- exposure
- unstable surface
- sand blasting or smothering by wind blown tailings
- varying water conditions (eg drought on the higher banks and waterlogging and inundation on the delta and lower banks)
- browsing by animals

Chemical constraints

- varying state of oxidation of tailings
- high metal concentrations
- acid conditions in surface layers

A range of treatments and planting times were devised to test which of these constraints could be overcome, and which methods of revegetation would suit the varying characteristics of the banks and delta. These treatments included:

- broadcasting of fertiliser
- planting of wetland species (*Juncus* and *Restio*) at different seasonal times and with and without fertiliser
- direct seeding with exotic grass species, with the addition of lime and fertiliser

- direct seeding with native tree species, with the addition of lime and fertiliser
- planting of native tree seedlings, with the addition of lime, fertiliser and fertiliser tablets

The treatments were repeated at more than one site, with different planting times (Spring 1995 and Autumn 1996) in some cases. Fencing was used on two sites Bank M and the Left Bank of the Delta), and trials repeated at fenced and unfenced sites.

Experimental layout

Plots were established as 10m x 10m squares, with the exception of the general fertiliser broadcast areas. They were generally sited on a given Bank in a position which gave some variation across the plot, for example a plot may be set so that it runs from a dry area down into a damper zone.

Juncus and *Restio* plots were planted with these species at 1 metre intervals. Plant material was gathered from a range of sites nearby and divided if necessary to provide propagules of suitable size. Mattock holes were made, the plant material placed in these, then the tailings material firmly tamped down around the base. Fertiliser for the *Juncus* and *Restio* plots was at a rate of 5 kg per 100m² of 8:4:10 high analysis fertiliser, which was hand broadcast over the plot prior to planting.

Native tree seedling plots were also planted at 1 metre spacing. Locally collected seed was grown for approximately six months prior to planting out. Two months before planting, 100 kg of Agricultural lime per 100m² was hand broadcast on the site and raked in. The species planted included *Acacia melanoxylon*, *A. dealbata*, *A. mucronata*, *A. verticillata*, *A. sophorae*, *Eucalyptus nitida*, *E. obliqua*, *Leptospermum scoparium*, *L. lanigerum*, *Melaleuca ericaefolia*, *M. squarrosa*. A fertiliser tablet was planted with each seedling, and 5 kg per 100m² of 8:4:10 high analysis fertiliser was hand broadcast on the plot prior to planting.

The direct seeding of exotics involved hand broadcasting of 200kg per 100m² of agricultural lime two months prior to seeding. The lime was raked in. Immediately prior to seeding, 5 kg per 100m² of 14:16:11 high analysis fertiliser was hand broadcast over the plot. Two kg of seed per 100m² was hand broadcast. The species included infertile Ryecorn (*Triticale*) and Concorde short rotation ryegrass (*Lolium*).

The direct seeding of native species was similar, however the rate of lime application was half that used for the exotic plots. The fertiliser rate was the same, however the fertiliser type was 8:4:10 high analysis. The native seed mix was bulked with clean sand to assist even distribution of seed during hand sowing.

Observations

The following tables record treatments for each bank and a brief description of observations made immediately prior to writing of this report in July 1996.

Bank	Plot	Treatment	Date establ'd	Observations
DELTA				
Right Bank	Note: This site prone to inundation. Material of experimental site sandy, with oxidised and unoxidised layers visible in mattock holes.			
	1	<i>Juncus/Restio</i> , no fertiliser	Spring '95	Above ground part of plants died, very few new shoots emerging.
	2	<i>Juncus/Restio</i> , + fertiliser	Spring '95	Above ground part of plants died, very few new shoots emerging.
	3	<i>Juncus/Restio</i> , no fertiliser	Autumn '96	Above ground part of plants died, very few new shoots emerging. Some <i>Restio</i> still have green colour.
	4	<i>Juncus/Restio</i> , + fertiliser	Autumn '96	Above ground part of plants died, very few new shoots emerging. Some <i>Restio</i> still have green colour.
	4A	Fertiliser around perimeter	Autumn '96	No observable result at present.
Left Bank	Note: Accumulated material at edges of fence and some branches washed into the plots indicate that this site is inundated on occasion. Surface crusting was severe in some parts of the experimental area, with varying depths of sandy material deposited of the hard layers.			
	5	<i>Juncus/Restio</i> , no fertiliser (fenced)	Autumn '96	Above ground part of plants died, very few new shoots emerging.
	6	<i>Juncus/Restio</i> , + fertiliser (fenced)	Autumn '96	Above ground part of plants died, very few new shoots emerging.
	7	Native tree seedlings, + lime and fertiliser (fenced)	Autumn '96	Trees alive, not much growth, show signs of stress (particularly eucalypts) and evidence of inundation.
	8	Direct seeding exotics, + lime and fertiliser (fenced)	Autumn '96	Good germination of grass, growth to 5 cm.
	8A	Direct seeding natives, + fertiliser around perimeter	Autumn '96	No observable result at present.

Bank	Plot	Treatment	Date establ'd	Observations
RIVER BANKS				
Bank A	Note: This site extends from vegetated edges of bank to river; one strip approximately 10 m wide was left with no fertiliser as a control.			
	9	Fertiliser broadcast	Spring '95	Some new growth of <i>Restio</i> at perimeter, no obvious difference to unfertilised site.
Bank C	Note: Trials were established on the higher, sandy sites on this bank. There was some layering of unoxidised and oxidised material in the mattock holes.			
	10	<i>Juncus/Restio</i> , no fertiliser, slash placed in windrows.	Spring '95	<i>Restio</i> survival and growth good in drier sites, <i>Juncus</i> survival and growth good in damper sites.
	11	<i>Juncus/Restio</i> , + fertiliser, slash placed in windrows.	Spring '95	<i>Restio</i> survival and growth good in drier sites, <i>Juncus</i> survival and growth good in damper sites.
	12	<i>Juncus/Restio</i> , no fertiliser, slash placed in windrows.	Autumn '96	As above, however healthier and more survival than Spring plantings. No observable difference between Fertilised and unfertilised plots.
	13	<i>Juncus/Restio</i> , + fertiliser, slash placed in windrows.	Autumn '96	As above, however healthier and more survival than Spring plantings.
	14	Native tree seedlings, + lime and fertiliser	Autumn '96	Good seedling survival and growth, <i>Acacia melanoxylon</i> seedlings heavily browsed.
	15	Fertiliser broadcast	Autumn '96	No observable result at present.

Bank	Plot	Treatment	Date establ'd	Observations
Bank D	Note: Mattock holes showed very locally variable conditions, with 1–2cm layers of oxidised and unoxidised tailings. The upstream end of the bank still had some unoxidised tailings on the surface, and widespread growth of <i>Juncus</i> and <i>Restio</i> which appeared to have been killed.			
	16	<i>Juncus/Restio</i> , no fertiliser, slash placed in windrows.	Spring '95	Above ground plant material mostly died, some growth from rhizomes. <i>Restio</i> better in drier areas, <i>Juncus</i> better in wetter areas.
	17	<i>Juncus/Restio</i> , + fertiliser, slash placed in windrows.	Spring '95	As above. No observable difference between fertiliser and non fertilised plots. Note: good exotic grass and weed growth where imported in soil material during planting.
	18	<i>Juncus/Restio</i> , no fertiliser, slash placed in windrows.	Autumn '96	As above, however better survival of plants, particularly <i>Restio</i> .
	19	<i>Juncus/Restio</i> , + fertiliser, slash placed in windrows.	Autumn '96	As above. Note: 10 cm eucalypt seedling germinated in slash (many seed capsules on slash material)
	20	Fertiliser broadcast	Autumn '96	Some moss evident.
	20A	Direct seeding exotics, + fertiliser	Autumn '96	Good germination, some browsing evident. Growth to 5 cm.
Bank F	This bank has unique characteristics which differentiate it from the other banks. The surface is strongly cemented, and large river cobbles and slag material are incorporated in this later. Many tree stumps are scattered over the surface, and there appears to be no great change to the original height of the bank.			
	21	<i>Juncus/Restio</i> , no fertiliser	Spring '95	Some survival, particularly <i>Juncus</i> in wet sites with free standing water.
	22	<i>Juncus/Restio</i> , + fertiliser	Spring '95	As above.
	23	<i>Juncus/Restio</i> , no fertiliser	Autumn '96	As above. Note: many <i>Restio</i> plants have fallen over.
	24	<i>Juncus/Restio</i> , + fertiliser	Autumn '96	As above.
	25	Fertiliser broadcast	Autumn '96	No observable result at present.

Bank	Plot	Treatment	Date establ'd	Observations
Bank H	This bank has similar characteristics to Bank M, and all treatments established on this bank were repeated on Bank M inside game-proof fencing. The tailings material was generally well sorted sands and silts, with semi permanent fresh water streams on the landward side.			
	26	<i>Juncus/Restio</i> , no fertiliser	Spring '95	Variable survival; <i>Juncus</i> better in wet areas.
	27	<i>Juncus/Restio</i> , + fertiliser	Spring '95	As above. Note: many <i>Caryx</i> and other seedlings observed.
	28	<i>Juncus/Restio</i> , no fertiliser	Autumn '96	Most plants still healthy.
	29	<i>Juncus/Restio</i> , + fertiliser	Autumn '96	As above.
	30	Native Tree seedlings, + lime and fertiliser	Autumn '96	Trees growing well; Eucalypt seedlings purple colour, looking stressed; <i>A. melanoxylon</i> seedlings heavily browsed.
	31	Fertiliser broadcast	Autumn '96	No observable result to date.
	32	Direct seeding exotics, + lime and fertiliser	Autumn '96	Grasses germinated and 3–5cm tall, good ground cover.
	33	Direct seeding natives, + lime and fertiliser	Autumn '96	Native seedlings just visible, less than 1 cm tall.

Bank	Plot	Treatment	Date establ'd	Observations
Bank M	This bank had similar characteristics to Bank H. The surface was well sorted sandy material, and showed deflation hollows and other features associated with wind erosion. The landward edge of the bank was being colonised by mosses and a dense population of <i>Restio</i> . This fringe serves as a nursery for rainforest species, which are colonising the bank from the existing rainforest edge.			
	34	<i>Juncus/Restio</i> , no fertiliser	Spring '95	Most plants still growing, new growth from rhizomes evident.
	35	<i>Juncus/Restio</i> , + fertiliser	Spring '95	As above. Note: some myrtle seedlings transported with soil material growing at bases of plants.
	36	<i>Juncus/Restio</i> , no fertiliser	Autumn '96	Plants still healthy following transplanting.
	37	<i>Juncus/Restio</i> , + fertiliser	Autumn '96	As above.
	38	Native tree seedlings, + lime and fertiliser (fenced)	Autumn '96	Excellent growth of all species.
	39	Fertiliser broadcast	Autumn '96	Visible brightening of mosses, and increase in extent of moss covered areas.
	40	Direct seeding exotics, + lime and fertiliser (fenced)	Autumn '96	Vigorous and dense growth of exotics, up to 20 cm tall.
	41	Direct seeding natives, + lime and fertiliser (fenced)	Autumn '96	Natives germinating, some 2–3cm tall, better growth than similar trial on Bank H.
	41A	Direct seeding exotics, + fertiliser	Autumn '96	Some germination evident, but very few plants visible, suspect heavy browsing in comparison to fenced plot.
Demo site	This site was chosen as a demonstration site because of its visibility and ease of access for establishment. It is a well formed, small bank in an eddy, and has good moss growth, particularly in the lee of established trees. This site showed the results of a branch which had fallen out of the rainforest canopy onto the tailings. There were numerous species flourishing in the area protected by the branch.			
		<i>Juncus/Restio</i> , native tree seedlings, + lime and fertiliser	Autumn '96	Wetland species not surviving well; trees growing slowly; moss growth good.

References

- ANZECC 1992. National Guidelines for the Assessment and Management of Contaminated Sites. ANZECC.
- Baker RA 1980. *Contaminants and sediments* (2 vols). Ann Arbor Press, Michigan.
- Dickson KL, Maki AW & Brungs WA (eds) 1987. *Fate and effects of sediment-bound chemicals in aquatic systems*. Pergamon, New York.
- Demars KR, Richardson GN, Yong RN & Chaney RC 1995. *Assessment and remediation of contaminated sediments*. ASTM STP 1293, ASTM Press.
- Ellis D, Poling G & Pelletier C 1994. *Case studies of submarine tailings disposal: Volume II, Further case histories and screening criteria*. US Dept of Mines, Juneau Alaska.
- EPA NSW 1993. Position Paper: NSW Natural Waters Sediment, Unpublished draft paper.
- Forstner U & Wittmann GTW 1981. *Metal pollution in the aquatic environment*. 2nd ed, Springer-Verlag, NY.
- Koehnken L 1996. Macquarie Harbour – King River Study. Draft report.
- Line ER 1994. *Potential biological consequences of submarine mine-tailings disposal: A literature synthesis*. US Bureau of Mines, OFR 36-94.
- Locher H 1995. *Sediment transport in the King River, Tasmania: A case study*. CRC for Catchment Hydrology, Monash University, Melbourne.
- Locher H & Keller R 1996. Influence of power station operations on sediment transport in the King River, Tasmania. Proceedings: 23rd Hydrology and Water Resources Symposium, May 1996.
- Miedecke John 1996. *Remediation options to reduce acid drainage from historical mining operations at Mount Lyell, Western Tasmania*. Mount Lyell Remediation Research and Demonstration Program. Supervising Scientist Report 108, Supervising Scientist, Canberra.
- National Research Council 1989. *Contaminated marine sediments: Assessment and remediation*. National Academy Press, Washington DC.
- Nazarov Alex & Russo Tony 1996. Mount Lyell submerged sediment remediation and treatability literature review. Supervising Scientist, Canberra. Unpublished paper. [This paper is a companion volume to this report, available on request from OSS.]
- Nijsson JPJ 1988. Rotterdam dredged material: Approach to management. In *Environmental management of solid waste: Dredged material and mine tailings*, eds W Salomons & U Forstner, Springer, Berlin.
- Palermo MR & Miller J 1995. Strategies for management of contaminated sediments. In *Dredging, remediation and containment of contaminated sediments*, Demars R et al, ASTM STP 1293, Philadelphia.
- Poling G & Ellis D 1993. *Case studies of submarine tailings disposal: Volume I: North American Examples*. US Dept of Mines, Juneau Alaska, OFR 89-93.
- PTI Environmental Services 1993. *Draft assessment and remediation of contaminated sediments (ARCS) Remediation guidance document*, USEPA, August 1993.

- Salomons W & Forstner U (eds) 1988a. *Chemistry and biology of solid waste: Dredged material and mine tailings*. Springer, Berlin.
- Salomons W & Forstner U (eds) 1988b. *Environmental management of solid waste: Dredged material and mine tailings*. Springer, Berlin.
- Taylor Jeff R, Weaver Tamie R, McPhail DC 'Bear' & Murphy Nigel C 1996. *Characterisation and impact assessment of mine tailings in the King River system and delta, Western Tasmania*. Mount Lyell Remediation Research and Demonstration Program. Supervising Scientist Report 105, Supervising Scientist, Canberra.
- Teasdale Peter, Apte Simon, Batley Graeme & Ford Phillip 1996. *The behaviour of copper in sediments and waters of Macquarie Harbour, western Tasmania*. Mount Lyell Remediation Research and Demonstration Program. Supervising Scientist Report 111, Supervising Scientist, Canberra.
- USACE 1989. *Management plan report, unconfirmed open water disposal of dredged material, Phase II, North and South Puget Sound*. US Army Corps of Engineers, Sept 1989.
- USEPA 1987. *An overview of sediment quality in the United States*. Office of Water, EPA-905-9-88-002, June 1987.
- USEPA 1990a. *Review of removal, containment and treatment technologies for remediation of contaminated sediment in the Great Lakes*. USEPA, Misc paper EL-90-25, December 1990.
- USEPA 1990b. *Managing contaminated sediments – EPA Decision Making Processes*. Sediment Oversight Technical Committee, EPA 506/6-90-002, December 1990.
- USEPA 1991. *Handbook, remediation of contaminated sediments*. EPA/625/6-91-028, April 1991.
- USEPA 1992. *Proceedings of the EPA's contaminated sediment strategy forums*. EPA Office of Water, EPA 823-R-92-007, September 1992.
- USEPA 1993a. *Selecting remediation techniques of contaminated sediment*. Office of Water, EPA-823-B93-001, June 1993.
- USEPA 1993b. *Assessment and remediation of contaminated sediments (ARCS) Program, Quality Assurance Program Plan*. EPA600/R-93-242.
- USEPA 1994. *EPA's contaminated sediment management strategy*. EPA 823-R-94-001. August 1994.
- Yoshinaga, K, 1995. Mercury-Contaminated Sludge treatment by Dredging in Minimata Bay. In *Dredging, remediation and containment of contaminated sediments*, Demars K et al, ASTM STP 1293, Philadelphia.