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Gunns Pulp Mill Water Supply

Tamar River Crossing Pipeline Installation

Prepared for

Gunns Limited

June 2006

Prepared by: Ian Woodward

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1. Introduction

Pitt & Sherry has been commissioned by Gunns Limited to prepare a report for the Tamar River crossing of the proposed pulp mill's water supply pipeline.

The scope of this document is limited to the river crossing. Construction of terrestrial sections of the pipeline and the supply of water itself are dealt with in separate documents under the Integrated Impact Statement (IIS).

This report identifies potential environmental impacts that could arise from the crossing construction, assesses the significance of those potential impacts and describes how those impacts will be managed. It includes information on the existing environment, the likely crossing methodology, site management details, and a summary of commitments.

There is a long history of silt dredging in the Tamar estuary, and a large number of studies on silt behaviour have been undertaken over the last 20 to 30 years. These studies provide a sound foundation upon which the potential impacts of the pipeline installation can be assessed, and this report is based on those studies. Additional site-specific geotechnical investigations have been undertaken for this project to determine the most appropriate construction methodology.

The proposed approach and the commitments made in this report will form a basis for the Resource Planning and Development Commission (RPDC) to set approval conditions for this component of the pulp mill project under the *State Policies and Projects Act 1993*.

The construction contractor will be required to prepare a Construction Environmental Management Plan (CEMP) prior to the commencement of work. Gunns will provide a copy of this plan to the Environment Division of the Department of Tourism, Arts & Environment for information. The Director of Environmental Management may then determine that additional or modified permit conditions are required, and these would be imposed through the issue of an environment protection notice under the *Environmental Management and Pollution Control Act 1994*.

2. Existing environment

2.1 Crossing location

The proposed crossing is located in the Tamar River, between Barnes Point, north of the Tamar Cut, and the University at Newnham, as shown on Figure 1.

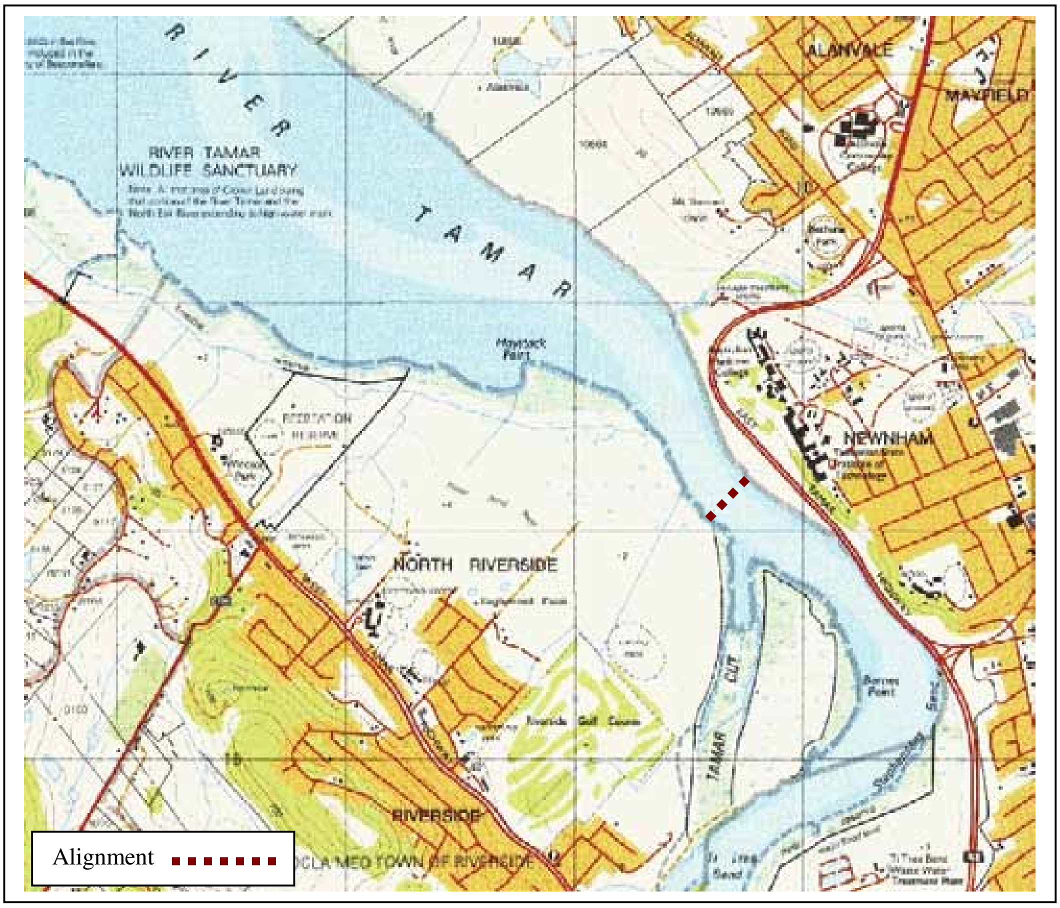

Figure 1: Alignment of the proposed water supply pipeline crossing (Base map source: Tasmap)

2.2 Geology

The geology of the Launceston area has been mapped by Longman *et al*[1], with more recent information compiled by Calver and Forsyth[2].

The Tamar Valley occupies a NNW-trending fault structure that has been produced by a series of normal faults that generally trend NNW-SSE and are downthrown to the east[3].

The elevated areas of the Tamar Valley are dominated by Jurassic dolerite. Considerable thicknesses of Tertiary sediments and basalt flows have accumulated in the floor of this structure. Alluvial and estuarine sediments have continued to accumulate in the floor of the valley throughout the Quaternary and extensive deposits of Holocene to Recent sediments, consisting of soft silts, stiff clays and gravels, are associated with the present day delta in the upper Tamar area.

The geology revealed by borehole investigations at the proposed crossing site is shown in Figure 2. At this site the Holocene to Recent sediments range from 2 to 15 m in thickness, with the thickness of the deposits increasing from east to west. These sediments are generally unconsolidated, varying from very soft to firm.

These sediments are underlain by gravels that probably represent Pleistocene terrace deposits associated with an ancestral Tamar River flowing through the site to an estuary below present day sea level. These gravels are likely to be generally unconsolidated to weakly consolidated.

Tertiary sediments consisting of minor claystones/siltstones/mudstones, thin layers of lignite, sandstones and moderately consolidated pebble conglomerates underlie the Holocene to Recent sediments and the Pleistocene terrace deposits. The sandstones and associated finer sediments were deposited in a delta that was periodically subjected to flows of dolerite cobbles from the sides of a trough. These sediments are generally of low strength, the variable distribution of carbonaceous material producing localised zones of weakness within the sediments. The conglomerates are only moderately consolidated and may tend to break around the cobbles under pressure of drilling or tunnelling.

Mottled duplex and stony gradational soils have developed on the Tertiary clays and gravels.

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[1] Longman, MJ, Matthews, WL and Rowe, SM. 1964. *Geological Atlas 1 Mile Series, Sheet 8315 S Launceston*. Department of Mines, Hobart.
[2] Calver, CR and Forsyth, SMF (compilers) 2005. *Map 3, Launceston – Geology. Tasmanian Landslide Hazard Series*. Mineral Resources Tasmania, Department of Infrastructure Energy and Resources, Hobart.
[3] Longman, MJ. 1966. *Geological Survey Explanatory Report, One Mile Geological Map Series, Launceston*, Tasmania Department of Mines.

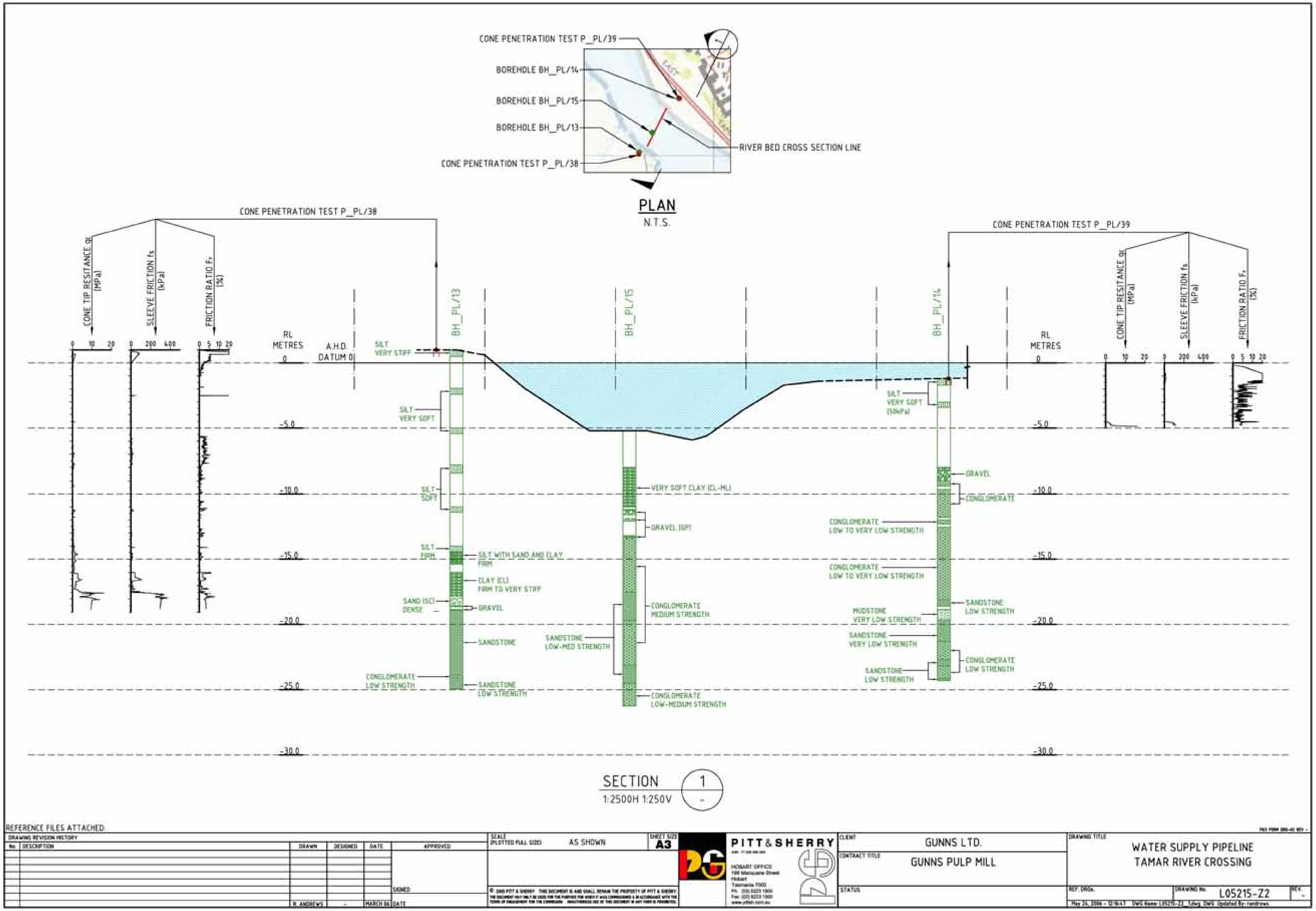

Figure 2: Tamar pipeline crossing geology based on information obtained from the 2006 geotechnical investigations.

These soils have gravelly sandy loam and gravelly clay loam surface textures, moderate to low permeability and an average depth greater than 2.0 m. They are prone to low streambank erosion and waterlogging on lower plains and swales.

Dark grey clay uniform soils with a surface clay texture have developed on the dark grey muds of the river terrace and floodplains. These soils have low permeability, average depth greater than 2.0 m and are prone to riverbank erosion, waterlogging and salting.

The river flats between the Tamar Cut and Haystack Point are currently farmed, being used for grazing and horse training facilities.

Significant portions of these flats are inundated at times of high flows in the South and North Esk Rivers and are also flooded at times of persistent heavy local rainfall.

2.2.1 Silt behaviour

Detailed studies[4] undertaken during the 1980s have outlined the general patterns of silt movements within the estuary. There have been no developments in feeder catchments or alterations to the estuary's morphology or flow regime since that time that would diminish the relevance or value of those studies and their conclusions to the present project.

Dredging undertaken over the years subsequent to those studies will have had a localised impact on silt behaviour as the river attempts to restore its local bottom profile to that in existence prior to dredging. However, these localised changes to silt movement would then have become subsumed by the more general pattern of movement. The scale of localised dredging is orders of magnitude lower than that of the general silt movements, and dredging at the scale that has been conducted cannot in itself change general patterns of silt behaviour. This conclusion is supported by the observation that over this period of time there does not appear to have been any major change in either silt build up or loss in the estuary, including at the proposed crossing site.

The detailed studies of the 1980s therefore remain highly pertinent and a sound basis for assessing the potential impact of the pipeline crossing construction.

[4] For example Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee; and Foster, D.N. (1987) *Progress report on silt monitoring of Tamar River*. Report to Tamar River Improvement Committee.

Dredging history

The Tamar River is in fact a combined estuary of the North Esk and the South Esk rivers. The head of the Tamar is located at the confluence of its tributaries, and the Tamar is tidal for its entire length.

Like most estuaries, the Tamar is a place of silt deposition because flow velocities decrease, reducing the sediment carrying capacity of the water. Silt build up creates problems for shipping, and for more than 100 years dredging has been undertaken to maintain navigational channels.

Dredging over the period from 1947 to 1966 removed an average of 160,000 m^3 each year (average of 438 m^3 per day) from the Tamar Estuary[5]. Dredging ceased between 1966 and 1987 following the relocation of major port facilities to Bell Bay. Dredging recommenced in 1988 and between 1988 and 1998 600,000 m^3 was removed, an average of 60,000 m^3 each year (164 m^3 per day)[6]. A total of 68,000 m^3 was removed between 2001 and March 2006, an average of 13,600 m^3 per year (37 m^3/day)[7].

Dredging has altered the natural balance of siltation and erosion in the upper estuary. Under "regime" conditions there is no long term erosion or siltation in this part of the estuary (but siltation will still occur at the foot of the delta in the middle part of the estuary). Removing silt by dredging means that the system would require additional deposition to return to the natural balance. It has been calculated that 643,350 m^3 of silt would need to be deposited in the Tamar Estuary to return it to natural regime balance[8].

Changes in the catchment of the estuary have also disturbed the regime balance. The diversion of water from Great Lake through the South Esk River and Trevallyn Power Station since 1955 has reduced the frequency of low flow conditions when high siltation rates would occur, effectively reducing the rate of siltation from approximately 100,000 m^3/year to 30,000 m^3/year in the estuary[9].

Siltation patterns in the Tamar Estuary are considered to be a consequence of its hydrology rather than the amount of silt coming from its tributaries, which have relatively low sediment yields[10]. While silt concentrations in the North

[5] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[6] Foster, D.N. (July 1999) *Notes on siltation April 1998 to April 1999* Report prepared for the Tamar River Improvement Committee.
[7] Pers.comm. Steve Ratcliffe, Launceston City Council
[8] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[9] Foster, D.N. (1987) *Progress report on silt monitoring of Tamar River*. Report to Tamar River Improvement Committee.
[10]Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.

and South Esk rivers are not high, over geological time scales large volumes of silt have nevertheless been deposited in the estuary.

Silt movements

An understanding of both the nature and behaviour of silt in the estuary is of critical importance when considering the proposed water supply pipeline crossing of the Tamar River for four primary reasons:

- The depth and degree of consolidation of the silt will influence the method of installation of the pipeline;
- There is a potential for the pipeline to be subject to vertical bending stresses due to gravity if the silt has inadequate bearing strength to carry the pipe;
- There is a potential for silt on the bed of the estuary to be scoured, thereby potentially exposing the pipeline to lateral bending stresses from water currents, and possibly also vertical stresses due to gravity if the pipe is undercut; and
- There is a potential for silt to be lifted into the water column during pipeline installation, to be carried downstream where it may be deposited in navigation channels and/or wildlife areas, causing physical impacts and possibly environmental impacts due to anthropogenic contaminants in the silt.

Deposited subtidal sediments are redistributed by a combined action of river flow and tides. Under tidal and flood conditions silt may be scoured from the bed and banks and taken into suspension but mud flats are highly resistant to scour under both tidal and flood conditions[11]. The general pattern of silt movement is for it to oscillate in the upper 15 km of the river, tending to move upstream on the flood tide at times of low river flow and then be carried downstream for about the same distance at times of river flooding[12]. When there is no freshwater flow through Cataract Gorge or the Trevallyn Power Station more silt is brought up-river under flood tide than is returned down-river during ebb tide[13].

Extensive tidal mud flats have formed on both sides of the estuary, and there are also mid channel islands (eg. Tamar Island) and shoals, which have also formed from silt deposition. These shoals and islands create navigational barriers to shipping, and for over a century active dredging has been undertaken to maintain navigation channels. The Tamar Island shoals act as a major sediment sink, and the Port of Launceston Authority actively encouraged siltation in this area by partially sealing off the channel to the west of Tamar Island[14].

[11] Foster, D.N. (April 1986) *Report to the Tamar River Improvement Committee 29 April 1986*.

[12] Donnelly, L. (September 1989) *Port of Launceston Channel maintenance by raking*.

[13] Foster, D.N. (1993) *Progress report on silt monitoring – Tamar River 1984-1993*. Report prepared for the Tamar River Improvement Committee.

[14] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.

The shoals, islands and mud flats form wetland areas, which are attractive to wildlife. The Tamar Island Reserve is a large and important wetland area downstream of the proposed crossing point.

On average 80,000 m^3 of silt is mobilised from the Tamar River per year (220 m^3 per day)[15]. It has been estimated that each year at least 15,600 m^3 (average 43 m^3 per day) of silt is deposited in the Tamar Island shoals, while upstream of Stephensons Bend an estimated 28,180 m^3 of silt is deposited (77 m^3 average per day)[16].

Stephensons Bend is 1 km upstream of the proposed pipeline crossing point and Tamar Island is 2.5 km downstream. The majority of the remaining silt would be deposited between Tamar Island and the foot of the delta, which is in the vicinity of Rosevears.

Flows in excess of 160-180 cumecs induce bed scour in Home Reach[17,18]. A cumec is a flow rate of one cubic metre per second. During flood events in excess of 200 cumecs, the net sediment transport (out of Home Reach) is downstream[19].

Measured silt transport at Kings Wharf during ebb and flood tides over a range of river flows is shown in Figure 3.

Figure 3 shows that in the absence of river flow 500 tonnes of suspended silt is carried upstream by each incoming tide. As river flow increases, the discharge counteracts the flood tide and progressively less silt is carried upstream by the tide. Eventually, at a river flow of about 280 cumecs upstream tidal flow is virtually non-existent and there is no upstream transport of silt.

[15] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.
[16] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[17] Foster, D.N. (1993) *Progress report on silt monitoring – Tamar River 1984-1993*. Report prepared for the Tamar River Improvement Committee.
[18] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[19] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.

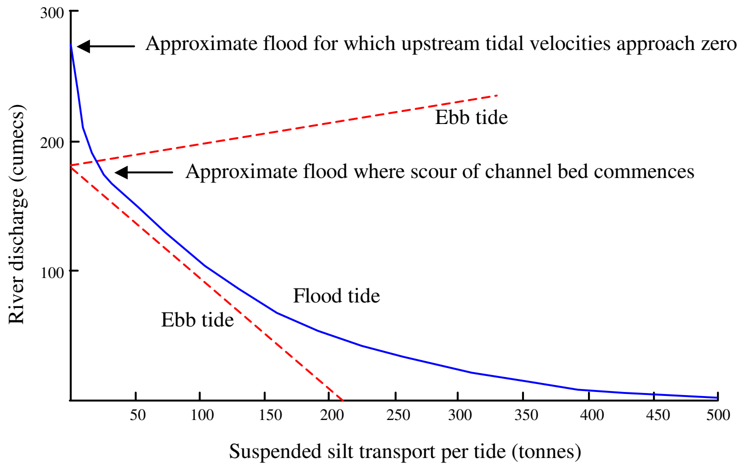

Figure 3: Measured silt transport at Kings Wharf during ebb and flood tides over a range of river flows[20]

On the ebb tide, the behaviour of the suspended silt depends on whether the river discharge is above or below a critical sediment scour threshold. At a river discharge of zero, approximately 200 tonnes of suspended silt is carried downstream on each outgoing tide. As river flow increases, the amount of suspended silt initially decreases, reflecting the relatively clean incoming river flow and the lesser amount of suspended silt returned on the flood tide.

Once the scour threshold flow of approximately 180 cumecs is reached, however, bed scour begins and more and more silt becomes entrained in the river discharge waters. For example, measurements[21] before and after a 325 cumec flood in the North Esk in October 1992 (peak velocity of 2.6 m/sec), showed a bed scour of 0.3 m.

For flows less than the scour threshold of about 180 cumecs, the net silt transport is upstream. Above the scour threshold flow, net silt transport is downstream.

The net transport of silt at Kings Wharf over a tidal cycle in relation to river discharge is shown in Figure 4.

[20] After Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[21] Foster, D.N. (1993) *Bed scour North Esk River.* Report to Tamar River Improvement Committee.

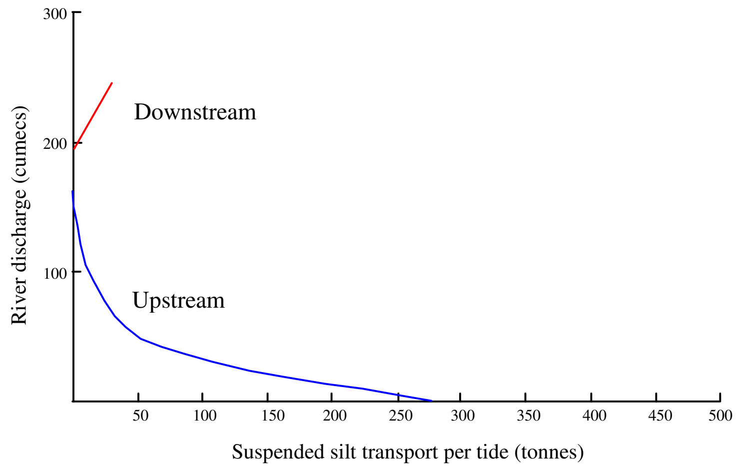

Figure 4: Measured silt transport at Kings Wharf during ebb and flood tides over a range of river flows[22]

In the absence of river discharge, a net 275 tonnes (approximately) of silt is transported up the estuary. Net transport reduces as river discharge increases. Only once the critical scour threshold is reach is net transport downstream.

Historical average flow data obtained from Hydro Tasmania for the period spanning 1994 to 2003 is shown in Table 1 (these data do not include flows from the North Esk River but that river's catchment is only about 5% of the Tamar's catchment[23]).

Table 1: Average discharges from the South Esk catchment[24]

	Power Station Average Flow (cumecs)	**Cataract Gorge Average Flow** (cumecs)	**Combined Average Flow** (cumecs)
Autumn	39	8	47
Winter	58	48	106
Spring	54	33	87
Summer	47	12	59

Average discharges are well below the silt scour threshold. Reference to Figure 3 and Figure 4 shows that at average summer or autumn discharge flows of approximately 50 cumecs upstream silt transport is approximately 200 tonnes per tide, and downstream silt movement is approximately 150 tonnes per tide, for a net upstream movement of 50 tonnes per tide. At average winter and spring discharge flows of approximately 100 cumecs, the net silt transport is slightly upstream, with about 15 tonnes of silt moving back and forth each tide.

[22] After Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.
[23] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[24] GHD (20November 2005) Collation of data for Gunns Pulp Mill IIS.

The average flows are two orders of magnitude below the extreme flood flows shown in Table 2 and Table 3.

Table 2: Historical flood records for the South Esk River at Launceston[25]

Date	Peak flood discharge (cumecs)	Estimate Average Return Interval (ARI)
December 1863	4625	1 in 200 year
July 1852	4190	1 in 140 year
April 1929	3964	1 in 100 year
September 1828	3300	1 in 60 year
July 1983	3160	1 in 50 year
May 1852	2790	1 in 30 year
May 1969	2670	1 in 25 year
November 1889	2670	1 in 25 year
June 1889	2640	1 in 25 year
May 1872	2430	1 in 20 year

Table 3: Flood levels for various Average Return Intervals[26]

ARI	Peak flood discharge
20 years	2500 cumecs
50 years	3200 cumecs
100 years	3700 cumecs
200 years	4700 cumecs

It has been estimated[27] that tributary inflows of approximately 1400 cumecs will occur about 12 times every 100 years, with a channel velocity at the confluence with the North Esk River of 2.5 m/sec, and inflows of 425 cumecs will occur about 8 times every 10 years, with a channel velocity of 2 m/sec.

Flood flow velocities decrease rapidly downstream of Kings Bridge. For example, in a 4250 cumecs flood the surface flow velocity at Kings Bridge would be in the order of 12 m/sec but downstream of the North Esk confluence, surface velocity would drop to 3 m/sec approximately[28].

The Tamar River's maximum diurnal tidal stream flow is about 280 cumecs at a velocity of 1m/sec at the confluence of the North Esk River when there is no significant flood flow from those rivers[29].

[25] Pers.comm.. Steve Ratcliffe, Launceston City Council after UNSW Water Research Laboratories
[26] Pers.comm.. Steve Ratcliffe, Launceston City Council after UNSW Water Research Laboratories
[27] Donnelly, L. (September 1989) *Port of Launceston Channel maintenance by raking*.
[28] Interpreted from Foster, D.N. (1992) *Assessment of the effect of a suggested development at the junction of the South Esk and Tamar Rivers on flooding*.
[29] Donnelly, L. (September 1989) *Port of Launceston Channel maintenance by raking*.

The relationship between river (tide) level, water velocity and suspended sediment concentrations at the head of the Tamar River and at Freshwater Point and Rosevears is shown in Figure 5, from work undertaken by the UNSW Water Research Laboratory (UNSW WRL).

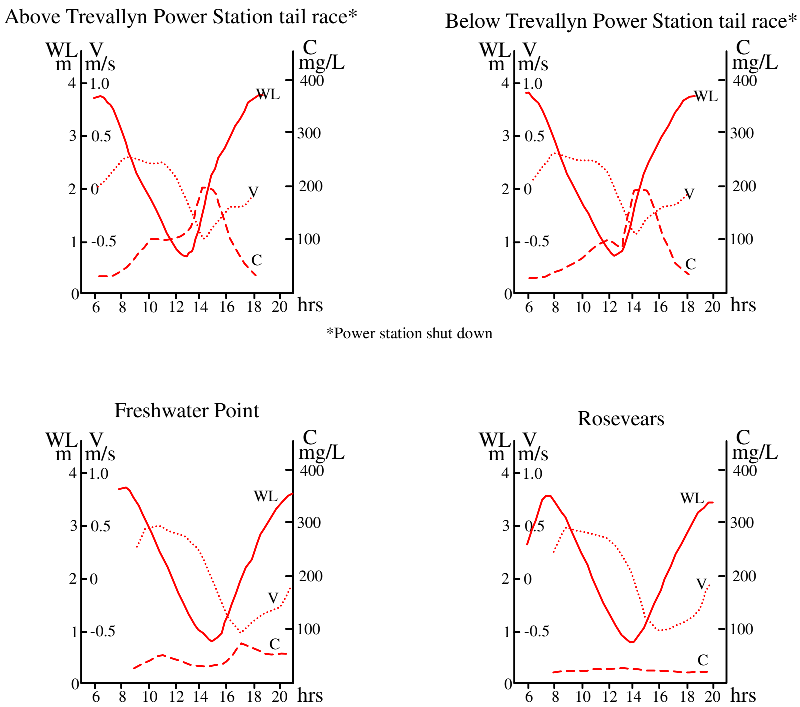

Figure 5: Examples of suspended sediment concentrations (C), water level (WL) and cross section average current velocity (V) at gauging stations in the upper Tamar River[30]

The UNSW WRL concluded[30] that current velocity tends to be higher and peakier on the flood tide and that upstream of Rosevears suspended sediment concentration peaks about half way through the flood tide, indicating that there would be upstream transportation of suspended sediment.

The UNSW WRL observed that with the power station shut down there is net deposition in Home Reach and net erosion between Ti-Tree Bend and Rosevears, with some sediment going downstream from Rosevears and a small amount going into the North Esk. With the power station running (64 cumecs) there is net erosion between Freshwater Point and Rosevears and from Ti-Tree Bend, while between Ti-Tree Bend and Freshwater Point deposition is increased by a factor of two and deposition in Home Reach is reduced by a factor of three.

Upstream of the pipeline crossing point (below the Trevallyn tail race), suspended sediment concentrations peaked at about 200 mg/L during the observation period and dropped to about 25 mg/L. More recent unpublished

[30] After UNSW Water Research Laboratory (April 1986) *Tamar River Siltation Study tide gauging January 1985*.

data[31] collected by the (now) Department of Tourism, Arts and Environment between 2003 and 2005 in a similar location measured a mean concentration of 41 mg/L in surface waters and 65 mg/L in bottom waters. At Freshwater Point, downstream of Tamar Island, suspended sediment concentrations measured by UNSW were less variable over the tide, and were about 50 mg/L. Further downstream, at Rosevears, concentrations were even more constant and were also lower, at about 20 mg/L.

Silt properties

Silt properties are shown in Table 4 and Table 5. The silt has a significant clay component and a large range in moisture content, cohesion and residual shear strength.

Table 4: Properties of the upper Tamar estuary alluvial silt[32,33]

Parameter	Typical	Range
Moisture content	120 %	100 – 225 %
Bulk (wet) density	1.35 t/m^3	1.3 – 1.45 t/m^3
Fill density	1.85 t/m^3	
Grading	Silt 60%, clay 40%	
Effective cohesion	6 kPa	1.44 – 14.4 kPa
Effective angle of internal friction	22^o	14 – 23.5^o
Residual shear strength		2 – 20 kPa
Pore pressure ratio	0.9	
Underwater equilibrium silt slope	14^o	
Intertidal equilibrium silt slope	5^o	

Table 5: Silt particle size analyses[34]

Source	% clay (<0.002 mm)	% silt (<0.02 mm)	% fine sand (<0.15 mm)	Organic matter and soluble salts
West Tamar*	56	23	21	4
Ti Tree**	61	21	18	4

* Composite of samples from 6 settling ponds. ** Top 100 mm of *in situ* silt.

[31] Reported in Aquenal (June 2006) *Aquatic environmental investigation at proposed Tamar River crossings for Gunns pulp mill water supply pipeline*. Report prepared for Gunns Limited.

[32] Inglis, O.G. (August 1988) *Siltpond stability*. Report prepared for Tamar River Improvement Committee.

[33] Inglis, O.G. (October 1989) *Tamar River Improvement Works – embankment stability*. Report prepared for Launceston City Council.

[34] Department of Primary Industry (September 1989) *Report on analyses of Tamar River silt*. Report prepared for Stephenson Maunsell & Partners.

Scouring of silt from the estuary bed or banks requires the shear stress from the flowing water to exceed the yield stress of the *in situ* silt. Shear stress increases with increasing velocity.

The yield stress of the silt has been determined to be at least 1 Pa, even when the solids component is as low as 9%[35].

Preliminary modelling currently being undertaken by WBM Oceanics for Launceston City Council has calculated tidal velocities in the vicinity of the crossing point[36]. These are shown in Table 6.

Table 6: Predicted tidal flow velocities in the vicinity of the crossing point[37]

Point of tide	Velocity
Maximum peak ebb velocity	0.56 m/sec
Average peak ebb velocity	0.44 m/sec
Maximum peak flood velocity	0.67 m/sec
Average peak flood velocity	0.48 m/sec

Even at maximum peak tidal velocities, the yield stress of the silt exceeds its shear stress[38]. Under tidal conditions alone, silt is therefore unlikely to become entrained in the water column by horizontal water flow. However, in turbulent conditions and/or during physical disturbance (such as dredging), silt may be lifted vertically into the water column and become suspended.

For many years a procedure known as "raking" was used in times of significant tributary inflow to disturb silt in the navigation channels for it to be carried down river on the flood flow, assisted by the ebb tide, where it would be deposited on mud flats. In the vicinity of the pipeline crossing, the river section normally raked was Home Reach to No.7 light (Barnes Point)[39].

The most effective raking was found to occur at tributary inflows of 850 cumecs, developing a water velocity of 2 to 2.5 m/sec but flows of 425 cumecs and a velocity of 1.5 to 2 m/sec were considered sufficient to warrant raking. Raking was attempted on the ebb tide with no tributary inflow but the results were questionable[40]. This experience suggests that simple agitation of the silt surface (as distinct from vertical forcing) is unlikely to move silt into suspension unless river flows are 425 cumecs or more.

[35] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.
[36] The model's downstream extent will be approximately 500 m upstream of the crossing point.
[37] Steve Ratcliffe, Launceston City Council, pers.comm. after WBM Oceanics
[38] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.
[39] Donnelly, L. (September 1989) *Port of Launceston Channel maintenance by raking*.
[40] Donnelly, L. (September 1989) *Port of Launceston Channel maintenance by raking*.

Suspended silt settles very slowly. In a static settling test, a silt slurry has been observed[41] to settle at only 0.19 mm/minute. In turbulent conditions, settling rates could be expected to be even lower. Following initial settling, consolidation of silts is also likely to be very slow, with the time for 50% consolidation at least 7 years and for 80% consolidation more than 10 years and possibly up to 20 years[32]. While weakly consolidated, the silt will remain vulnerable to resuspension.

2.3 Water quality

Water quality parameters of significant relevance to the pipeline crossing construction are confined to suspended solids concentrations, the release of acidic and oxygen demanding sulphides from the deep silts, and the potential for suspended silt to be contaminated by historical pollution.

Other parameters, such as the concentrations of dissolved nutrients and dissolved heavy metals, are of academic interest only and have no significant relevance to the pipeline crossing project. Information on these parameters is available elsewhere[42,43].

Suspended solids consist of silt and clay, phytoplankton, decaying organic matter and other particles derived from both natural and anthropogenic sources. High levels of suspended solids may adversely affect ecosystems during suspension, by reducing light penetration and affecting primary production, and during settling by smothering organisms, clogging gills of fish and changing the nature of substrata[44]. Regular monitoring of suspended solids at 16 sites along the Tamar Estuary has occurred since 1971. Results have indicated levels of 5-10 mg/L in the lower reaches and increasing levels up the estuary, with lower light penetration occurring during periods of high flooding and a trend of decreasing penetration from the mouth of the estuary towards the head[45].

These trends are typical of estuaries, particularly those with deltas.

As shown in Figure 5, suspended silt concentrations are in the order of 20 mg/L at Rosevears, 50 mg/L further upstream below Tamar Island and can reach 200 mg/L below the Trevallyn Power Station tail race, which is about 2 km upstream from the crossing point. A range of between 50 and 200 mg/L at the crossing point could reasonably be expected to be commonly

[41] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.

[42] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.

[43] Unpublished Department of Tourism, Arts and Environment data reported in Aquenal (June 2006) *Aquatic environmental investigation at proposed Tamar River crossings for Gunns pulp mill water supply pipeline*. Report prepared for Gunns Limited.

[44] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.

[45] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.

experienced. Suspended silt concentrations, however, are likely to be much higher in the local vicinity of a scour during a flood. Silt concentrations would also be elevated throughout the estuary following a flood as distributed silt slowly settles out.

In addition to the concentration of silt particles themselves, the concentrations of contaminants within the silt are also of relevance. Resuspension of contaminated silt may make the contaminants more biologically available.

Contamination levels of Tamar River silt are shown in Table 7, together with the NSW *Environmental Guidelines for the Use and Disposal of Biosolids Products 1997* guideline contamination levels for sediments based on biological effects[46], the *Tasmanian Biosolids Reuse Guidelines 1999* acceptance criteria and the *National Environment Protection (Assessment of Site Contamination) Measure 1999* ecological investigation levels.

Table 7: Contaminant concentrations in silt in comparison to guideline concentrations[47]

Analyte	Concentration in silt (mg/kg)	NSW Guideline ERL* (mg/kg)	NSW Guideline ERM* (mg/kg)	Tasmanian Grade A acceptance (mg/kg)	Tasmanian Grade B acceptance (mg/kg)	NEPM ecological investigation level (mg/kg)
Arsenic	24	-	-	20	20	20
Cadmium	0.3 – 5.3	5	9	3	20	100
Chromium	53 – 79	80	145	100	500	-
Copper	14 – 67	70	390	100	1000	100
Lead	4 – 63	35	110	150	420	600
Mercury	<0.5	0.15	1.3	1	15	1
Nickel	25 – 39	-	-	60	270	60
Selenium	7.7	-	-	5	50	-
Zinc	92 - 480	120	270	200	2500	200

ERL: effects range low – adverse effects 10% of the time
ERM: effects range median – adverse effects 50% of the time

Cadmium, chromium and copper approach and lead and zinc exceed the low effects guideline value, and zinc exceeds the median effects level.

More recent analysis for a wide range of analytes conducted for the Tamar Dredging Project found that all were below the NEPM Ecological Investigation Levels[48] apart from manganese, vanadium, zinc and sulphur, and silt was considered to be suitable for reuse[49].

[46] NOAA criteria cited in Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[47] Launceston City Council report on November 1993 and October 1998 analysis results
[48] The then draft *National Environment Protection Measure (Assessment of Site Contamination) Measure 1999*
[49] SEMF (February 2001) *Proposed Tamar Dredging Project – Environmental Impact Statement*. Report prepared for Launceston City Council.

The median background oxygen concentrations in Tamar estuary water[50] in the vicinity of the crossing is approximately 8 mg/L, ranging down to approximately 6 mg/L. These levels are typical of estuaries.

For both the physical and contamination effects of silt, the relevant criterion for assessing the potential impact of the pipeline crossing construction is the scale of silt resuspension that might be caused by the construction work relative to natural volumes, rates of resuspension and suspended silt concentrations.

2.4 Aquatic biota

Edgar *et al*[51] classified Tasmanian estuaries into 9 groups based on physical variables (catchment area size, estuarine drainage area size, area of open water, estuarine perimeter length, presence of seaward barrier, standardised salinity of surface water midway along estuary in summer and winter, estimated tidal range midway along estuary and total annual runoff). Within each of the nine groups, estuaries were ranked by level of anthropogenic disturbance using human population density data, and the estuary with least disturbance assigned the highest conservation rank (Class A).

The Tamar Estuary formed its own group and was classified as Class A.

Edgar *et al* found that the mouth of the Tamar Estuary has an exceptionally high diversity of both invertebrates and fish. This is highlighted by the number of invertebrate species found in each estuary type (Table 8).

Table 8: Mean number of species collected from sites in different estuary groups in Tasmania[49]

Group	Estuary	Crustacea	Gastropoda	Bivalvia	Polychaeta	Other	Total
I	Barred low salinity estuary	8.4	3.4	1.4	3.6	4.6	21.4
II	Small open estuary	13.4	6.4	6.6	7.9	3.3	37.6
III	Marine inlet	16.9	6.9	8.7	13.9	4.8	51.1
IV	Hypersaline lagoon	6.5	4.5	3.0	4.5	3.0	21.5
V	Mesotidal river estuary	11.1	2.9	4.0	7.3	3.3	28.6
VI	**Tamar**	**29.5**	**8.0**	**9.0**	**24.5**	**3.0**	**74.0**
VII	Microtidal drowned river valley	9.4	3.6	3.7	6.2	4.3	27.2

[50] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[51] Edgar, G.J., Barrett, N.S. and Graddon, D.J. (1999) A classification of Tasmanian estuaries and assessment of their conservation significance using ecological and physical attributes, population and land use. Tasmanian Aquaculture and Fisheries Institute Technical Report Series No 2.

Group	Estuary	Crustacea	Gastropoda	Bivalvia	Polychaeta	Other	Total
VIII	Large open microtidal river	5.8	1.8	0.3	1.5	2.8	12.0
IX	Wanderer	2.0	0.0	0.0	0.0	0.0	2.0

Importantly for the pipeline crossing project, however, this very high diversity was found in the lower sections of the estuary (Low Head and Paper Beach), downstream from the foot of the silt delta (Rosevears) which itself is more than 10 km downstream of the crossing point.

Open coast species progressively drop out with distance up the estuary. Once south of Batman Bridge, the intertidal fauna becomes much simpler and south of Dilston the intertidal fauna becomes extremely simple[52]. This pattern is typical of estuaries in general, which have low diversity compared with the adjacent fully marine and fully freshwater systems[53].

A survey of the distribution of intertidal invertebrates in the Tamar estuary divided the estuary into four zones: A, B, C and D[54]. Zone A was between Low Head and George Town, and essentially marine; zone B was between George Town and the Batman Bridge; zone C was between the Batman Bridge and Windermere; and zone D was south of Windermere to the head of the estuary.

Of the 117 species found in zones B, C and D, 113 occurred in zone B, 46 occurred in zone C and only 12 occurred in zone D. The species found in zone D are shown in Table 9. Of 28 common species selected for distributional mapping, only 4 were found south of Tamar Island (Table 9).

Table 9: Intertidal invertebrate species with a mapped distribution restricted to south of Freshwater Point (zone D)[55]

Phylum	Family	Species	Observations
Annelida	Tubificidae	Unknown	An oligocaete (earthworm), only found in Zone D
Mollusca	Mytilidae	*Xenostrobus inconstans*	Common. Also found in zones B and C. Intertidal on hard substrates, about mid-tide level. Can tolerate muddy conditions. Found as far south as Freshwater Point.
	Hydrobiidae	*Tatea rufilabris*	Abundant. Also found in zones B and C. On mud surface in very sheltered areas. Found as far south as the north

[52] Smith, B.J. (1995) Tamar Intertidal invertebrates: An Atlas of the Common Species. Queen Victoria Museum and Art Gallery.

[53] Barton, K. (November 2003) *Estuarine health monitoring and assessment review*. Report prepared for the Victorian State Water Quality and Assessment Committee.

[54] Smith, B.J. (1995) Tamar Intertidal invertebrates: An Atlas of the Common Species. Queen Victoria Museum and Art Gallery.

[55] Smith, B.J. (1995) Tamar Intertidal invertebrates: An Atlas of the Common Species. Queen Victoria Museum and Art Gallery.

Phylum	Family	Species	Observations
			end of Tamar Island.
		*Potamopyrgus antipodaru**	Abundant. Only found in zone D. Surface of mud, stones and vegetation within tidal influence. Found from the north end of Tamar Island south to the head of the estuary. An introduced species from New Zealand.
	Assimineidae	*Assiminea (Metassiminea) buccinoides*	Very common. Also found in zones B and C. On surface of mud at and above high tide level, particularly in the mouths of inflow creeks.
	Ellobiidae	*Ophicardelus ornatus*	Common. Also found in zones B and C. On mud and under logs at or above high tide level in very sheltered bays and on salt marshes, within the reach of spring tides. Furthest south is Freshwater Point (2 km north of Tamar Island).
	Aphibolidae	*Salinator fragilis**	Abundant. Also found in zones B and C. On surface of mud in sheltered inlets and bays from just below neap high tide to just above spring high tide. Found as far south as the south end of Tamar Island.
Crustacea	Palaemonidae	*Palaemonetes sp*	Also found in zone C. No further information available.
	Grapsidae	*Paragrapsus gaimardii**	Very common. Also found in zones B and C. Sheltered shores over a wide range under rocks and burrowing in mud. Found throughout the estuary as far south as Mowbray.
		Helograpsis haswellianus	Locally common. Also found in zones B and C. Under rocks or burrowing in a variety of firm mud types above the high tide level. Found as far south as Freshwater Point.
	Ocypodidae	*Macrophthalamus latifrons*	Not common. Also found in zones B and C. Intertidal only, amongst weeds and on mudflats. Found as far south as Freshwater Point.
	Hymenosomatidae	*Amarinus laevis**	Locally common. Also found in zones B and C. On mud and under stones in brackish estuaries in the southern half of the Tamar. Found south of Gravelly Beach.

*Distribution includes areas south of Tamar Island

Like the simplification of biota with increasing upstream distance from an estuary's mouth, there is also a simplification moving from riparian zones, through intertidal zones to the mid-channel benthos. This is particularly so in deltaic estuaries like the Tamar. The muds and silts of deltas are subject to frequent physical disturbance due to flood scouring. While normal tidal currents are not strong enough to scour the silt bed, scouring during river flood flows is common (see section 2.2.1).

Under conditions of frequent physical disturbance, pioneering infaunal species tend to dominate the fauna. In estuaries, the pioneering species are usually suspension feeders that feed near the surface or from the water column and deposit feeders that feed within the sediments[56]. These species are also usually tolerant of low oxygen conditions.

Polychaete worms are the typical suspension feeders of sandier estuarine environments. These animals are able to quickly colonise and recolonise disturbed sand. Other rapid colonising fauna common to disturbed estuarine sediments are amphipods and bivalves. In siltier mud, suspension feeders are less abundant and the dominating infauna are deposit feeders, which particularly include polychaetes (notably *Capitella*) and gastropods (snails). Detritus feeders and predators, such as crabs, other polychaetes (eg. *Neanthes*) and other gastropods (eg. the carnivorous *Nassarius*) also occur. In transition zones, suspension and deposit feeders may compete against each other — deposit feeders can exclude suspension feeders by increasing turbidity and suspension feeders may exclude deposit feeders by their tubes consolidating sediments[57].

Its appears that no previous subtidal surveys of the benthic fauna of the upper Tamar silts have been undertaken, even for an environmental assessment of dredging[58], highlighting the low significance placed on potential impacts on benthic organisms in the upper estuary.

For the purposes of the current project, a survey of the benthic infauna along the crossing alignment was commissioned by Gunns and undertaken by Aquenal[59].

A total of 10 species were recorded, comprising 3 crustacean species, 4 mollusc species, 2 annelid species and a single insect larva. The species and the number of individuals found in the samples are listed in Table 10.

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[56] D.M. Deeley, D.M. and E.I. Paling, E.I. (December 1999) *Assessing the ecological health of estuaries in Australia*. Land and Water Resources Research and Development Corporation Occasional Paper 17/99 (Urban Subprogram, Report No. 10)

[57] D.M. Deeley, D.M. and E.I. Paling, E.I. (December 1999) *Assessing the ecological health of estuaries in Australia*. Land and Water Resources Research and Development Corporation Occasional Paper 17/99 (Urban Subprogram, Report No. 10).

[58] SEMF (February 2001) *Proposed Tamar Dredging Project – Environmental Impact Statement*. Report prepared for Launceston City Council.

[59] Aquenal (June 2006) *Aquatic environmental investigation at proposed Tamar River crossings for Gunns pulp mill water supply pipeline*. Report prepared for Gunns Limited.

Table 10: Benthic infauna species and numbers of individuals recorded along the pipeline alignment

Class/Order	Species	Abundance
Amphipoda	Corophium sp	322
Gastropoda	Potamopyrgus antipodarum	59
Polychaeta	?Barantolla lepte	45
Bivalvia	Montacuta dromaensis	6
Gastropoda	Ascorhis victoriae	4
Polychaeta	Neanthes vaalii	3
Decapoda	Amarinus laevis	2
Gastropoda	Tatea rufilabrus	2
Amphipoda	Aorid sp	1
Insecta	Chironomid sp	1
	Total	**445**

A single species of Corophiid amphipod contributed approximately 70% of all individuals collected, molluscs contributed 18% and annelids 11%.

Grab samples of the estuary bed were all very similar in appearance regardless of location or depth. They were all unvegetated, soft grey-brown mud over darker brown to black, soft mud. No burrows or evidence of macro flora or fauna were observed.

Aquenal noted that the infauna observed in the survey represents a typical, low diversity community from a shallow mudflat environment with a strong freshwater influence.

One hundred and ten fin-fish species were documented in the Tamar Estuary as part of a 1991 audit by the former Tasmania Parks, Wildlife and Heritage[60]. The distribution of these fish species was related to salinity tolerance and availability of habitat. The most common fish species known to inhabit the estuary include the yellow-eyed mullet (*Aldrichetta forsteri*), pufferfish (*Sphareroides hamiltoni*), garfish (*Hemiramphus melanochir*), flounder (Family Pleuronectidae) and cod (Family Moridae). The threatened Australian grayling (*Prototroctes maraena*) occurs in the upper reaches of the estuary[61].

Protected fish species with the potential to inhabit this area include: the eastern potbelly seahorse (*Hippocampus abdominalis*), short snouted seahorse (*Hippocampus breviceps*), weedy sea dragon (*Phyllopteryx taeniolatus*), and a diversity of pipefish species. Many of these fish species, as well as other marine species and their environs are also protected under the Tasmanian *Living Marine Resources Management Act 1995*.

[60] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[61] Bryant, S.L. and Jackson, J. (1999) *Tasmania's Threatened Fauna Handbook*. Threatened Species Unit.

The introduced mosquito fish *Gambusia holbrooki* has also been recorded from the Tamar River in the vicinity of the crossing point[62]. This species is listed as a controlled fish under the *Inland Fisheries Act 1995*[63].

Sharks visit the lower reaches of the Tamar Estuary to use it as a breeding and refuge area. The waters south of a line between West Head and Low Head have been declared a Shark Refuge Area under the *Living Marine Resources Management Act 1995*.

Large aquatic marine mammals have also occasionally been recorded in the lower reaches of the Tamar Estuary. These include the cetacean species: blue whale (*Balaenoptera musculus*), humpback whale (*Megaptera novaeangliae*), pygmy right whale (*Caperea marginate*), strap-toothed beaked whale (*Mesoplodon layardii*), southern bottlenose whale (*Hyperoodon planifrons*), short finned pilot whale (*Globicephala mararhynchus*), southern right whale (*Eubalaena australis*) and killer whale (*Orcinus orca*), as well as the common dolphin (*Delphinus delphis*) and the bottlenose dolphin (*Tursiops truncatus s. str.*). The Australian fur seal (*Arctocephalus pusillus*) and the New Zealand fur seal (*Arctocephalus forsteri*) have also been recorded in the estuary.

2.5 Riparian biota

The Tamar “River” technically is a misnomer. Rather than being a river in its own right, it is the combined estuary of the South Esk and North Esk rivers. Strictly speaking there is no Tamar River. Unlike typical estuaries, the delta is at the head of the estuary — normally, deltas are at the mouth of an estuary. Silt deposition from the head of the estuary down to approximately Rosevears has created a delta and associated shoals, flats and wetlands.

These have formed where the flows from the North and South Esk Rivers drop as they spill into the broader reaches of the estuary. As silt is trapped and stabilised by aquatic vegetation, it progressively builds up and becomes more exposed to drying between tides, which further acts to bind silt particles together by interparticle forces[64]. This process creates silt shoals and silt islands (eg. around Tamar Island) in the channel and also builds mud flats and wetlands on the shores of the estuary.

Some of these, such as the Tamar Island Wetlands reserve, are important wildlife habitats encompassed by the Tamar River Conservation Area, which stretches through the upper reaches of the Tamar Estuary.

[62] http://www.parks.tas.gov.au/reserves/tamar/FaunaFlora.pdf
[63] http://www.ifs.tas.gov.au/fact_sheets/Gambusia.html
[64] Foster, D.N., Nittim, R. and Walker, J. (October 1986) *Tamar River Siltation Study*. Report prepared for the Tamar River Improvement Committee.

Prior to human intervention, the estuary's intertidal mudflats were largely bare, apart from the green algae *Enteromorpha*[65]. The exotic saltmarsh grass, rice grass (*Spartina anglica*), was introduced to the estuary in 1947 by the Department of Agriculture in an attempt to stabilise the mudflats and force stream flow into the central channel to scour it to maintain navigation depths[66]. Rice grass has an extensive root system which is very effective at stabilising silt and trapping additional silt.

Rice grass now covers over 450 ha of the estuary's tidal flats, often in extensive meadows[67]. Infestations are almost entirely downstream of Tamar Island but islolated populations occur as far upstream as Tamar Cut, near the crossing point[68].

Sea grass beds of *Zostera muelleri* are found within the Tamar Estuary, including extensive areas around the mouth of the estuary between West Head and Low Head. This aquatic angiosperm grows on mudflats in the intertidal zone, and is recognised as an ecologically significant community that provides habitat for a diversity of animal species[69]. Rice grass can out-compete and displace this important sea grass species.

Tamar Island Wetlands Reserve

The Tamar Island Wetlands Reserve is approximately 60 hectares of mud flats, lagoons and islands, and lies approximately 2.5 km to the north of the investigation area.

A description of the Reserve follows[70]:

> The Tamar Estuary, and in particular the wetlands reserve, remains a stronghold for one of Tasmania's endangered vegetation communities, coastal paperbark forest. *Melaleuca ericifolia* is the only native tree remaining in the wetlands, forming several areas of scrub and forest, providing habitat for frogs, reptiles, birds and mammals.
>
> The reed beds and sedgelands are dominated by the common rush (*Phragmites australis*), a grass species that grows to about three metres in height. The wetlands reserve is one of the last native grass wetlands in the Tamar Estuary. In other parts the introduced rice grass (*Spartina anglica*) dominates much of the estuary's foreshore areas.
>
> During the summer the great bindweed (*Calystegia sepium*) can be seen twining up the stems of the *Phragmites*. In Tasmania Calystegia is found only in wetlands within the Launceston region and for this reason it is classified as an endangered species. Also

[65] Phillips, A.D. (1975) *The establishment of* Spartina *in the Tamar Estuary*, Tasmania. Papers and Proceedings of the Royal Society of Tasmania 109: 65-75.
[66] Pringle, A.D. (1993) Spartina anglica *colonisation and physical effects in the Tamar Estuary, Tasmania*. Papers and Proceedings of the Royal Society of Tasmania 127: 1-11.
[67] Department of Primary Industries and Water (July 2003) *Rice grass newsletter*. http://www.dpiw.tas.gov.au/inter.nsf/WebPages/ECAL-5PQ87Y?open (accessed 17 May 2006)
[68] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[69] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[70] http://www.deh.gov.au/water/wetlands/publications/wa13/tamar.html. Further information on the wetland's biota is at http://www.parks.tas.gov.au/reserves/tamar/FaunaFlora.pdf.

> growing amongst the Phragmites is the endangered gipsywort (*Lycopus australis*) and the rare mud dock (*Rumex bidens*).
>
> There are areas of spike rush (*Eleocharis acuta*) sedgeland on the mudflats and reeds such as the rare sea club rush (*Bolboschoenus caldwellii*) and the sharp club rush (*Schoenoplectus pungens*). Water ribbons (*Triglochin procera*) are abundant throughout the wetlands, the tuberous roots of which were once used by Aborigines for food.
>
> Amongst the native low-lying vegetation communities invasive species are encroaching, such as blackberry (*Rubus fruticosus*) and cumbungi (*Typha orientalis*). Weeding is an ongoing task in the reserve, with regular working bees tackling cumbungi, blackberry, broom and other remnants from farming days and domestic garden escapees.
>
> The Tamar Island Wetlands are rich in vertebrates and invertebrates. They are an important breeding area for five of Tasmania's frog species, including the vulnerable green and gold frog, (*Litoria raniformis*).
>
> Birds are by far the most abundant vertebrate species found at the Tamar Island Wetlands. Some are resident and stay all year round; others are migratory and visit only during the warmer summer months whilst others are occasional visitors, making the journey south when drought conditions on the mainland become too severe.
>
> The wetlands occasionally host a number of birds listed on the Japan-Australia Migratory Bird Agreement and the China-Australia Migratory Bird Agreement. These include: Cattle Egret (*Ardeola ibis*); Crested Tern (*Sterna bergii*); Curlew Sandpiper (*Calidris ferruginea*); Greenshank (*Tringa nebularia*); and the Red-necked Stint (*Calidris ruficollis*).

Like all estuarine wetlands, the Tamar Island Wetlands Reserve is a transition phase between subtidal silt deposits and river flats. Over a short period of geological time (6,000 years[71]), accumulation of silt in the estuary's delta has formed deposits that are now above the normal limit of the tide. These deposits have become stabilised and vegetated by plants and a complex wetland ecosystem has developed.

The stabilising vegetation acts to trap more silt, further lifting the average height of the wetlands as successive floods spill through the wetlands and drop sediment when the water velocity reduces. Gradually, the wetlands will become progressively less exposed to flooding and hence progressively drier. Eventually, they will become river flats, similar to other flats elsewhere along the estuary. Silt deposition is therefore both the creator and destroyer of the wetlands.

The drying of the wetlands will lead to a reduction in species diversity as the complex wetland habitats come to be replaced by simpler river flat habitats. This is a natural process that will occur over hundreds to thousands of years.

The short and long term evolution of the wetlands will be complicated by the dredging of silt, which redistributes silt from the estuary bed to silt ponds in particular areas of existing river flats. Removal of silt from the estuary bed alters the natural processes of silt transport and deposition. Locally, removed silt will be replaced by silt bed flow from adjacent areas as the estuary bed profile reshapes in response to the dredging. Removal of silt and its placing into silt ponds also removes a potential source for deposition elsewhere in the delta.

[71] Foster, D.N. and Nittim, R. (1987) *Siltation of the Tamar River* in Foster, D.N. and Bowen, D.F.E. (eds) 8th Australasian Conference on Coastal and Ocean Engineering.

Deliberate changes to deposition rates may also alter wetland evolution. Numerous efforts have been made over the years to trap silt in the vicinity of the Tamar Island shoals, as a means of reducing the suspended silt load and hence reducing the amount of silt that would be available for settling in navigation channels.

The evolution of the wetlands may also be complicated by climate change, subject to the relative rates of deposition and sea level rise. If sea level rise exceeds silt deposition rates, the wetlands will become more and more tidal, and wetland species will be replaced by estuarine species.

The deposition of silt in the wetlands is therefore both a natural process and one that has been actively encouraged. The risk of additional silt deposition from silt disturbed during the construction of the pipeline crossing must be considered and assessed in this context.

Tamar Cut vicinity

A report[72] on the botanical values of Tamar Cut, to the immediate south of the pipeline crossing, concluded that the area has been extensively modified by agriculture and river modification works, and that little native vegetation remains. Wetland areas in the cut have a high component of exotic species, although they are nevertheless useful areas for birds. Adjacent paddock areas were considered to have little value for wildlife, apart from an area of *Juncus* sedgeland, which is fringed with a good stand of *Melaleuca* swamp forest.

The Department of Primary Industries Water and Environment's GTSpot database records the following threatened plant species in the vicinity of the crossing site (Figure 6).

Bolboschoenus medianus marsh club-rush, listed as rare under Tasmanian *Threatened Species Protection Act 1995.* There are two populations of this species, one in the midlands and the other on the Tamar River.

Bolboschoenus caldwellii sea club-rush, listed as rare under Tasmanian *Threatened Species Protection Act 1995.* The Tamar Conservation area is not listed as a key site for the species.

In addition to these plants, *Haliaeetus leucogaster*, the white-bellied sea eagle, listed as vulnerable under Tasmania's *Threatened Species Protection Act 1995* and a listed migratory species under the Commonwealth *Environment Protection Biodiversity Act 1999*, has been sighted in the vicinity of the crossing location. However, no nesting habitat for this species occurs within several kilometres of the crossing point.

[72] Harris, S. (September 1989) *Tamar Cut silt area – report on botanical values*. Report to the Tamar River Improvement Project Committee.

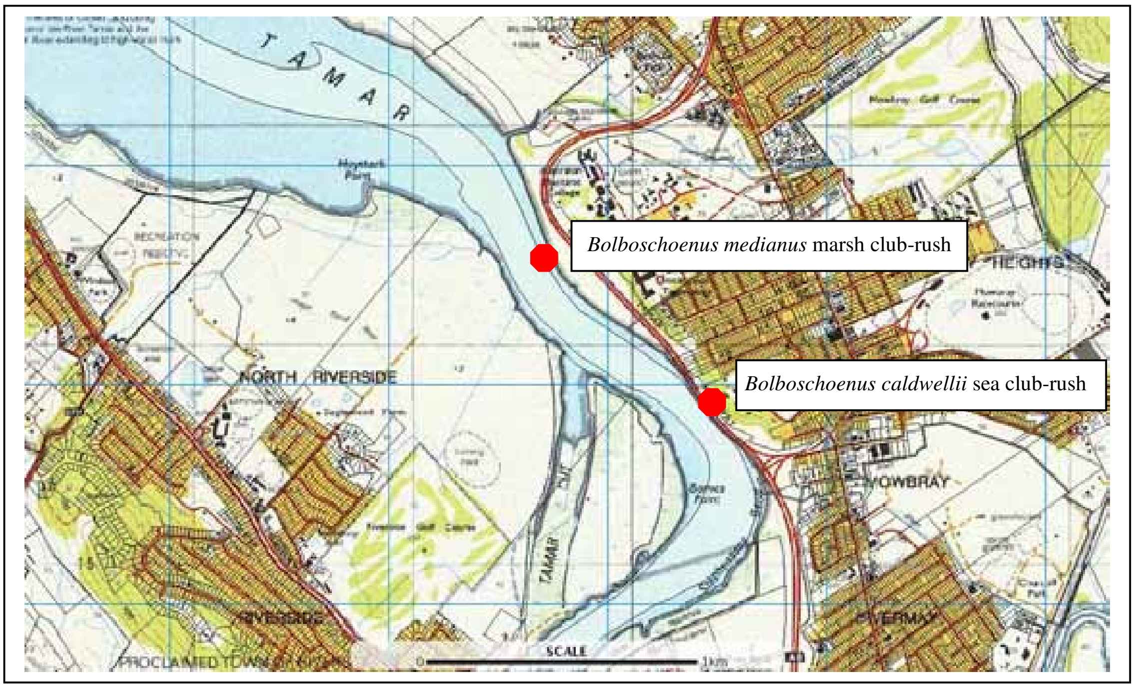

Figure 6: Location of known threatened species in the vicinity of the crossing

3. Construction parameters

3.1 Construction options

Areas of the estuary silt bed rise and fall. For example, a loss of 0.5 to 0.8 m observed over a period of about a year was followed by a gain of a similar amount when resurveyed 3 years later[73]. Monitoring over the last 3 years has shown changes of up to 1 m in places[74], and numerical modelling suggests that scour in Home Reach (about 2 km upstream of the crossing point) may be as much as 1.7 m in flood flows[75].

Between Home Reach and Tamar Cut the estuary has cyclic deposition patterns, while from Tamar Cut to beyond Tamar Island mudflats are generally accreting[76].

Although scour at the pipeline crossing point is likely to be less because of a greater river cross sectional area, allowing for a scour of up to 1.5 m over and above a normal rise and fall of up to 1 m (ie. a total of 2.5 m below the sediment surface) at the crossing point would be a prudent design measure.

Allowing for an additional risk buffer of 1 m, the minimum depth of burial of the top of the pipe should therefore be 3.5 m. The pipe will be 1 m in diameter, so the bottom of the pipe must be 4.5 m below the surface of the silt. Allowing a further 0.5 m buffer for estuary bed irregularities means that the bottom of the pipe would need to be approximately 5 m below the silt surface. Silt and/or soft clay depths range from approximately 15 m on the western side to 6 m in the middle of the main channel to 7 m on the eastern side (Figure 2).

Tunnelling under the silt (thereby avoiding its disturbance) presents considerable technical difficulties and would be very costly.

Materials in the crossing zone consist of soft to stiff clays of variable thickness overlying gravel layers with both vertical and lateral variability; these gravels overlie conglomerates of variable thickness and strength. It is considered unlikely, therefore, that a tunnel could be excavated solely in one material type, but would more likely encounter significant variations in material type.

A tunnel in these materials would require complete support for the entire length. As the tunnel would be wholly within the groundwater zone, extensive dewatering would be required for the entire period of construction. As the

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[73] Ingles, O.G. (1994) *Stability of the west bank of the Tamar River adjacent to the mooring pile area*. Report prepared for Pitt & Sherry.
[74] Pers.comm. Steve Ratcliffe, Launceston City Council after UNSW Water Research Laboratories
[75] Hranisavljevic, D., Nittim, R. and Cox, R.J. (April 1994) *Launceston Flood Protection Scheme re-assessment*. UNSW Water Research Laboratory Technical Report 94/03.
[76] Clark, B. November 2000) Upper Tamar estuarine sedimentation: an analysis of trends. Unpublished Honours thesis, University of Tasmania.

tunnel face could not be completely sealed off from groundwater inflow, such inflows may present a significant risk to construction workers.

Any tunnel would also need to be constructed to significantly larger dimensions than those of the proposed pipeline in order to facilitate the access of construction crews, machinery and materials, and would also need to be sealed from groundwater inflow prior to pipe installation.

A suitable area for the disposal of tunnel waste would also need to be established nearby.

Because of these practical difficulties with tunnelling, some form of dredge installation through the silt is instead necessary.

Standard dredging for pipeline installation involves removing spoil to create an open trench, laying the pipeline and then returning the spoil to the trench to bury the pipeline. If this method were used for the Tamar crossing, the spoil would need to be stored on the river flats, adjacent to the trench. The trench would need to be capable of standing open for long enough for it to be completed and the pipeline laid. Because of the nature of the silt, this is considered to be problematic.

The silt is only weakly cohesive, and the underwater equilibrium slope (angle of repose) is only 14^{o} (Table 4). If the base of an open trench needed to be, say, 3 m wide[77], and it was 5 m below the surface of the silt, the required trench width at the silt surface would need to be almost 50 m.

For a nominal trench length of 300 m (which includes the transitions on either side of the river), a nominal 30,000 m^3 of silt would need to be removed for storage on the river flats. In practice, much greater volumes would need to be removed because the trench would infill as it is being excavated. The amount of infill would depend on how long it takes to excavate the trench, the time it is kept open and estuary flow conditions during this time.

Volumes would also increase due to the intertidal equilibrium being only 5^{o} (Table 4). Where the trench cut through intertidal areas it would need to be over 100 m wide for the sides to remain stable while the pipe was being laid.

Storage of silt in ponds on the river bank is a routine activity associated with navigational dredging. However, these ponds would need to be on the western bank of the estuary, which is freehold agricultural land. An alternative would be to store the silt in the nearby Tamar Cut but past proposals to use the Cut for silt storage have been rejected[78].

Although Tamar Cut does not have any recognised heritage status, it is considered by Council to be an interesting part of local history, in particular

[77] Depending on the open trenching method used, the base of an open trench could in fact be up to 10 m wide
[78] Pers.comm. Geoff Brayford, Launceston City Council

that of a significant attempt to change the course of the Tamar River in order to facilitate shipping movements. Use of the Cut for silt storage could detract from its historical value.

Furthermore, the Cut currently acts as a floodway for the Tamar River and disposal of silt in the area of the Cut would diminish its capacity to perform this role.

The silt storage would need to be permanent. Return of the silt to back fill the trench would not be viable. The silt simply would neither settle nor consolidate quickly enough.

Rather than settling to fill the tench, returned silt would be carried downstream and/or upstream with currents, and in time be deposited elsewhere.

Back filling the trench with imported fill would also be problematic. Dumped rock would settle down through the underlying silt, and a much greater volume of rock than the nominal 30,000 m^3 trench volume would be required. Backfilling an underwater trench with such large volumes of rock would also be a major materials handling task.

The most practical way to back fill an open trench would be to allow it to refill naturally by bed flow. This is not through settlement of suspended or scoured silt but rather through bed load movement. Over time, the profile of the estuary bed would reshape in response to the excavation, gradually filling in the trench. Trials with silt traps in the estuary have shown that deep holes refilled within 2 to 3 years[79]. A pipeline trench would probably take longer to completely fill because it would be constructed to the angle of repose of 14^{o}, in contrast to the silt traps, which were probably dredged with higher bank angles. Nevertheless, the pipeline would be covered relatively quickly, possibly within months.

However, the large scale removal of silt necessary to form an open trench carries a considerable risk of destabilising the estuary banks, particularly if more than the nominal volume needs to be removed in order to counter infilling during trench opening and then natural infilling is relied upon after the pipe has been laid. Infilling would source silt from adjacent areas of the estuary bed and banks. On the eastern side of the crossing, the East Tamar Highway runs alongside the estuary, and could potentially be undercut if silt moves from the banks to fill the trench.

An area of Stephensons Bend, close upstream of the crossing point already has a notable area of erosion, possibly due to direct impacts from the Trevallyn Power Station discharge[80].

[79] Pitt & Sherry (1999) *Tamar and North Esk dredging optimisation and scour impact study*. Report prepared for Launceston City Council.

[80] Clark, B. November 2000) Upper Tamar estuarine sedimentation: an analysis of trends. Unpublished Honours thesis, University of Tasmania.

Construction of the pipeline crossing by open trenching is therefore not favoured. The preferred construction method is some form of *in situ* trenching, by which the pipe is sunk through the silt into the estuary bed without bulk silt removal.

The most prospective installation method is jet trenching.

3.2 Jet trenching

Jet trenching injects air or water by air lifts, water eductors or submersible pumps to liquefy sediment *in situ*. Depending on the particular form of jet trenching, the liquefied sediment can either be removed from the trench by displacement or pumping or left in place to allow the pipeline to sink down into it under gravity. In the latter case, a jetting machine rolls back and forth along the pipeline to excavate the trench and allow the pipeline to sink.

Jet trenching has two important attractions for this project. Firstly, it can allow the trench width to be only 2 to 3 m rather than the 50 m or more that would be required for open trenching, given the low angle of repose of the silt. Secondly, the characteristics of the silt make it suitable for sinking the pipeline down through liquefied silt, thereby avoiding the need to remove the silt from the trench. The silt has low cohesion and already has a high moisture content (Table 4), and liquefaction should be simple and rapid.

Jet trenching will therefore reduce the disturbance of the estuary bed to a minimum.

There are different types of jet trenching.

For the Tamar crossing, water jetting is preferred over air jetting. Air jetting would lift sediment particles into the water column on bubbles and result in a higher turbidity than water jetting.

The most commonly used “on-surface” form of jetting uses a machine that is pulled back and forth on wheels or a sled along the sediment surface over the top of the pipeline, with “lances” protruding into the sediment either side of the pipe. Powerful jets of water (or air) are injected through these lances to liquefy the sediment. The lances need to be long enough to extend to the depth of the desired trench. The pipeline sinks as the sediment is progressively liquefied. In this form, the trenching machine and the pipeline are not connected.

An alternative “on-pipe” form of jetting uses a smaller machine that is connected to the pipeline by rollers. The machine is pulled back and forth along the pipeline on these rollers, injecting water below the pipe, which progressively sinks. The jetting machine stays with the pipe as it sinks through the sediment, continuing to roll back and forth. The buoyancy of the pipe can be controlled by adding water and the jetting machine is stabilised by buoyancy tanks. Once the pipe (and machine) have reached the desired depth, the jetting machine can be recovered by pulling it along the pipeline to where it emerges from the sediment.

The on-pipe form is only suited to certain sediment and pipe types. Not only do the sediments need to be suitable for easy liquefaction but they also need to be weak enough to allow the machine to be pulled through them without requiring such a pulling force that the pipe could be damaged. Similarly, the pipe itself needs to be large and strong enough to allow the machine to roll along it accurately and to withstand the pulling forces exerted. Typical jetting machines[81] are 4 to 6 m long, weigh between 3 and 9 tonnes and require a pulling force of 1 to 5 tonnes.

Although the final form of jet trenching used will be subject to what is offered by the successful design and construct tenderer, it is expected that both the sediments and the pipe for the Tamar crossing are well suited to an on-pipe water jetting machine.

A generic description of jet trenching is provided below, which allows potential environmental impacts to be assessed. The final jet trenching methodology will depend on what potential contractors offer through a design and construct tender process following project approval.

3.2.1 Preferred dredging methodology

Jet trenching, using water jetting from an on-pipe machine, is the preferred dredging approach because it would allow a much narrower trench width (2 to 3 m rather than 50 m or more) and is suitable for sinking the pipeline down through liquefied silt, thereby avoiding the need to remove the silt from the trench. Jet trenching is the preferred dredging approach because it will reduce disturbance of the estuary bed to a minimum.

3.3 Silt disturbance

Although the amount of silt that needs to be disturbed by jet trenching is an order of magnitude less than what would need to be removed by open trenching, jet trenching will lift some silt into suspension in the water column, causing a silt plume.

Based on information from the Cheng Tou Jiao to Tai Po gas pipeline project[82], which in turn was based on monitoring experience from six other major projects, a conservatively high figure of 20% will be assumed as the proportion of disturbed silt that will become suspended. This is less than

[81] Ocean Engineering Services www.oes.net.au

[82] Hong Kong and China Gas Company (2003) *Environmental impact assessment report for the proposed submarine gas pipelines from Cheng Tou Jiao liquefied natural gas receiving terminal, Shenzhen to Tai Po gas production plant, Hong Kong – Annex B: Water quality modelling and assessment information*. Hong Kong Environment Protection Department EIA Report 0892003.

hybrid forms of jet trenching, such as jet ploughing, which can release 30% of silt into the water column[83].

The Tou Jiao to Tai Po gas pipeline is a bundled pair of 0.5 m diameter pipes. The bundle is of an equivalent diameter to the proposed Gunns water supply pipeline, and other information from that project is comparable and will be adopted here — the volume of material fluidised (assuming a trench fluidisation slope of 1:1) will be 3.13 m^3 for each metre of pipe length for each metre the pipe is lowered and the speed of the machine will be 0.01875 m/sec (1.125 m/min).

Using these figures, the rate of silt disturbance on each pass will be 3.13 x 0.01875 = 0.05869 m^3 per second. With the assumption that 20% of this will become suspended in the water column, the rate of silt suspension will be 0.05869 x 0.2 = 0.011738 m^3 per second.

The Cheng Tou Jiao to Tai Po gas pipeline used an on-surface jetting machine, whereas an on-pipe machine is likely to be suitable for the Tamar crossing. For the gas pipeline project, the rate of disturbance, and hence silt suspension, increased as the pipe sunk because the injection lances extended all the way from the surface to the pipe position. With an on-pipe machine, the rate of disturbance should remain the same as the pipe sinks and the rate of silt suspension should reduce because of the cap provided by the overlying silt. While there may still be some agitation of the silt surface after the machine becomes buried, the capping effect would suppress vertical forcing movements (assuming water rather than air jetting is used). As noted in section 2.2.1, simple agitation of the silt surface is unlikely to release significant amounts of silt into the water column unless river flows are 425 cumecs or greater. This discharge rate represents about a once a year flood and it is unlikely that the pipeline contractor would choose to proceed with the installation during such conditions.

The assessment of the potential impacts of the silt plume, both in concentration and range, can be indicated by the use of a simple one-dimensional model[84].

The model calculates a distribution of constituent concentrations, assuming the discharge is a plane source extending over the full depth of a uniform stream channel. Real estuaries are much more complicated than this assumption and accurate numerical models are correspondingly much more complex and beyond the requirements of this assessment. A more accurate prediction of the behaviour of silt plumes that might be generated during dredging activities or a similar pipeline installation project may become possible when a numerical model of the estuary becomes available but this will not occur within the

[83] Connecticut Siting Council (September 2002) *Northeast Utilities Service Company application for a Certificate of Environmental Compatibility and Public Need for the replacement of a submarine electric transmission cable system from Norwalk, Connecticut to Northport, New York*. Docket No. 224.
[84] Metcalf and Eddy (1991) *Wastewater Engineering Treatment Disposal and Reuse*. McGraw-Hill.

timeframe of the pulp mill assessment process. This model is being developed by WBM Oceanics for Launceston City Council to assist with the managing of dredging operations not related to the pulp mill project.For the purposes of assessing the scale of impact of the pipeline construction numerical modelling of silt plumes is not necessary. It is sufficient to assess the potential impacts of silt resuspension against normal suspended silt movements in the estuary, both natural and from routine dredging.

In the simple one-dimensional model, the distribution of concentrations is given by:

$$C = \frac{C_1}{2} e^{-Kx/U} \left[\mathrm{erf}\left[\frac{y + b/2}{2} \sqrt{\frac{U}{E_y x}} \right] - \mathrm{erf}\left[\frac{y - b/2}{2} \sqrt{\frac{U}{E_y x}} \right] \right]$$

where C = effective source concentration = $Q_D C_D / UbH$

Q_D = discharge flow rate (m^3/sec)

C_D = discharge concentration (kg/m^3)

U = cross-section-averaged velocity (m/sec)

b = source width (m)

H = river depth (m)

y = lateral coordinate from centre of source (m)

E_y = lateral diffusion coefficient (m2/sec) $\cong 0.6Hu^*$

u^* = shear velocity (m/sec) = $\sqrt{(gHs)}$

g = acceleration due to gravity (m/sec^2)

s = stream slope (m/m)

erf = error function (from tables or using Metcalf & Eddy approximation)

The above distribution needs to be constrained by the river banks, and this is done by creating image sources symmetrically from the real source with respect to the river banks, which are then summed to produce a combined distribution of concentrations.

As with any model, the assumptions used place limitations on the reliability of extrapolating to a real situation. For example, the estuary is not a uniform channel, and turbulence will play a significant role in actual mixing. Also, the tidal wedge will create significant vertical variations. Nevertheless, the model provides a valuable indication of the likely extent of the mixing zone and of the distribution pattern of silt concentrations downstream and cross-stream of the discharge. The use of the model as a uniform channel will also predict a 'worst case' scenario as no mixing through turbulence will be taken into account.

The jetting machine will be pulled back and forth along the pipeline. The silt plume caused by sediment suspension will move back and forth with the machine. At any given time, the plume can be considered to be a point source at a particular location. For modelling purposes, the centre of the main river channel will be considered.

The behaviour of a plume will vary as the flow rate of the receiving waters varies. In a tidal environment, there will be variation over the course of a day, as ebb and flood flows respectively combine or work against river discharges.

For modelling purposes, an average condition was assumed, comprising average river discharges for summer/autumn (the most likely time of construction), average tidal flows and mid-tide water depths.

The average river flow during summer/autumn is approximately 50 cumecs (Table 1).

The average peak tidal velocity is 0.46 m/sec (Table 6). At mid tide, the average water depth at the crossing point will be 3.5 m in the middle of the main channel, which is 200 m wide. The cross-sectional area of the channel at this water depth is approximately 350 m^2. The tidal flow will therefore be 0.46 x 350 = 160 cumecs.

On the ebb tide, the river discharge of 50 cumecs will add to the ebb discharge of 160 cumecs for a total ebb flow of 210 cumecs. On the flood tide, the 50 cumec river discharge is assumed to reduce net flood flow by 30% to 145 cumecs, by inference from Figure 3.

Silt suspended at a rate of 0.011738 m^3/sec per metre of pipe will discharge 0.011738 x 5 = 0.05869 m^3/sec across a 5 m wide trenching machine. At a bulk wet density of 1.35 t/m^3, the initial silt concentration will be 1.35 x 10^6 mg/L.

Table 11 summarises the parameter values used in the model.

Table 11: Model parameter used for one-dimensional modelling of silt plume

Parameter	Value
Discharge flow rate	0.05869 cumecs
Discharge concentration	1.35 x 10^6 mg/L
River flow rate	210 cumecs (ebb tide); 145 cumecs (flood tide)
River width	200 m
River depth	3.5 m
Source width	5 m
Distance from left bank	100 m
Stream slope	0.002 m/m (nominal 1 m in 500 m)

The modelled silt concentrations with distance downstream during the ebb tide are shown in Figure 7 and the modelled concentrations with distance upstream on the flood tide are shown in Figure 8.

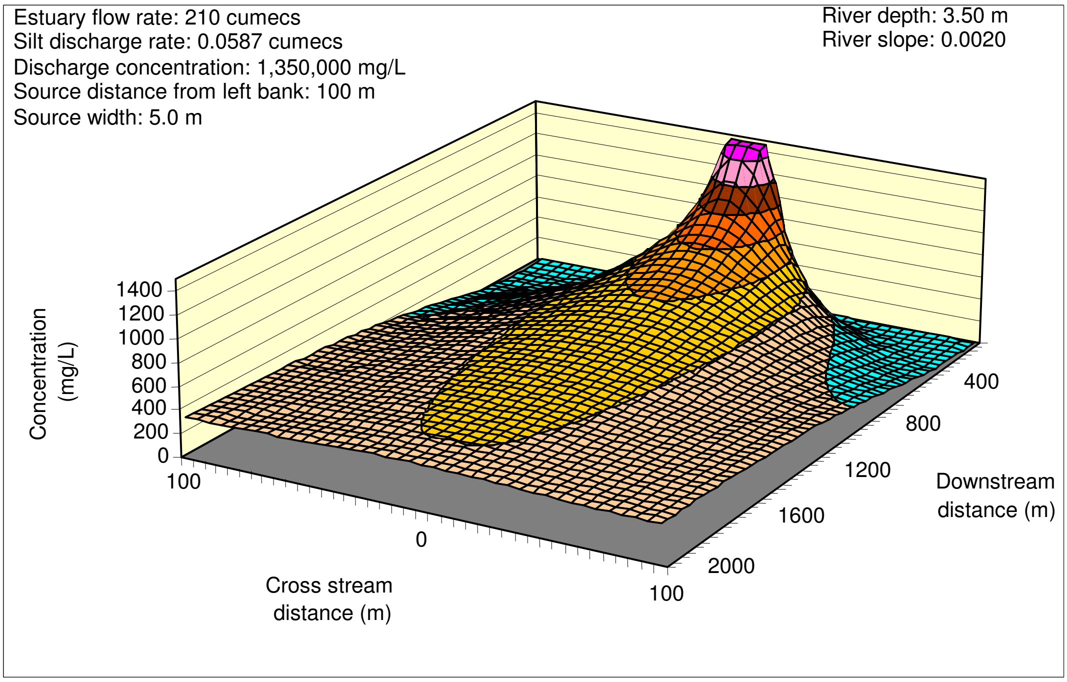

Figure 7: Modelled ebb tide silt plume dimensions and concentrations at mid tide for average river flow and average peak ebb tide velocity

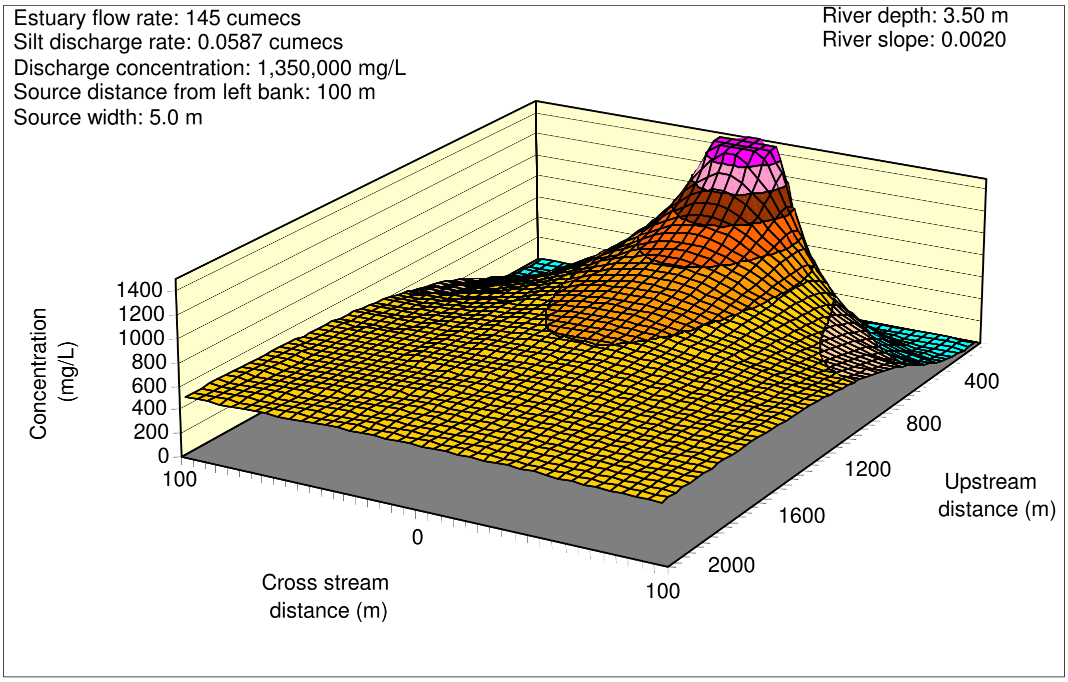

Figure 8: Modelled flood tide silt plume dimensions and concentrations at mid tide for average river flow and average peak flood tide velocity

Although the simplifying assumptions used in the model mean that the predicted silt plume dimensions and concentrations can only be taken as indicative, the modelling highlights the importance of net river flow rate on downstream silt concentrations. On the ebb tide, with higher net flow rates (downstream), the model's central plume concentrations after complete mixing across the estuary's width drop to approximately 390 mg/L at a distance of 2 km downstream. On the flood tide, with lower net flow rates (upstream), the model's plume concentrations after complete mixing are approximately 540 mg/L at a distance of 2 km upstream. At this distance, the concentrations in both cases are close to uniformity across the river, and further reductions by dilution will be negligible.

It is important to note that the modelled concentrations are not predictions of concentrations that will actually be achieved.

The modelling assumes that silt discharge from the trenching operations is continuous. In practice, the discharge will not be continuous but rather will be in the form of an extended pulse discharge, where the pulse extends over a period of hours. The model assumptions of a continuous discharge will overestimate the likely concentrations after complete mixing.

If the trenching machine travels at 0.01875 m/sec (see above), the machine will require approximately 300/0.01875/3600 = 4.5 hours to make the nominal 300 m traverse.

The total volume of silt released to suspension in the water column during this 4.5 hours would be 4.5 x 3600 x 0.011738 = 190 m^3, using the expected 0.011738 m^3/sec generation rate. This compares with the average daily silt mobilisation rate in the estuary of 220 m^3 (section 2.2.1).

At the assumed average summer/autumn river discharges of 50 cumecs, downstream silt movement is 150 tonnes per (approximately 6 hour) ebb tide (section 2.2.1). The combined river and ebb tide velocity at this discharge under the model assumptions is 210 cumecs (above). Using these figures, the background silt concentration under the model conditions would be (150 x 1000 x 1000)/(6 x 3600 x 210) = 33 mg/L.

While the model's silt plume concentrations are an order of magnitude greater than estimated average background concentrations in the estuary, the model's plume concentrations are comparable with examples of measured background silt concentrations provided in Figure 5, which show values of between about 100 and 400 mg/L, depending on the state of the tide. The model's silt concentrations in the plume on the ebb tide after full mixing are therefore within the range of concentrations commonly experienced in the estuary, notwithstanding the fact that the model overestimates concentrations because of its assumption of a continuous discharge.

The pipe installation and its silt plume as modelled effectively represent a common silt scour event which would be occurring during a river flow at which scouring would otherwise be uncommon. Scouring does not normally occur at average river flows of 50 cumecs. It usually occurs at flows of more than 180 cumecs (section 2.2.1).

Rather than install the pipe during average river flows as modelled, it could be installed at either much lower flows or much higher flows.

At lower river flows, the plume concentration would be greater due to the lesser dilution but the background silt concentration would be higher. At zero river inflow (ie. only a 160 cumecs ebb tidal flow), the model's plume centre concentration is approximately 490 mg/L after complete mixing. At zero river inflow, downstream silt movement is 200 tonnes per ebb tide (section 2.2.1) and the background silt concentration under the model conditions would be (200 x 1000 x 1000)/(6 x 3600 x 160) = 58 mg/L.

At higher river flows — for example, 100 cumecs (ie. a combined river and ebb tidal flow of 260 cumecs) — the plume concentration would be lower due to the greater dilution but the background silt concentration would also be lower. At this example river inflow, the model's plume concentration is approximately 330 mg/L after complete mixing. At this river inflow, downstream silt movement is 100 tonnes per ebb tide (section 2.2.1) and the background silt concentration under the model conditions would be (100 x 1000 x 1000)/(6 x 3600 x 260) = 18 mg/L.

It appears that there are no silt concentration advantages to be gained from selecting particular low or high river flows for the installation. Practical considerations, notably the risk of the pipeline string bending or becoming unmanageable in high current velocities, are likely to be the determining factor for what river conditions are most appropriate for the installation. This will be a matter for the installation contractor but an assumption that average river conditions will apply is reasonable.

The model's plume concentrations on the ebb tide are significantly lower than plume concentrations on the flood tide. The first pass of the trenching machine could therefore be timed to commence on the turn of the tide, so that discharge is downstream. Subsequent passes could similarly be timed until the trenching machine is completely buried and silt suspension rates reduce.

Timing the first passes to coincide with the ebb tide would prevent high concentrations of silt being carried upstream. Silt instead would be carried downstream beyond Tamar Island, where it would settle more quickly before some is returned upstream again on the turn of the tide. Given the nature of the silt, it is likely that it will require several tides for the silt to settle completely. However, the proposed timing will maximise settling rates.

3.4 Potential use of silt curtains, settling ponds or thickeners

The proposed use of jet trenching is the most practical means to reduce the amount of silt lifted into suspension. If further reductions in silt pluming were desired, the suspended silt would need to be either screened or settled out of the water column.

3.4.1 Silt curtains

Silt curtains are often used is dredging operations to reduce downstream turbidity. Silt curtains are vertical, flexible structures suspended from the water surface to a particular depth, usually about 0.5 m, from the bottom. The gap at the bottom is to allow mudflow to pass beneath the curtain.

Silt curtains do not contain the suspended sediment but rather force it down to close to the sediment surface where it accumulates as mud flow, which then moves downstream under the curtain. Up to 95% of the suspended material can enter this mudflow[85].

As discussed in section 2.2.1, however, although *in situ* Tamar silt has a high yield which resists entrainment, once suspended it settles only very slowly. Silt emerging as mudflow underneath a silt curtain will therefore be highly vulnerable to resuspension again downstream of the curtain.

Use of a silt curtain is therefore unlikely to reduce either the mass of silt that will enter suspension down stream from the crossing operations or the extent of the plume.

Maximum current velocities of 0.5-0.8 m/sec are a widely accepted limit for silt curtain deployment, and the USEPA advises against the use of silt curtains in currents greater than 0.5 m/sec due to increasing difficulties of isolating the dredging operation from surrounding water[86]. Even without river flow, average and maximum peak tidal velocities in the Tamar are 0.44 m/sec and 0.67 m/sec respectively (Table 6) and even in low flows velocities of 1 m/sec could be expected (section 2.2.1).

There is no apparent environmental benefit to be gained by using silt curtains on this project, and the practical difficulties of using silt curtains effectively in the strong current velocities of the Tamar make their use problematic.

3.4.2 Settling ponds

If 190 m^3 of silt is assumed to become suspended during a pass of the trenching machine across the river (see section 3.3) and two passes are required before the pipe and trenching machine become buried (and silt suspension reduces), a nominal minimum of 380 m^3 of silt might be targeted for settling.

This silt would be in an already suspended form. To recover it into a settling pond it would need to somehow be sucked from suspension, presumably from inside a silt curtain. Even if this was practical, very large volumes of water would also be sucked. Suction dredges sucking directly from *in situ* Tamar

[85] United States Army Corps of Engineers (September 2005) *Silt curtains as a dredging management practice*. ERDC TN-DOER-E21.
[86] United States Army Corps of Engineers (September 2005) *Silt curtains as a dredging management practice*. ERDC TN-DOER-E21.

sediment typically generate slurries in the order of 20% solids[87]. Sucking instead from a suspension would probably generate a slurry an order of magnitude less dense, say 2% solids.

The total slurry volume to remove 380 m^3 of silt might therefore be in the order of 380 x (100/2) = 19,000 m^3.

If this volume was pumped to a settling pond 1 m deep, the area of the pond would need to be 19,000 m^2, approximately 140 x 140 m.

The use of silt ponds is an established practice for routine Tamar dredging operations. However, these ponds are permanent and a silt pond for the crossing would also need to be permanent (by intent the sediment would not be returned to the river) and only freehold land is available in the vicinity.

Permanently alienating a large area of freehold land to achieve a questionable environmental benefit for a transient (few days) issue is considered to be unwarranted and unjustifiable.

3.4.3 Thickeners

The potential use of thickeners for Tamar silt has been considered by Slurry Systems PL for the Tamar River Improvement Committee for normal channel dredging operations[88].

Slurry Systems advised that a thickener sized to deal with 5 tonnes of silt per hour would require a thickening tank of approximately 60 to 80 m in diameter, with a capital cost in the order of $2 to 3 million.

Jet trenching for the pipeline could generate 0.011738 m^3/sec of silt (section 3.3) or 42 m^3 = 42 x 1.35 = 57 tonnes per hour. Even without the problems of recovering silt from suspension described in section 3.4.2, a thickener is not a viable proposition.

3.4.4 Mitigation option summary

There are three potential mitigation options that might be used to reduce the impact of silt disturbance: silt curtains, settling ponds and thickeners.

Use of a silt curtain is considered unlikely to reduce either the mass of silt that will enter suspension down stream from the crossing operations or the extent of the silt plume generated by the dredging process. This apparent lack of environmental benefit, together with the practical difficulties of using silt curtains effectively in the strong current velocities of the Tamar River, makes their use problematic.

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[87] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.

[88] Slurry Systems PL (February 1994) *Tamar River Launceston harbour siltation*. Report prepared for Unisearch Limited.

Only freehold land is available in the vicinity for a settling pond, which would need to be permanent as the sediment would not be returned to the river. The permanent alienation of a large area of freehold land to achieve a questionable environmental benefit for a transient (few days) issue is considered to be unwarranted and unjustifiable.

As a thickener capable of handling the projected volume of silt would require a very large tank, with a very high capital cost, it is not considered to be a viable option.

Because of the impractability of post-disturbance silt mitigation, it would be unreasonable and problematic to set turbidity compliance limits for the trenching activities. If such limits were set and were exceeded, there would simply be no way of achieving compliance other than by abandoning the trenching and hence installation of the pipeline.

Silt impact mitigation will therefore be by adoption of the least disturbing trenching method available – on-pipe jet trenching – and by timing trenching to coincide with the ebb tide, at least until the pipeline has sunk below the sediment surface and silt suspension diminishes.

3.5 Pipe options

Basic pipe material options are steel or polyethylene.

Mild steel (cement lined) is the normal material of choice for subsea pipelines, although steel pipe of 1 m diameter is not readily available in Australia. Steel is less flexible than polyethylene, and therefore less likely to bend in water currents during installation or sag under load during operation. It has negative buoyancy, helping it to sink through the silt during jetting. This positive attribute might also be a negative attribute and require pipe supports to be used to prevent ongoing sinkage below the desired depth.

Steel is also vulnerable to corrosive attack in an acidic environment, which is likely to be found at depth in the silt due to the presence of hydrogen and sulphides. If steel is used, it would need a protective coating.

Steel pipe would also need cathodic protection.

Polyethylene pipe of 1 m diameter is also not readily available in Australia. Polyethylene is lighter than steel, and therefore possibly more manageable on land. However, it is more flexible and more likely to bend in water currents during installation or sag under load during operation. It also has a lower pressure rating than steel, and polyethylene pipe may need special manufacture for this project. It has positive buoyancy (it will float when full of water), requiring weights to help sink it during installation and maintain it in place during operation.

3.5.1 Preferred option

Steel is expected to be the material ultimately chosen for the crossing because it is less likely to bend in water currents during installation, making installation of the pipeline easier. Furthermore, a steel pipeline is less likely to sag under load during operation.

A steel pipeline will require a protective coating, probably epoxy externally and concrete internally, and will also require cathodic protection. Piers may be required for support when the pipeline is full to prevent ongoing sinkage below the desired depth within the silt and also to prevent movement if the pipeline is emptied of water. These requirements will be determined as part of the detailed design.

The following description of the construction process is based on the expectation of steel pipe being used.

3.6 Construction stages

3.6.1 Outline

The pipeline will be winched across the river, probably on floats, sunk onto the river bed and stabilized by ropes and anchors.

It is possible that the contractor may opt to drag the pipeline across the river bed rather than floating it across then sinking it. Due to space limitations, the pipeline stringing area will need to be on the western bank (see section 3.6.2) and pulling would therefore be from the eastern bank.

Once the pipeline is in place, a jetting machine will then roll along the submerged pipeline and inject high pressure water underneath the pipeline. The pipeline will then gradually sink into the liquefied river bed. The pipeline will connect to the land based pipeline in large concrete chambers installed below ground level at each river bank.

A schematic representation is shown in Figure 9.

More detail on the expected construction stages follows.

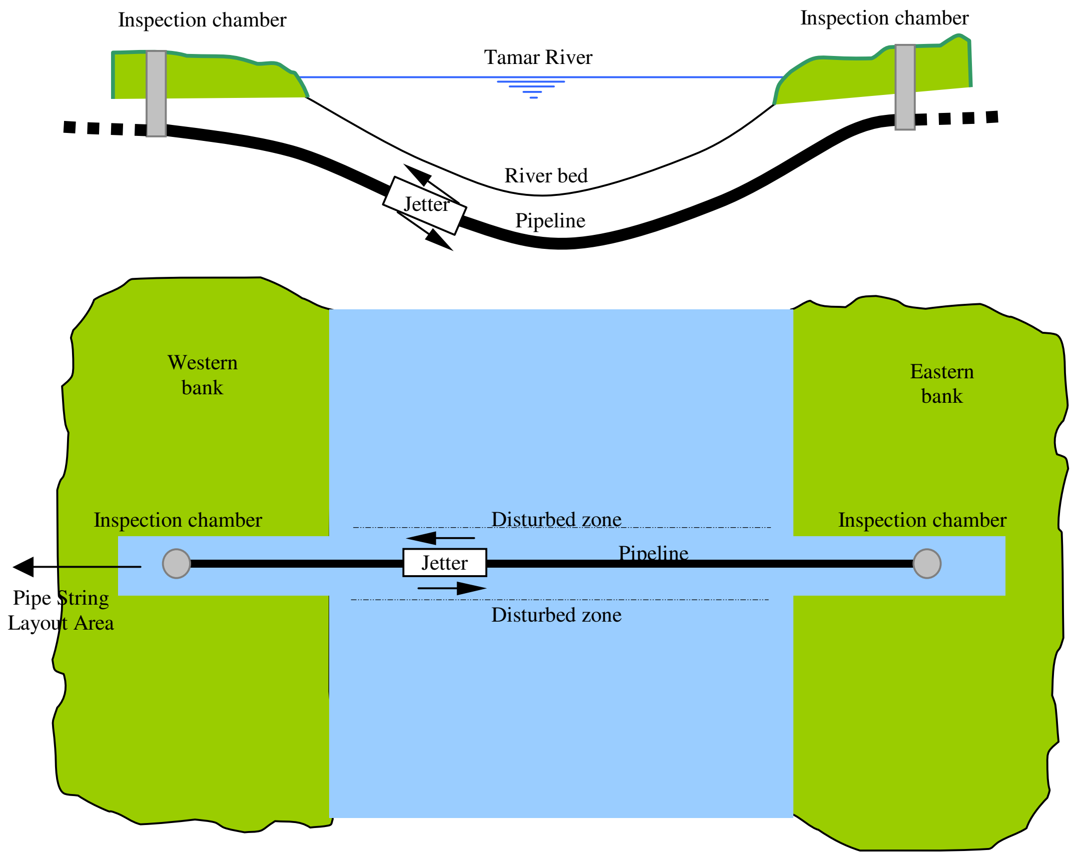

Figure 9: Schematic representation of the crossing construction

3.6.2 Stage 1

Work areas will be established on both sides of the river. At both work areas there will also be site sheds, containers, construction plant and equipment.

A work area on the western side of the river approximately 400 m long by 50 m wide will be required for the delivery, storage and fabrication of the pipeline string.

On the eastern side of the river a work area approximately 200 m long by 50 m wide will be required to accommodate the winch and associated equipment that pulls the pipe across the river.

The pipe string will be constructed on the western work area by joining sections of pipe to create a pipe string approximately 400 m long. Once the pipe string is fabricated it will be pressure tested.

On each side of the river a trench will be excavated to provide a curved transition from the land based trench to the under river trench. These trench sections will be excavated into the outer edges of the river bed and may require sheet piling and shoring to prevent collapse of the trench. A slip pad or roller will be installed at the start of the western trench and end of the eastern trench to minimize friction and damage to the pipeline during winching.

The excavated silt and soil from the transition sections of the trench will be temporarily stored adjacent to the trench until backfilling occurs.

Stay wires and anchor points will be installed to prevent the pipe string from moving while it is winched across the river. The stay wires and anchor points could be installed in the river or on the river bank. The anchor points may be up to 200 m upstream and downstream of the pipeline on both sides.

Pumps and compressors will be set up on the western shore to drive the jetting machine. Barges and work boats will be mobilized.

Establishment of the work areas and edge trenches is expected to take 2 weeks.

Excavation of the edge trenches is expected to take 2 weeks. During this time the pipe string will also be constructed.

3.6.3 Stage 2

The pipe string will be pulled across the river by the winch mounted on the eastern side. If the pipe is dragged across the river rather than being floated across, the leading pipe end will be fitted with a sled to prevent it ploughing into the river bed silt during winching. During winching the pipe string will be monitored from barges and boats on the river. The pipe will be positioned so that each end matches into the land based pipeline. The pipeline will be secured to the stay wires and anchor points.

Once in position, the pipe string will sit on the river bed under its own weight. Some sections of pipe may span undulations in the river bed profile.

This stage is expected to take 1 to 2 days.

To minimise disruption to river traffic, once commenced Stage 2 would continue around the clock until complete.

3.6.4 Stage 3

The jetting machine will be mounted on the pipeline and jetting will begin. The jetting machine will roll up and down the pipeline liquefying and displacing the silt surrounding the pipeline. As the silt is displaced the pipeline will gradually sink under its own weight. Water may be pumped into the pipe to reduce its buoyancy. The jetting machine will continue rolling up and down the pipeline displacing silt until the base of the pipeline has sunk to the desired level, nominally 5 m below the surface of the silt. During this stage of the operation work boats and barges will be operating on the river.

This stage is expected to take 3 to 4 days.

To minimise disruption to river traffic, once commenced Stage 3 would continue around the clock until complete.

3.6.5 Stage 4

During this stage scour protection will be placed over sections of the pipeline if and as required. The scour protection will probably comprise rock spalls placed over a proprietary open weave erosion control mat. The mat could be up to 20m wide.

Scour protection is likely to be both necessary and practical only at the river edges, where the pipeline transitions from under river to land. In the channel sections, the approximately 5 m of silt cover will itself provide adequate scour protection given that flood scours are likely to be less than 2 m (section 3.1).

On the edge sections, scour protection may be necessary to assist restabilisation of the river banks, which are vulnerable to undercutting (section 3.1).

This stage is expected to take 3 to 4 days.

3.6.6 Stage 5

Once the pipe has achieved its design level it will be permanently anchored to the land pipeline at each end via connection to an inspection chamber. The chambers will allow connection of the under river pipe to the land based pipe, access to isolation valves and access to the pipe for diver maintenance inspection.

The chambers are expected to be nominally 3 to 4 m in diameter and 2 to 3 m deep. The manholes may be sheet piled prior to construction to allow safe excavation. It is possible that the chamber bases may require piling.

A cathodic corrosion protection system will be installed. This will require a permanent electricity supply.

Pressure testing would be carried out prior to backfilling of the land trenches.

The river banks on either side of the crossing will be reinstated and stabilised. A proprietary open weave erosion control mat is likely to be used to assist the stabilisation and minimise subsequent undercutting. The banks will be vulnerable to scouring and undercutting until the fill has consolidated and the banks become revegetated.

This stage is expected to take 3 to 4 days.

3.6.7 Stage 6

During this stage all river crossing plant and equipment will be demobilized.

Clean up, reinstatement and rehabilitation of the work areas either side of the river will be undertaken.

Bare soil will be resown with native wetland plants, such as *Juncus*.

Survey points will be established for regular monitoring of the river bank profile, which will be undertaken until it has been confirmed that the river banks at each end of the crossing are stable.

This stage is expected to take 5 to 10 days.

3.6.8 Stage 7

Gunns will require the pipeline crossing contractor to undertake regular monitoring of the crossing's disturbed areas and also upstream and downstream areas initially on a daily basis until bank stability has been confirmed and thereafter on a weekly then monthly basis for the duration of the contractor's defects liability period (likely to be at least 36 months). The contractor will also be required to undertake additional inspections during and following flood events. Remedial responses will be undertaken if significant scouring, undercutting or slumping occurs or if vegetation fails to survive.

Significant scouring will be considered to be scouring of the river bed in the vicinity of the river bank sufficient to be likely to result in undercutting and hence slumping of the bank.

In the event of any dispute between Gunns and the contractor as to the significance of scouring or bank instability during the defects liability period, Gunns will engage an independent consultant to make recommendations.

After the expiration of the defects liability period, Gunns will continue to undertake regular inspections, at least every 6 months and following major flood events, for the life of the project.

This stage will continue for the duration of the contractor's defects liability period (likely to be at least 36 months) and thereafter by Gunns itself for the life of the pulp mill project.

3.7 River bank infrastructure

3.7.1 During construction

The western bank will be the main area of operations for the pipeline crossing.

The western work area (nominally 400 m long by 50 m wide, and along the pipeline alignment) will require hardstand for:

- Pipe storage
- Pipe joining (welding)
- Pipe string preparation (nominally 250-300m length)
- Site offices
- Car parking
- Lockable compound.

The following services are expected to be required:

- High voltage electricity
- Potable water
- Telephone connection
- Toilet facilities
- Worksite lighting
- The current access road will require some improvement
- The main hydraulic sledge compressors will be housed on site.

The eastern bank will be the receiving area of operations for the pipeline crossing. The eastern work area (nominally 200 m long by 50 m but subject to detailed design given space limitations on this side) will require hardstand for:

- Site offices
- Car parking
- Lockable compound.

The following services are expected to be required

- HV Power
- Potable water
- Telephone connection
- Toilet facilities
- Worksite lighting
- Signage for safe traffic management for access to the East Tamar Highway.

On each bank there will also need to be temporary storage of bank excavation material. While this will not be as fluid as bed silts, it will still be likely to require bunding. Only small volumes, in the order of tens of cubic metres, are anticipated.

3.7.2 Permanent

Permanent riverbank infrastructure is expected to be:

- Inspection chambers on each bank. These are likely to be either cast *in situ* or precast concrete. They will comply with access and egress provisions of AS2865:2001 *Safe Working in a Confined Space*. They will have a sealed cover slab and a sealed and lockable lid to prevent unauthorized access and stop infiltration or exfiltration from the system.

- Cathodic protection system on the east bank, with electricity supply.

- A check valve or valves located upstream and down stream of the crossing to allow safe access to the under water pipeline and to allow isolation during maintenance works.

4. Potential environmental impacts and their management

Significant credible impacts are largely confined to construction impacts arising from the disturbance of silt and the weakening of river banks.

There are additional, very low probability, potential impacts that could arise in the event of a pipeline breach at some point along the crossing.

The potential impacts and proposed mitigation measures are as follows.

4.1 General environmental management measures

In addition to specific environmental impact mitigation measures, some general measures will be implemented.

Commitment 1: Gunns will include the commitments described in this report, together with any additional requirements imposed by the pulp mill assessment process, as tender specifications for the design and construct contract to be let for the crossing construction.

Commitment 2: If detailed design determines that any of these commitments require amendment, a report describing and justifying the amendment will be provided to the Director of Environmental Management, together with a request to modify relevant permit conditions if and as necessary.

Commitment 3: The construction contractor will prepare a Construction Environmental Management Plan and submit it to the Director of Environmental Management at least one month before works commence.

Commitment 4: The construction contractor will maintain a 24 hour telephone information service to advise the public of the nature and timing of operations.

4.2 Physical disturbance of benthic biota

The benthic biota in the vicinity of the pipeline crossing will be very resilient to physical disturbance. The benthic environment in this area would be inherently unstable due to frequent and erratic scouring from flood discharges. As described in section 2.2.1, bed scouring in Home Reach further upstream is initiated when river discharge reaches approximately 180 cumecs, a discharge that could be expected to occur every few months.

The Tamar at the crossing point is a similar width to Home Reach, so the scour threshold inflow rate for the crossing would be similar. Scouring of the estuary bed in the vicinity of the crossing is therefore likely to occur several times a year.

Under these existing conditions of regular physical disturbance, the silt infauna will be dominated by a very small number of opportunistic species, likely to be present in high numbers (see section 2.4). The number of species is small because only a few species are able to cope with the combination of the wide salinity fluctuations in the upper estuary and the frequent physical disturbance of their habitat.

Gross disturbance of the sediments by the pipeline installation will therefore be neither an unusual nor a significantly harmful occurrence for these species. The nature of the silt and the nature of the pipeline installation method means that the infauna will simply be displaced with the sediment, with little direct impact damage. They may be moved a short distance up or down stream depending on the currents at the time before settling onto the estuary bed again to re-establish themselves. The disturbed sediments would also be quickly recolonised from adjacent areas, just as would occur following flood scouring.

Impacts on the benthic fauna from jet trenching installation of the pipeline are expected to be negligible, and confined to temporary displacement and recolonisation.

Commitment 5: Water jet trenching will be used for the installation of the pipeline through the bed silts of the estuary.

Commitment 6: Unless determined to be impractical during detailed design for the crossing, the jet trencher will be an "on-pipe" type that will stay with the pipeline as it sinks into the silt.

As noted in section 2.4, the mosquito fish (*Gambusia holbrooki*), an introduced pest species, has been recorded in the vicinity of the crossing. The construction of the pipeline will not favour this species or lead to its wider spread. The mosquito fish prefers slow flowing or still waters, amongst aquatic vegetation at the edge of waterbodies in water depths of 10 cm or less, and it bears live young[89]. While it is conceivable that fish of this species could occur in shallow areas on either side of the crossing, there would be no eggs that could be dispersed with the silt. Like other fish species, the most likely effect of the trenching operations would be to cause the fish to move away from the area for the duration of the disturbance, and the impacts on the species would therefore be neutral.

[89] Global Invasive Species Database (http://www.issg.org/database/species/ecology.asp)

4.3 Physical effects of silt suspension on biota

The disturbance of silt by jet trenching will be orders of magnitude less than open-then-backfill trenching but some silt will nevertheless be lifted into suspension and hence transported up and/or down the estuary until it settles out somewhere.

The silt plume created by the pipe installation will be similar to commonly experienced natural scour plumes but it is likely to occur at a river flow less than that at which scour events normally occur.

As shown by the modelling described in section 3.3, if the jetting occurred on the ebb tide under average flow conditions, the concentration of silt after complete mixing downstream of the crossing will rise above the likely background at that time of 25 mg/L. The model's plume concentrations are approximately 390 mg/L. While this is an overestimation of the actual concentrations because of the model's assumption of continuous discharge, the actual plume concentrations are nevertheless likely to be several times the background concentration. If trenching occurred on the flood tide, potential plume concentrations could be 40% higher again.

To minimise silt plume impacts, trenching should ideally be confined to the ebb tide. This ideal is constrained by the need for the pipeline trenching process to proceed to completion as quickly as possible because:

- The installation of the pipeline will disrupt river traffic, and constitute a navigational hazard until the pipeline has become buried in the silt;
- The pipeline will be vulnerable to sagging (gravity) or bending (water current) damage while it is suspended above the silt; and
- Confining trenching to the ebb tide would notionally double the trenching time, with associated cost implications.

An appropriate compromise is for the initial pass of the trenching machine to commence close to the end of a flood tide. At approximately 4.5 hours per pass of the machine (see section 3.3), almost two complete passes could be achieved before the next flood tide becomes dominant. This may be sufficient to largely bury the pipe below the silt surface. If burial is adequate after the initial pass(es) of the machine, and there is no significant risk to the integrity of the pipe, trenching could then be halted until the next ebb tide.

Commitment 7: The initial passes of the trenching machine will be timed to commence at the end of a flood tide and, subject to any practical difficulties that might be encountered, the design aim will be to maximise burial of the pipe before the end of the following ebb tide.

Commitment 8: If the pipe has achieved burial below the silt surface after the initial pass(es) of the machine, and there is no significant risk to the integrity of the pipe, trenching will be halted until the next ebb tide.

As burial becomes progressively deeper, the amount of silt suspended by the trenching activity will progressively diminish, and the benefits of confining trenching to the ebb tide will diminish. A decision on the timing of ongoing trenching machine passes relative to tide will be taken based on turbidity monitoring. Subject to safety and pipeline integrity constraints, if the turbidity monitoring shows that trenching during the flood tide is resulting in plume concentrations more than a nominal 20% higher (half the increase likely when the trenching is occurring near the surface) than those in an equivalent position during the preceding ebb tide, trenching activity will cease.

Commitment 9: Subject to safety, navigation and pipeline integrity constraints, trenching activity will cease during flood tides if monitoring shows that the silt plume concentrations are more than 20% higher than those that occurred in an equivalent position during the previous ebb tide's trenching.

The pipeline crossing point is approximately 2500 m upstream of the Tamar Island shoals. At the maximum peak ebb tide velocity of 0.56 m/sec (ignoring river discharge), water would take 75 minutes to travel this distance. With a settling velocity of less than 0.19 mm per minute even in static water, silt would only need to be lifted 14 mm off the estuary bed to still be suspended by the time it reaches the shoals. With river discharge and higher velocities the lift required would be even less. It is therefore almost certain that silt entrained into the water column during installation of the pipe will on an ebb tide travel at least as far as the shoals before settling. Similarly, with the maximum peak flood tide velocity of 0.67 m/sec, silt would only need to be raised 14 mm from the bed to still be suspended in the 75 minutes it takes a flood tide to travel the approximately 3000 m to Home Reach at the head of the estuary.

The slow settling rate of the silt means that silt entrained in the main channel is unlikely to settle out until it reaches the toe of the delta, downstream of Rosevears. As normally happens with suspended silt in the Tamar, the plume silt is likely to be carried up and down the estuary with the tides several times while it gradually settles out.

Commitment 10: Turbidity monitoring will be taken at various locations upstream and downstream of the crossing during and following installation to delineate the physical extent of the plume and describe how the plume dissipates over space and time.

Commitment 11: In addition to turbidity measurements, water samples will be taken at times and locations to be determined in consultation with Launceston City Council to assist calibrating and/or testing of any numerical models of estuary dynamics prepared for them or others. Samples will be analysed for silt concentration.

Commitment 12: Turbidity and silt concentration data collected will be provided to Launceston City Council for use as Council sees fit.

Commitment 13: A report on the silt plume behaviour will be prepared and submitted to the Director of Environmental Management within 3 months of completion of the crossing construction contract.

It is expected that biota in the water column would simply respond to this temporary increase in silt concentrations in the same manner that they do in response to a natural scour event. After complete mixing, the plume concentrations are unlikely to be exceptional relative to concentrations that would frequently occur in the estuary.

The likely duration of the trenching silt plume (several days) would also be of a similar order to what would commonly occur during natural scour events.

Prior to complete mixing, such as in the centre of the plume near its source, concentrations will be much higher than would normally be experienced away from the immediate location of a natural scour event. Again, however, it is expected that biota in the water column would simply respond to this artificial "scour" in the same way that they would respond to a natural scour in their vicinity – by moving away or by avoiding it in the first instance. Organisms will have plenty of warning of something to be avoided, either through the noise and disturbance from the jetting operations themselves or from increasing silt concentrations. As described in section 2.4, the organisms inhabiting the sediments will be well adapted to frequent disturbance and subsequent recolonisation.

Impacts on swimming fauna from jet trenching installation of the pipeline are expected to be negligible, and confined to avoidance behaviour.

4.4 Physical effects of silt deposition on biota

If the suspended silt is carried into vegetated areas on the banks of the estuary, such as the Tamar Island Reserve wetlands, it may become trapped and settle there.

The significance of this silt deposition must be assessed in the context of existing conditions. As described in section 2.2.1, not only is silt deposition in these wetland areas a natural occurrence that created the wetlands in the first place, deposition in the vicinity of Tamar Island has been actively encouraged over many years as part of navigation channel maintenance activities. Each year, some 80,000 m^3 (average 220 m^3 per day) of silt is mobilised from the Tamar River and at least 15,600 m^3 (average 42 m^3 per day) of silt is deposited in the Tamar Island shoals.

The silt plume will be a concentrated burst of silt over one or two tides. The total volume of silt that might be disturbed and then settled is equivalent to only a few days of normal deposition.

The biota in the areas where plume silt is likely to settle will be naturally adapted to conditions of regular silt deposition. Indeed, as discussed in section 2.5, the estuary's delta and associated wetland areas have been created by silt deposition, and are in a state of continual evolution. Silt deposition arising from the pipeline installation will be neither exceptional nor harmful to these ecosystems.

Impacts on fauna and flora of the estuary's delta and wetlands from installation of the pipeline are expected to be negligible, and consistent with the natural conditions of these areas.

4.5 Physical effects of silt deposition on navigation channels

The volume of silt that might enter suspension from the pipeline installation process will be negligible relative to the total volume of silt in the estuary. Due to its slow settling rate, the suspended silt will become widely dispersed before it settles and gross deposition in localised areas of navigation channels is not a credible scenario.

Even if the silt all settled in the upper estuary, where navigation channels are routinely dredged, the potential impact on channel depths will be inconsequential. At worst, settled silt could be considered to be material that otherwise would not be there and in need of dredging but the thickness of the settled layer is likely to be in the order of millimetres only.

4.6 Chemical effects of silt on biota

Silt contamination in the Tamar estuary is historical, and unrelated to the current project.

Nevertheless, the current project will introduce silt into suspension and hence potentially make these contaminants more bioavailable.

The contaminants of Tamar estuary silt are described in section 2.3. As shown in Table 7, cadmium, chromium and copper approach and lead and zinc exceed the low effects guideline value, and zinc exceeds the median effects level. A low effects level means adverse biological effects 10% of the time and a median effects level means adverse effects 50% of the time.

Apart from a few heavy metals, contamination levels are below the NEPM Ecological Investigation Levels and overall the contamination levels are low enough for it to be considered suitable for reuse applications[90].

As with the other potential impacts of silt on biota, the scale of the potential impacts of the contamination on biota must be assessed against the background exposure of biota to such contamination, and also against exposure from alternative installation methods.

[90]SEMF (February 2001) *Proposed Tamar Dredging Project – Environmental Impact Statement*. Report prepared for Launceston City Council.

Like the other potential impacts, the exposure caused by dredging will be in a concentrated burst on a scale comparable with exposure to natural scouring, which is likely to occur several times a year naturally. This natural exposure has been occurring for many decades (and possibly more than one hundred years) since contamination started, and will continue for many decades (or longer) to come.

The trenching will release silts primarily from the upper layers of the sediment bed, which would be likely to have similar levels of contamination to samples analysed for navigational dredging operations (reported in Table 7). The trenching will move down to greater depths than navigational dredging or natural scouring would normally reach and there may be different levels of contamination at those greater depths. However, with increasing depth these silts will progressively be less likely to reach the surface during the trenching (being capped by overlying layers). The contamination levels in silt suspended during the jet trenching are therefore likely to be similar to those normally occurring in navigational dredging or natural scouring.

Some form of jet trenching is considered to be the most practical means of installing the pipeline. It is also a method that will cause an order of magnitude or more less silt suspension than dredge-then-backfill trenching.

The only way to achieve less silt disturbance would be to drill the pipeline under the silt or to remove the silt from the estuary entirely by suction dredging for permanent storage on the river banks.

The former method is not practical (see section 3.1).

The latter method would require the use of permanent silt ponds similar to those used for the storage of dredged silt from channel maintenance. As discussed in section 3.1, these would need to be large because of the large volumes of silt needed to be removed to allow the trench to stand open during pipeline installation.

The scale of disturbance to the bed of the estuary and the cost and area of land disturbance required to construct permanent silt ponds is unjustifiable given the low ecological risks presented by the contamination in the silt.

4.7 Chemical effects of silt on water quality

Silt will be anoxic and sulphidic at depths. Oxygenation of sulphides exposed to the overlying water during the trenching process could lead to the formation of sulphuric acid, H_2SO_4, and could also remove oxygen from the water. Metals in the silts could also move into dissolution. These chemicals could be toxic to organisms.

Silt is expected to be suspended at a rate of 0.011738 m^3/sec (section 3.3). At a density of 1.35 t/m^3 (Table 4), 15.83 kg/sec of sediment will be released.

Sulphate and total sulphur concentrations in silt have been reported for Tamar dredging operations[91]. If the difference between these sulphur forms is conservatively assumed to all be sulphide, the average concentration of sulphide in the sediments is 2600 mg/kg. This could form 7963 mg/kg of H_2SO_4.

If H_2SO_4 is conservatively assumed to be formed instantaneously on release, 7963 x 15.8 = 125,815 mg/sec of H_2SO_4 could be generated as the silt comes into suspension. At the modelled estuary flow of 210 cumecs, the final concentration of this H_2SO_4 would be 125815 mg/210 kL = 0.6 mg/L.

The seawater of an estuarine environment has high alkalinity. For example, in full seawater there is 28 mg/L of HCO_3 (bicarbonate)[92], which is just one of the many providers of alkalinity. This is well in excess of the neutralising requirements for 0.6 mg/L H_2SO_4.

Acid generation from silt suspension is therefore concluded to be an insignificant environmental concern.

The chemical oxygen demand from 2600 mg/kg of sulphide being converted to sulphate is 5320 mg/kg. If 15.83 kg/sec of sediment is released, the oxygen demand will be 5320 mg/kg x 15.83 kg/sec ≈ 84,000 mg/sec. If this oxygen demand is supplied by the model flow of 210 cumecs, the oxygen demand will be 84000 mg/210 kL = 0.4 mg/L.

The median background oxygen concentrations in Tamar estuary water[93] in the vicinity of the crossing is approximately 8 mg/L, ranging down to approximately 6 mg/L. After full mixing, the potential depression of oxygen levels due to the chemical oxygen demand of sulphides is therefore approximately 4-7%.

The reduction will be higher at the head of the plume, where dispersion of chemical oxygen demand has yet to occur but this would be an area avoided by swimming organisms. Benthic organisms could be affected but these species are typically tolerant of low oxygen environments (section 2.4).

Oxygen depletion by the release of chemical oxygen demand in silt to the water column is therefore concluded to be an insignificant environmental concern.

Zinc provides a good indicator of the potential impact from heavy metal dissolution as silt is suspended. It is highly toxic at low dissolved concentrations, and concentrations in the silt are high relative to other metals.

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[91] SEMF (February 2001) *Proposed Tamar Dredging Project – Environmental Impact Statement*. Report prepared for Launceston City Council.

[92] The Open University (1989) *Seawater: Its composition, properties and behaviour*. Permagon press.

[93] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.

The average of zinc concentrations reported[94] for the Tamar dredging operations was 190 mg/kg, equivalent to 3008 mg/sec in a 15.83 kg/sec silt release. If all this zinc dissolved on sediment release and then was diluted by the modelled 210 cumecs estuary flow, the increase in dissolved zinc concentrations would be 3008 mg/210 kL = 14.3 µL.

The median background zinc concentrations in Tamar estuary water[95] is approximately 70 µg/L, ranging up to 1170 µg/L.

The (worst case) increase in dissolved zinc concentrations is therefore in the order of 20% of the median background concentration.

Based on the above, dissolution of heavy metals in general by the release of contaminated silt to the water column is therefore concluded to be an insignificant environmental concern.

4.8 Disturbance of riparian flora

Although the potential environmental impacts of the terrestrial component of the pipeline are outside the scope of this report, it is possible that the river banks in the vicinity of the crossing have populations of *Bolboschoenus medianus* marsh club-rush or *Bolboschoenus caldwellii* sea club-rush, both of which are threatened species and both of which have been previously recorded in the vicinity of the crossing point (section 2.5).

A terrestrial flora survey has been undertaken for the whole water supply pipeline route[96]. No threatened species were found in the vicinity of the proposed crossing point. Nevertheless, confirmation flora surveys of the riverbanks and adjacent work areas will be undertaken following final design.

Commitment 14: During the detailed design process, confirmation flora surveys of riparian vegetation that could be disturbed by construction activities will be undertaken, and if any threatened species are found any necessary permits to take under the *Threatened Species Protection Act 1995* will be sought and/or appropriate management measures will be incorporated in the Construction Environmental Management Plan.

Commitment 15: Any areas found to contain threatened species close to, but not directly impacted by construction activities, will be identified on construction plans and will be cordoned off for the duration of the works.

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[94] SEMF (February 2001) *Proposed Tamar Dredging Project – Environmental Impact Statement*. Report prepared for Launceston City Council.
[95] Pirzl, H. and Coughanowr, C. (1997) *State of the Tamar Estuary – a review of environmental quality data to 1997*. Office of the Supervising Scientist Report 12.
[96] GHD (May 2006) *Proposed beach kraft mill in northern Tasmania flora report*. Draft report prepared for Gunns Limited.

4.9 Destabilisation of river banks

On each side of the crossing, short (tens of metres) sections of trenching through the river banks will be required to bring the pipeline up from its crossing depth to its terrestrial component depth.

Sheet piling will be used to hold these sections open during construction.

Commitment 16: Sheet piling will be used to hold the river bank cuts open during construction.

Cutting through the river banks could potentially make these sections of river bank more vulnerable to erosion from flood flows, particularly on the eastern shore, which is on the outside of a bend.

Appropriate bank restitution and soft armouring will be required to mitigate this risk. This will be a matter for detailed design by the selected construction contractor.

The armouring will need to be consistent with the strength of adjoining, undisturbed sections of the river bank. Armouring that is too weak will be inadequate. Armouring that is too strong could set up scour effects in adjoining undisturbed banks sections, which would be softer.

Commitment 17: River bank cuts will be filled, stabilised and armoured as necessary to ensure that they have a similar resistance to erosion as adjoining undisturbed sections of bank.

4.10 Amenity impacts from suspended silt

The Tamar Estuary naturally is often turbid. High concentrations of silt are common occurrences.

Nevertheless, subject to the background silt concentrations at the time of pipeline installation, the works potentially could create a visible plume, particularly if the work is undertaken after a prolonged period of non-scouring river flows, which would have led to low background concentrations.

However, such a plume is likely to be of short duration, probably in the order of one or two days, and its visibility would progressively decrease once the pipe and trenching machine have sunk below the silt surface.

With the expected round the clock operations (see section 3.6.4), probably a third of the silt pluming would take place during the dark.

With plume visibility likely to be in the order of only one or two days, visual amenity impacts are considered to be insignificant.

Launceston City Council will be notified in advance of trenching commencing so that they can respond to any public queries that may be received.

Commitment 18: The construction contractor will notify Launceston City Council at least 24 hours in advance of trenching commencing.

4.11 Other amenity impacts

Lights from round the clock operations would be a noticeable change from the normal visual environment. Noise may also be noticeable, particularly at night.

The quantum of these impacts will be dependent on the equipment used by the construction contractor, which cannot be determined until the design and construct tender selection process.

Gunns will control impacts by requiring, as a condition of tender, the contractor to avoid visual and noise impacts that would cause an environmental nuisance (as defined by the *Environmental Management and Pollution Control Act 1994*).

The level of noise that constitutes "environmental nuisance" is not prescribed, and will depend on particular circumstances and people's sensitivities. Generally, an increase of more than 5 dB(A) above background is considered to be excessive for ongoing operations. For short term construction activities, higher levels are usually considered to be tolerable, recognising that they will be of a limited duration. For example, the 2003 draft Tasmanian *Environment Protection Policy (Noise)* proposed construction noise limits 20 dB(A) above background for construction periods of up to 4 weeks and 10 dB(A) above background for longer construction periods. Although this draft was withdrawn it nevertheless provides a useful guide to what is considered to be acceptable. The Victorian Environment Protection Authority's noise control guidelines[97] allow up to a 10 dB(A) increase for up to 18 months and 5 dB(A) thereafter.

As a guide, an increase of 10 dB(A) above background will be adopted as a guideline maximum noise increase for the construction activities.

Commitment 19: The construction contractor will ensure that light and noise from the operations do not cause an environmental nuisance; a maximum increase of 10 dB(A) above background will be adopted as a guideline noise target.

[97] EPA Victoria Publication TG 302/92

4.12 Potential impacts from a pipeline rupture

The contents of the pipeline will be freshwater, which in itself is environmentally benign. However, the pipeline water will have different characteristics to the estuary's water. The water in the pipeline will be of different quality, salinity and temperature from that of the water in the estuary at the pipeline crossing point.

As the water in the pipeline will be obtained from a freshwater source (Trevallyn Dam) it will be of lower salinity than estuary water. In addition, the pipeline intake will be positioned on the bottom of the dam, a minimum of 18 m below the dam water level. This water is therefore likely to be colder than the water that normally passes through the Trevallyn Power Station, which is drawn from higher up in the water column, and much colder than estuary water. If a thermocline[98] develops in the dam, it is possible that the pipeline intake water will also have a lower oxygen concentration than surface waters, particularly if there is decomposing detritus at the bottom of the dam.

A pipeline rupture located somewhere along the crossing will release the pipeline water into the estuary, causing a mixing zone within which the oxygen, salinity and temperature of the two water types equilibrate. The size of this mixing zone will depend on the scale of the rupture, and hence on the rate and volume of pipeline water released. A small rupture could go unnoticed and continue to release small volumes of pipeline water indefinitely; a catastrophic rupture could release the full 31 ML (40 km x 1 m diameter) volume of the pipeline over a period of a few days (emergency response would shut off the intake but the pipeline contents would drain until the pipeline was empty).

It is unlikely that biota within the mixing zone will be significantly affected by the differences in water quality, regardless of the rate of release. Organisms in the vicinity of the crossing will be well adapted to reduced oxygen levels (see section 2.4), and salinity and temperature fluctuations are normal occurrences in an estuary due to tidal changes and flood inflows.

The most significant impacts that would arise from a pipeline rupture would be the disturbance of overlying silt by the jet of water released from the rupture, and the disturbance of silt that would be required to reach the rupture point to make repairs.

Jetting of water through a pipeline rupture would be under very high pressure, and the jet would force a hole through the overlying silts (the direction would depend on the position of the rupture). The sides of this hole would collapse inwards, to be similarly entrained in the jet. Eventually, a crater would form in the silt with sides having an angle of repose of 14% (see Table 4). The entrained silt would move into suspension and be dispersed down current.

[98] A temperature induced layering of warmer surface waters over colder bottom waters, which acts to reduce mixing between surface and bottom waters

A rupture would therefore create a substantial (albeit temporary) silt plume until the pipeline water was fully drained. Emergency response would probably take advantage of the crater formed to gain access to make repairs but additional silt disturbance for access may be required.

The impacts of suspended silt have been discussed in preceding sections.

The principal mitigation measure against potential impacts from a pipeline rupture will be to avoid a rupture in the first place. The engineering and cost implications of a rupture would be very high, and avoidance of pipeline failure will be a paramount objective. Appropriate quality assurance measures during pipeline construction will be adopted to meet relevant standards. The relevant standards will be determined during detailed design.

Commitment 20: To minimise the risk of pipeline failure, quality assurance inspection measures will be undertaken during construction to satisfy relevant construction quality standards.

5. Summary of commitments

Commitment 1: Gunns will include the commitments described in this report, together with any additional requirements imposed by the pulp mill assessment process, as tender specifications for the design and construct contract to be let for the crossing construction.

Commitment 2: If detailed design determines that any of these commitments require amendment, a report describing and justifying the amendment will be provided to the Director of Environmental Management, together with a request to modify relevant permit conditions if and as necessary.

Commitment 3: The construction contractor will prepare a Construction Environmental Management Plan and submit it to the Director of Environmental Management at least one month before works commence.

Commitment 4: The construction contractor will maintain a 24 hour telephone information service to advise the public of the nature and timing of operations.

Commitment 5: Water jet trenching will be used for the installation of the pipeline through the bed silts of the estuary.

Commitment 6: Unless determined to be impractical during detailed design for the crossing, the jet trencher will be an "on-pipe" type that will stay with the pipeline as it sinks into the silt.

Commitment 7: The initial passes of the trenching machine will be timed to commence at the end of a flood tide and, subject to any practical difficulties that might be encountered, the design aim will be to maximise burial of the pipe before the end of the following ebb tide.

Commitment 8: If the pipe has achieved burial below the silt surface after the initial pass(es) of the machine, and there is no significant risk to the integrity of the pipe, trenching will be halted until the next ebb tide.

Commitment 9: Subject to safety, navigation and pipeline integrity constraints, trenching activity will cease during flood tides if monitoring shows that the silt plume concentrations are more than 20% higher than those that occurred in an equivalent position during the previous ebb tide's trenching.

Commitment 10: Turbidity monitoring will be taken at various locations upstream and downstream of the crossing during and following installation to delineate the physical extent of the plume and describe how the plume dissipates over space and time.

Commitment 11: In addition to turbidity measurements, water samples will be taken at times and locations to be determined in consultation with Launceston City Council to assist calibrating and/or testing of any numerical models of estuary dynamics prepared for them or others. Samples will be analysed for silt concentration.

Commitment 12: Turbidity and silt concentration data collected will be provided to Launceston City Council for use as Council sees fit.

Commitment 13: A report on the silt plume behaviour will be prepared and submitted to the Director of Environmental Management within 3 months of completion of the crossing construction contract.

Commitment 14: During the detailed design process, confirmation flora surveys of riparian vegetation that could be disturbed by construction activities will be undertaken, and if any threatened species are found any necessary permits to take under the Threatened Species Protection Act 1995 will be sought and/or appropriate management measures will be incorporated in the Construction Environmental Management Plan.

Commitment 15: Any areas found to contain threatened species close to, but not directly impacted by construction activities, will be identified on construction plans and will be cordoned off for the duration of the works.

Commitment 16: Sheet piling will be used to hold the river bank cuts open during construction.

Commitment 17: River bank cuts will be filled, stabilised and armoured as necessary to ensure that they have a similar resistance to erosion as adjoining undisturbed sections of bank.

Commitment 18: The construction contractor will notify Launceston City Council at least 24 hours in advance of trenching commencing.

Commitment 19: The construction contractor will ensure that light and noise from the operations do not cause an environmental nuisance; a maximum increase of 10 dB(A) above background will be adopted as a guideline noise target.

Commitment 20: To minimise the risk of pipeline failure, quality assurance inspection measures will be undertaken during construction to satisfy relevant construction quality standards.

Tasmania

DEPARTMENT *of*
INFRASTRUCTURE,
ENERGY *and* RESOURCES

ROADS AND PUBLIC TRANSPORT DIVISION

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Mr Greg Stanford
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Dear Greg

I refer to our discussions of 6 June 2006 regarding the proposed pulp mill water supply pipeline and the East Tamar Highway in the vicinity of the Tamar River crossing at Alanvale.

As I indicated previously, I have some concern regarding the stability of the East Tamar Highway embankment if a major excavation is undertaken adjacent to the highway to facilitate the installation of a micro-tunnelled crossing of the Tamar River for the pulp mill water supply pipeline. The foundation material in this area near the river has a very high moisture content and is of a very low shear strength. In addition to the risk of settlement due to inadequate stabilisation of the excavation, I am concerned that drying from the excavation will create moisture gradients that could cause movement of the highway foundations due to the moisture sensitivity of the subgrades.

It would be advisable that alternative techniques be investigated for the installation of the pipeline at this location to minimise the likelihood of short or long-term damage to the road infrastructure.

Yours sincerely

Peter Todd
GENERAL MANAGER ROADS AND PUBLIC TRANSPORT

27 June 2006