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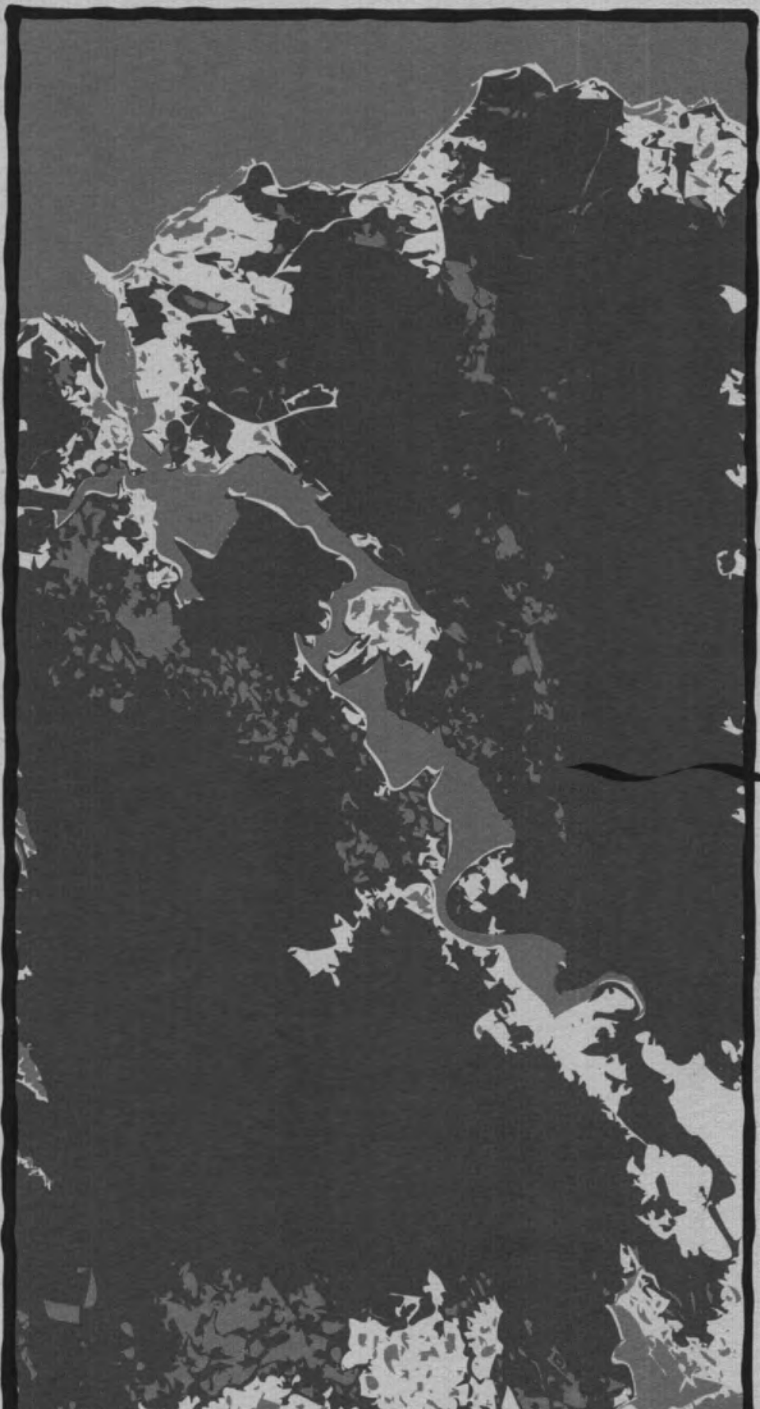

State of the Tamar Estuary

Helga Pirzl & Christine Coughanowr

Natural Heritage Trust

Tasmania

supervising scientist report **128**

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A review of environmental quality data to 1997

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This report was funded by the Natural Heritage Trust, a Commonwealth initiative to improve Australia's environment, as part of the RiverWorks Tasmania program. RiverWorks Tasmania is a three year joint program managed by the Tasmanian Department of Environment and Land Management and the Commonwealth Supervising Scientist Group to improve the environmental quality of several Tasmanian estuaries, specifically the Tamar, Derwent, Huon and Macquarie Harbour systems. The primary objectives of RiverWorks Tasmania are:

- to undertake a series of capital works projects designed to reduce or remove significant historical sources of pollution;
- to invest in mechanisms that will provide for sustainable environmental improvement, beyond the completion of the capital works program;
- to develop practical and innovative mechanisms for improving environmental conditions which can be transferred to other areas of Tasmania and other Australian States;
- to produce public education/information materials.

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Executive summary

This report, prepared as an initial project of RiverWorks Tasmania, is a compilation and synthesis of existing information about the Tamar Estuary and was prepared to help identify significant pollution sources and evaluate proposed remediation works. The report provides a brief overview of the Tamar's physical setting and uses, identifies and quantifies major pollutant inputs, and reviews and synthesises environmental quality data on water, sediments and biota.

The Tamar is a narrow, highly tidal estuary, with large freshwater inputs at its head, and is generally considered to be well-flushed. Broad tidal flats and wetlands border a relatively deep central channel, and become more extensive in the estuary's upper reaches. The Tamar's large tidal range (3 m) and strong tidal currents have resulted in an active sediment transport regime marked by rapid sedimentation in the upper reaches and a long history of dredging. The Tamar's catchment is very large (10,000 km^2) and land cover types are predominantly forests (52%) and agricultural lands (37%). River flows from the South Esk Basin are influenced by hydropower developments at Poatina and Trevallyn.

The estuary is an important recreational and scenic resource, particularly for the City of Launceston (population 66,000) situated at its head, as well as for numerous smaller communities along the eastern and western shores. The Tamar is Tasmania's second largest port and supports a large industrial area at Bell Bay and Long Reach (metal- and wood-processing industries). Several large conservation areas are associated with the estuary, including the Tamar River Wildlife Sanctuary and the Tamar River Mouth Nature Reserve.

A variety of point and non-point sources discharge contaminants to the estuary. Point sources include 10 sewage treatment plants and 4 major industrial plants (Comalco, TEMCO, North Forest Products and Boral Timber Tasmania), while diffuse sources include urban run-off (sometimes combined with sewer overflows in Launceston), atmospheric and ground-water pollution, and agricultural and mining run-off from the catchment. Until the late 1980s/early 1990s, the majority of urban, industrial and mining emissions had little treatment. Contaminants associated with these sources include pathogens, nutrients, organic matter and suspended solids (mostly derived from sewage, urban run-off and agricultural inputs from the catchment), as well as metals, fluoride and cyanide (associated with mining and metal processing industries). There have been significant decreases in most end-of-pipe emissions over the past 5 to 10 years - particularly due to sewage treatment plant upgrades and improved wastewater treatment at TEMCO and Comalco. The remaining significant inputs are probably now derived from diffuse sources, such as urban run-off (particularly combined sewer overflows), ground- and surface-water emissions from tips and contaminated sites, mining and agricultural wastes from the South Esk catchment and atmospheric emissions from industry and urban activities. Some pollutants may also be derived from contaminated sediments within or adjacent to the estuary.

The Tamar Estuary shows indications of environmental degradation in several areas. These conclusions, however, are supported by very limited information, as most monitoring programs and studies relating to the Tamar's environmental quality are over 10 years old, were typically of short-duration, covered limited areas and rarely included the full range of contaminants. Furthermore, our understanding of the processes which control environmental quality in the Tamar is poor, particularly with respect to estuarine circulation and sedimentation. It is strongly recommended that surveys of water quality, sediment contamination and biota be carried out and that the on-going monitoring program be revised accordingly. It is possible that that the major issues and areas of concern identified in this report could be revised significantly, once additional information becomes available. On the basis of the existing data, however, the following environmental issues appear to be of most concern in the Tamar Estuary.

Sedimentation in the Tamar's upper reaches has been an issue of long-standing concern, both for reasons of amenity and environmental quality. The estuary receives inputs of sediments from the catchments of the South and North Esk Rivers, which, through the action of tidal currents tend to accumulate as fine-grained silt deposits in the upper reaches of system. Rapid siltation in the Home Reach section of the Tamar causes difficulties with navigation and may increase the probability of flooding along the South Esk and North Esk Rivers. These sediments are considered unsightly by many people, and also serve as an effective trap for heavy metals and other contaminants. The upper estuary has been extensively dredged over the past 50 to 100 years and large areas of dredge spoils have been deposited along the banks of the upper Tamar. Few additional disposal sites are available, and it is estimated that the remaining sites have only a few more years' capacity. Some of the dredge spoil piles adjacent to the Tamar appear to be contaminated with heavy metals, particularly cadmium, zinc and chromium. Environmental impacts of dredging activities and dredge spoil disposal have never been adequately investigated.

Water contamination by ***pathogens*** (as indicated by faecal bacteria) derived from sewage and abattoir wastes has historically been a problem in the upper estuary, with levels frequently exceeding guidelines for secondary contact recreation. Since 1994, however, when the Hoblers Bridge wastewater treatment plant was upgraded and began treating abattoir wastes, there has been a significant improvement. Still, several sites in North Esk River and upper Tamar (above Freshwater Point) exceed guidelines for primary contact recreation. Sources of faecal contamination in this area are unknown and unquantified, but presumably reflect some combination of urban run-off, sewage, agricultural run-off and wildlife.

Heavy metals, particularly zinc, cadmium and lead, appear to be elevated in several areas of the Tamar - notably the upper estuary around Launceston, Deceitful Cove and (possibly) Middle Arm. Heavy metal concentrations in water, sediment and shellfish collected from the estuary have been in excess of recommended Australian and international guidelines, and as recently as 1993, it was recommended that oysters collected from the Tamar should not be consumed due to heavy metal contamination. Historical sources of heavy metals have included industries at Bell Bay and Launceston, and mining wastes from the South Esk catchment (Aberfoyle/Storeys Creek mines) and Beaconsfield. Diffuse sources of heavy metals may include ground-and surface-water emissions from tips and contaminated sites, urban run-off, and contaminated sediments/dredge spoils in or adjacent to the estuary.

The Tamar is not known to experience nuisance algal blooms, and little data are available on ***nutrients*** or chlorophyll *a* in the Tamar, beyond some indications of elevated phosphates in the upper reaches. However, nutrient inputs from sewage treatment plants and agricultural activities in the South Esk catchment are relatively high

Organic compounds have not been widely monitored in the Tamar. Hydrocarbons in oysters were recently surveyed in the lower estuary, in response to the *Iron Baron* oil spill of 1995, and were found to be relatively low. Elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) and phenols have been measured in Deceitful Cove. Few data are available for organochlorine pesticides and no data are available for polychlorinated biphenyls (PCBs).

Introduced species have been identified as an issue of concern, particularly rice grass and the Pacific oyster, which have colonised large areas of mudflats throughout the estuary. Concerns have been raised that other potentially destructive species (e.g. toxic dinoflagellates, Northern Pacific seastar) could also be introduced to the Tamar via ships' ballast water. Little information is available on the environmental status of seagrass beds and wetlands, which are vital components of the estuarine system.

On the basis of the available data, it appears that the Tamar is environmentally degraded in several areas, particularly in the vicinity of Launceston and near major industrial and mining areas. There have been a number of significant reductions in industrial and sewage pollution over the past 10 years, which have resulted in some observable improvements in water quality - particularly with respect to faecal indicator bacteria and dissolved oxygen levels in the upper estuary. As major point sources around the estuary are progressively upgraded, it is anticipated that diffuse sources will become the major contributors of contaminants. These diffuse sources - urban, agricultural and mining run-off, atmospheric inputs, ground-water contamination, contaminated sediments - tend to be difficult and expensive to remediate and will require strategic 'whole-of-estuary' planning to address effectively.

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Acknowledgments

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1 Introduction

The Tamar Estuary, situated along Tasmania's northern coastline, is one of the State's larger estuaries (100 km^2), extending approximately 70 km from the City of Launceston, at its head, to Bass Strait. The Tamar is a narrow estuary with a deep, well-defined channel, bordered by shallow tidal flats and wetlands. This diverse and productive ecosystem is characterised by a 3 metre tidal range and large freshwater inputs from the North and South Esk Rivers. The combination of a large sediment load from the catchment and strong tidal currents has resulted in rapid sedimentation in the upper reaches of the estuary - and a long history of dredging.

The estuary is an important recreational and scenic resource, particularly for the City of Launceston (pop. 66,000), as well as for numerous smaller communities along the eastern and western shores. The Tamar is Tasmania's second largest port and supports a large industrial area at Bell Bay and Long Reach (metal- and wood-processing industries). Contaminants enter the estuary from a variety of point and non-point sources: these include treated sewage and industrial effluent, urban run-off (sometimes combined with sewer overflows in Launceston), atmospheric and ground-water pollution, as well as agricultural and mining run-off from the catchment. In July 1995, the grounding of the *Iron Baron* off the mouth of the Tamar resulted in a 300 tonne oil spill, affecting the estuary's lower reaches for a limited time.

Environmental concerns in the Tamar have broadly focused on:

- sedimentation/dredging issues;
- contamination of water, sediments and biota with pathogens, hydrocarbons, metals, and other contaminants (e.g. fluoride, cyanide, phenols);
- effects of introduced species, particularly rice grass and Pacific oyster.

To assist in meeting the objectives of RiverWorks Tasmania, a document which summarises the present environmental status of the Tamar Estuary was required. The following 'State of the Tamar Estuary' report was prepared to fill this need and is intended to:

- provide an overview of the Tamar's physical setting and uses;
- identify and quantify (where possible) major inputs, providing a 1996 'snapshot';
- identify, compile and review existing environmental quality data on water, sediments and biota.

This report is not based on new information or studies, but is a compilation and assessment of existing data on the Tamar Estuary. A review of the available information indicates that there have been few extensive monitoring programs/environmental quality investigations of the Tamar Estuary - far fewer than, for example, the Derwent, Macquarie Harbour or Huon estuaries. The limited information which has been collected is largely unpublished, and has never been fully compiled, reviewed or presented. Furthermore, the majority of reports and data are over 10 years old. Given the significant gaps in our knowledge about present environmental conditions in the Tamar, the findings presented in this report should be used and interpreted with care.

Although this report was specifically commissioned to assist the RiverWorks Tasmania Steering Committee in evaluating and prioritising proposed projects, particularly through the identification of 'hot spots' and significant historical sources of pollution, it is anticipated that this report will serve a number of broader purposes as well. These include:

- to inform and educate resource managers and the public;
- to identify gaps in the existing information base;
- to establish benchmarks for determining trends and improvements in the environmental quality of the estuary.

2 Physical setting

2.1 Geomorphology/geology

The Tamar River Estuary, illustrated in Figure 1, is formed at Launceston in the north east of Tasmania, by the confluence of the South Esk and North Esk Rivers. The morphology of the estuary is that of a drowned river valley, which was formed between 13,000 and 6,500 years ago, when sea level rose around 60 metres to near its current level (Foster *et al.*, 1986). The Tamar Estuary covers an area of approximately 100 km^2 and extends along a south east to north west axis for approximately 70 km, following a meandering path from Launceston to Low Head on Tasmania's north coast, where it enters the Bass Strait. The upper estuary is generally narrow, but below the Batman Bridge, the Tamar opens out into several long embayments or 'arms' known as East Arm, Middle Arm and West Arm.

The main channel is quite deep in the lower estuary, reaching 45 metres in depth near Bryants Bay (just off Deceitful Cove). However, above Swan Point (at Paper Beach), the estuary is subject to rapid infilling by sediments and becomes very shallow as it nears Launceston. Tidal mud flats border the main channel of the Tamar throughout its length. These have been colonised by the invasive rice grass *Spartina anglica* in the middle and upper reaches.

The estuary winds through the Tamar Valley, which is long and generally narrow, and is bordered by the high ranges and rolling hills typical of the local countryside. The geology of the Tamar Valley consists of tertiary and more recent deposits with substantial areas of Jurassic dolerite (Department of Mines, 1974). The estuary is located in the Tamar Graben, which physically defines the Tamar region between the Western Tiers and Eastern Highlands of Tasmania and from the Northern Midlands to Bass Strait. The northern end of the graben is defined by ridges of Jurassic dolerite, which form West Head and Low Head at the mouth of the Tamar. Drainage patterns in the lowlands and the Tamar Valley tend to be rectangular, reflecting the major lines of faulting and jointing.

2.2 The Tamar catchment

The Tamar and its tributaries drain a catchment area of approximately 10,000 km^2, comprising over one fifth of Tasmania's land mass in north east and central Tasmania (Figure 2). The South Esk Basin (consisting of the Macquarie, Meander and South Esk sub-catchments) occupies the majority of this total area, while the North Esk basin is only 500 to 600 km^2 in size. Topography in the catchment varies from the low hills and rolling plains characteristic of the agricultural regions in the Northern Midlands, to the high peaks and plateaus of the Western Tiers, Ben Lomond Range and Eastern Highlands.

The principal land use types within the Tamar catchment, as indicated in Table 1, are forests and agriculture. Urban land uses occupy only a small percentage of the catchment area, primarily in the immediate vicinity of the estuary. Industrial zones are mostly restricted to the region surrounding Launceston, and to the area south east of George Town. Based on 1994 census data, the total population in the catchment is estimated to be in the order of 119,000, approximately one-half of which are concentrated in Launceston and its suburbs (ABS, 1995). Other significant towns include George Town (pop. 7000), Longford,

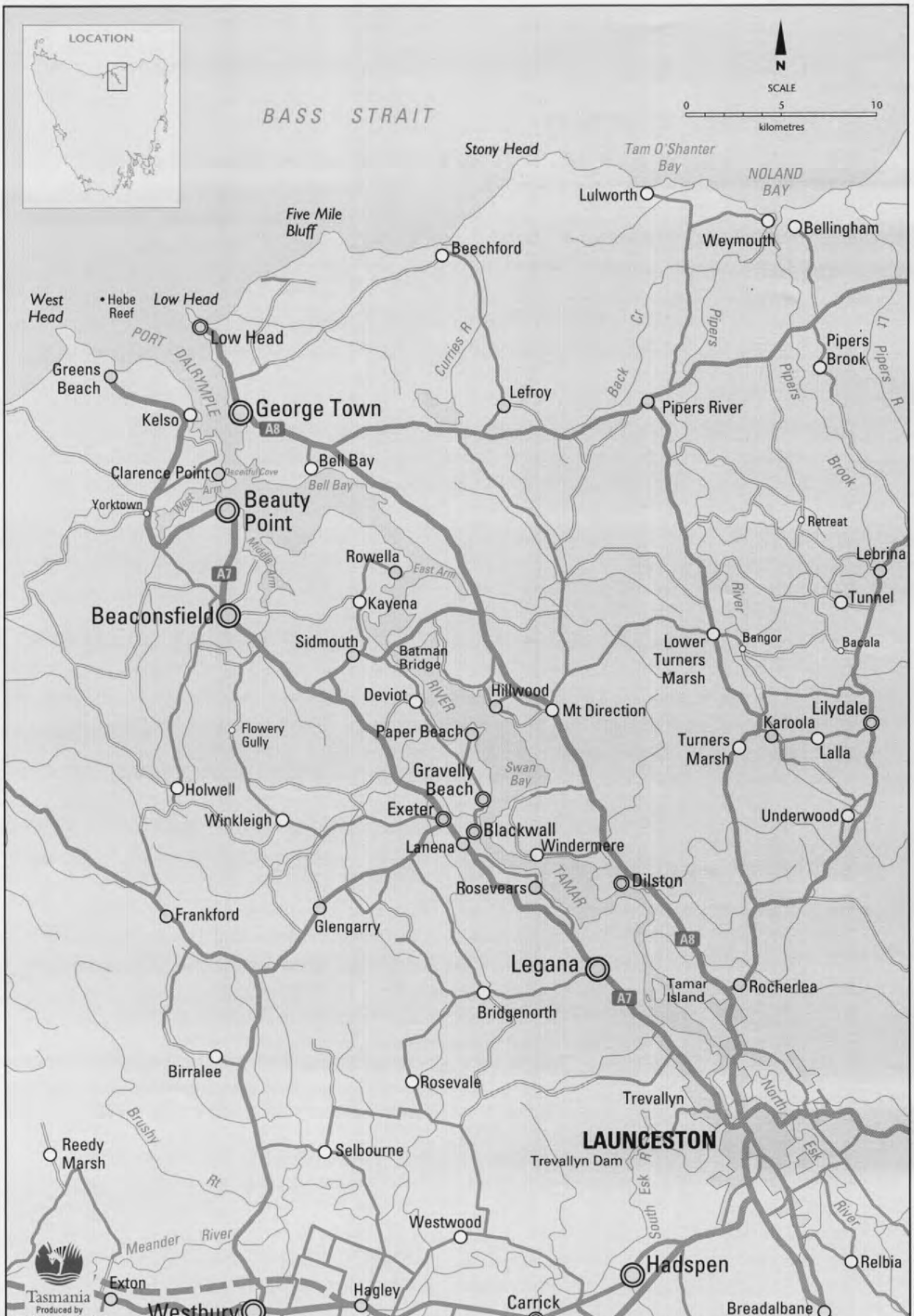


Figure 1 The Tamar Estuary

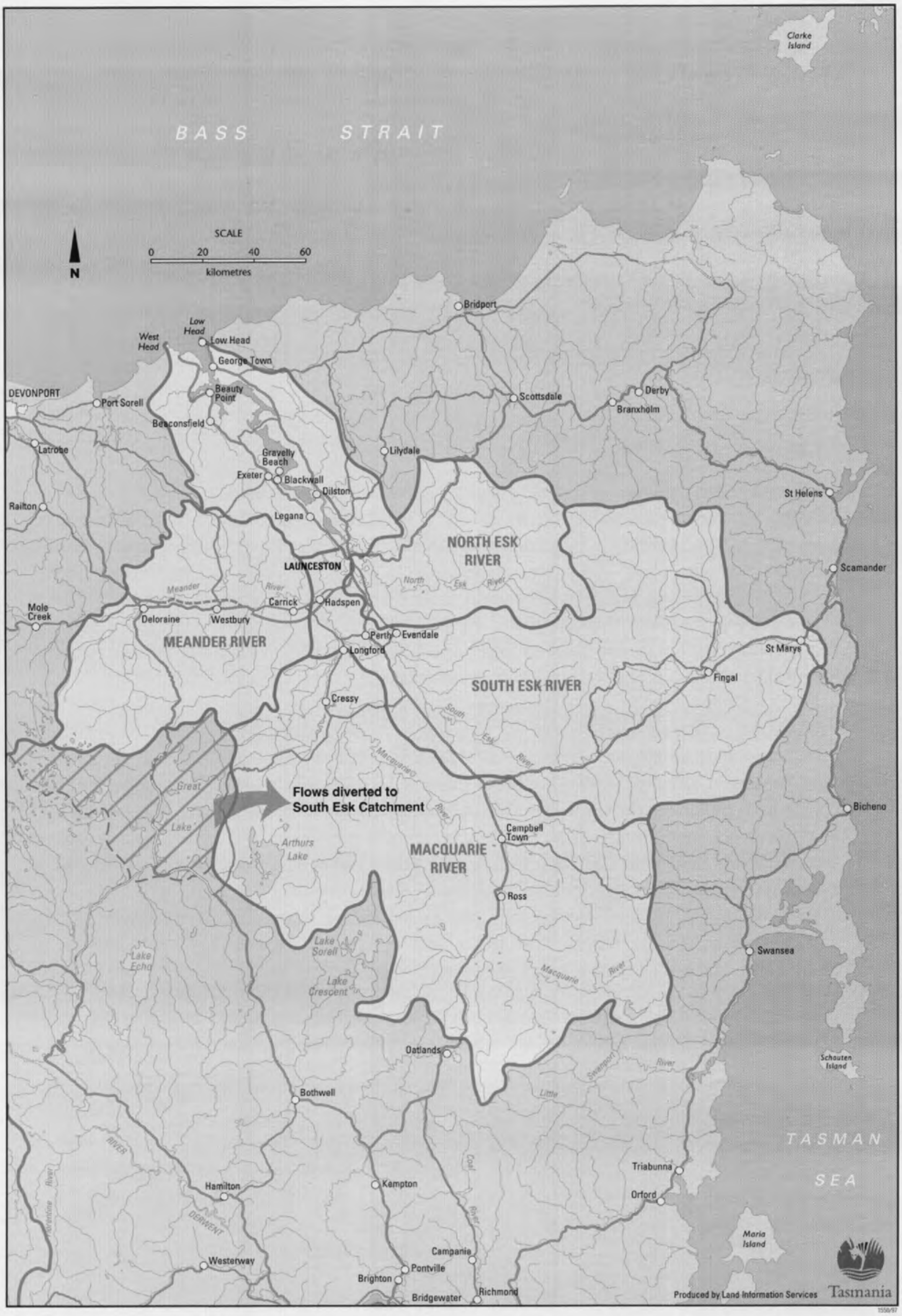


Figure 2 The Tamar Estuary catchment

Deloraine and Westbury. In the more distant regions of the catchment, small areas of the highlands are protected as national parks .

Table 1 Land use areas within the Tamar catchment

Land Use	% of total catchment
Woodland, forest and rainforest	52
Agriculture	37
Heath and scrub	9
Water Storages	2
Urban	0.5
Total	***100***

(DELM, 1996)

2.3 Meteorology

The Tamar region experiences a cool, temperate climate, with mean monthly air temperatures at Launceston ranging from a maximum of 17.9°C in February to a minimum of 7.2°C in July (pers. comm., BOM 1997). Wind directions in the region are strongly influenced by the topography of the Tamar Valley, with geostrophic winds deflected by the surrounding mountains, resulting in predominantly north westerly or south easterly winds. Down-river katabatic flows are also frequent, particularly in winter. The topography of the Launceston area encourages an inversion layer to form on cold winter nights, trapping pollutants. This often results in poor air quality in the Launceston basin.

Precipitation is routinely measured at a number of sites around the Tamar, including Georgetown and Launceston. As indicated in Figure 3, precipitation in the catchment is quite variable, ranging from 500-600 mm/yr near Campbell Town and Ross to 1,800 mm/yr in the mountainous regions in the north east. The mean annual rainfall in the vicinity of the estuary ranges from 600-1,000 mm/yr, with 678 mm/yr recorded at Launceston. Table 2 summarises long-term rainfall statistics for Launceston (at Ti-Tree Bend). Mean monthly rainfall varies seasonally, ranging from a minimum of 26 mm in February to a maximum of 87 mm in August. During 1996, total precipitation was higher than average and extremely variable, with higher than average rainfall recorded in January and August and very dry conditions during May, June and December (see Figure 4 for comparison).

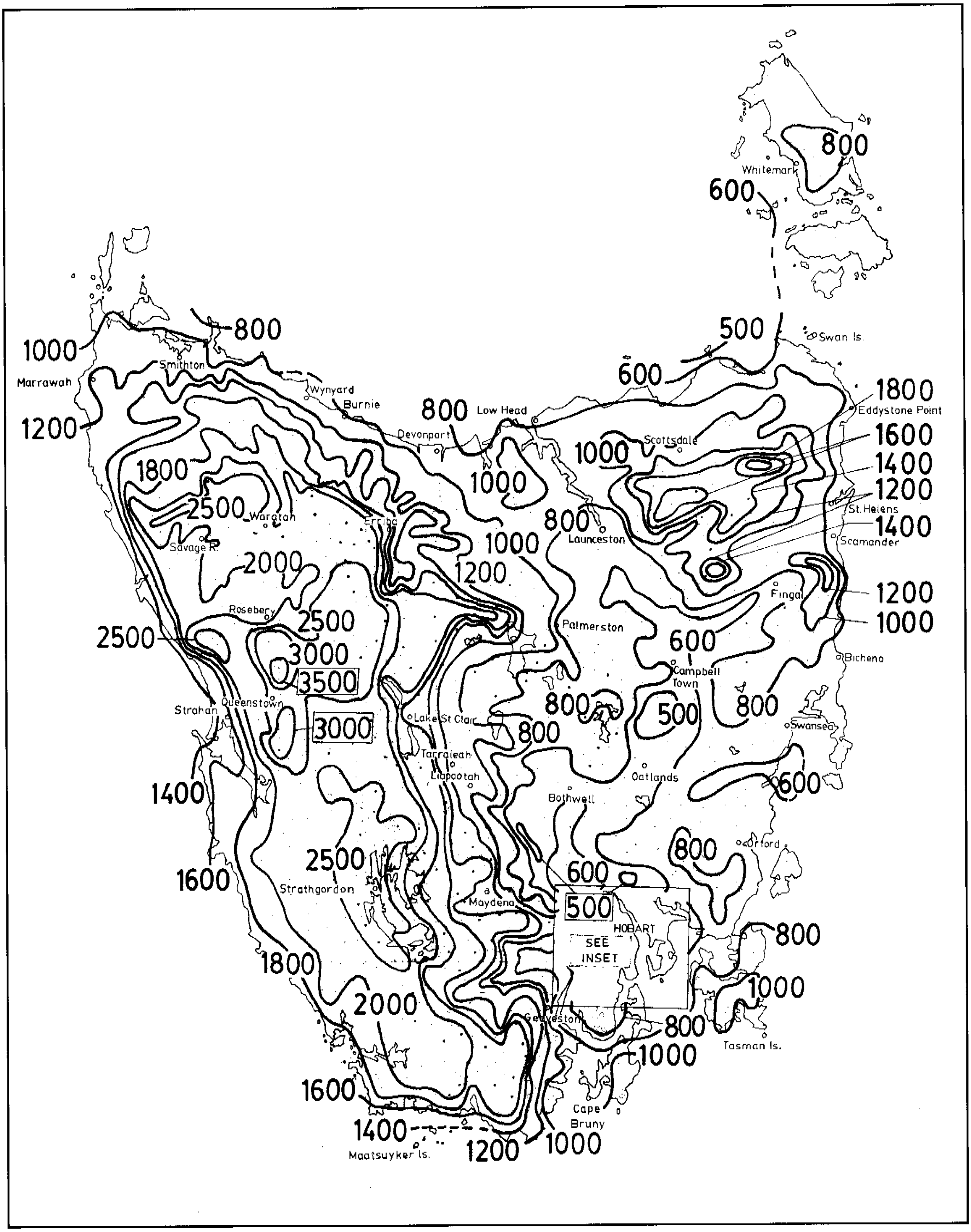


Figure 3 Mean annual rainfall map, Tasmania
(Hobart Bureau of Meteorology)

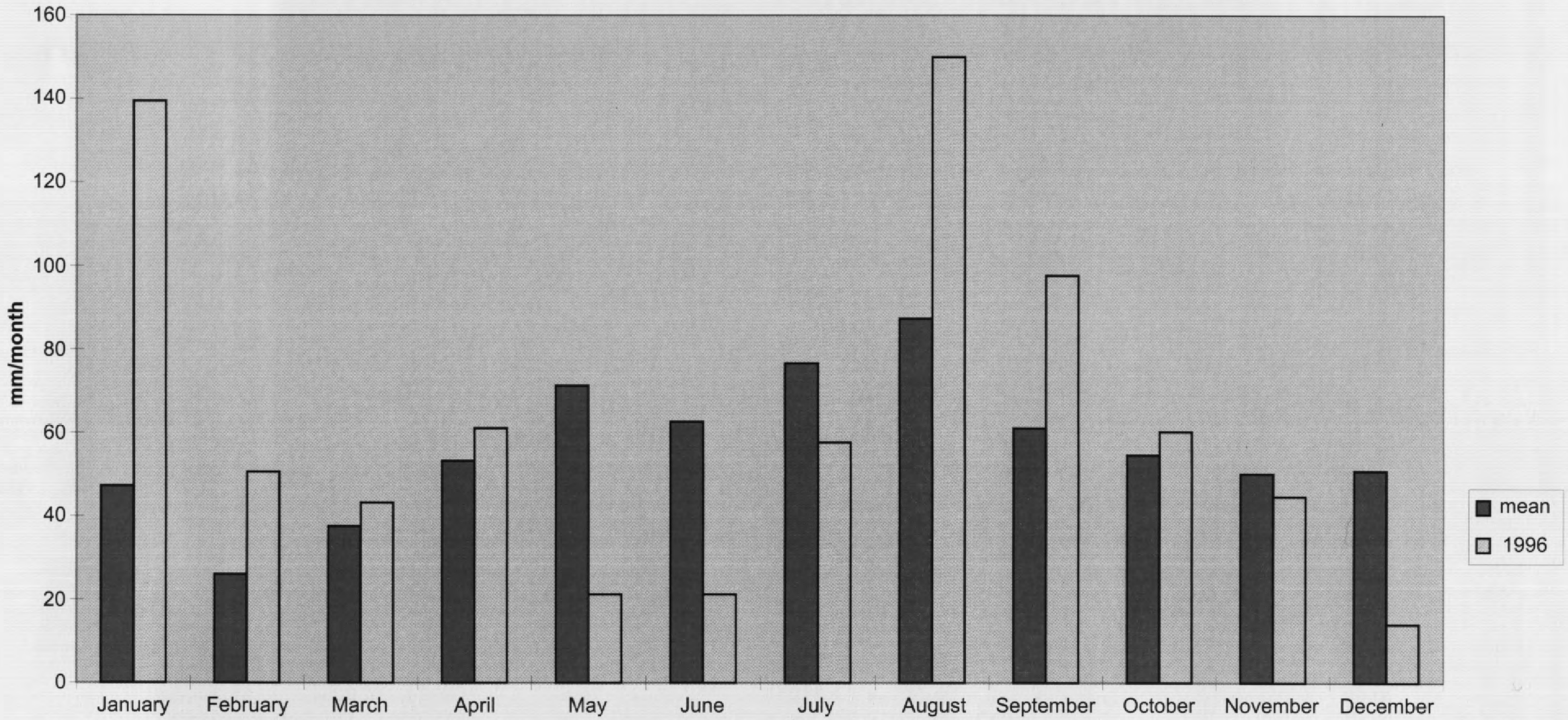


Figure 4 Launceston - 1996 monthly precipitation compared with long term mean

Table 2 Rainfall statistics for Launceston (Ti-Tree Bend)

Month	Mean 1980-present mm	Median 1980-present mm	1996 mm
January	47.2	36.8	139.4
February	26.0	23.6	50.6
March	37.5	34.8	43.2
April	53.2	41.6	61.0
May	71.2	69.9	21.2
June	62.6	58.1	21.2
July	76.6	75.4	57.6
August	87.3	64.0	150.0
September	61.0	66.8	97.6
October	54.6	55.8	60.2
November	50.1	50.4	44.6
December	50.8	51.2	14.0
Total	***678.2***	***697.4***	***760.6***

(Bureau of Meteorology, 1997)

2.4 Tributaries

The two main tributaries of the Tamar Estuary are the North Esk River and the South Esk River (fed by the Meander and Macquarie Rivers). The South Esk River is the longest river in Tasmania (214 km) and is the main source of freshwater flows and sediments to the Tamar. Mean annual flows from the South Esk Basin are approximately 70 cubic metres per second (cumecs). Flow gauging of the North Esk at Ballroom has indicated mean annual flows of 5.6 cumecs (HEC, 1995), though mean flows from the entire North Esk catchment probably approach 10 cumecs.

The flow characteristics of the South Esk (and Macquarie) River are greatly influenced by the operations of the Trevallyn/Poatina Power Scheme, which generates hydro-electric power in the Tamar catchment. The flow of the South Esk River is intercepted by the Trevallyn Dam, located approximately 5 km upstream from the Tamar. Some bed load which enters the Trevallyn Dam is trapped; however, as it is a relatively small capacity reservoir, there is no significant effect on flows or suspended sediments introduced into the estuary during floods. The dam regulates flows through the Cataract Gorge by diverting water to the Trevallyn Hydro Power Station, and in dry conditions, the majority of flows from the South Esk system enter the Tamar at Ti-Tree Bend (through the power station tail race), rather than via the Cataract Gorge. Operation of the Poatina Power Station also has a significant influence on flows in the Macquarie River, and ultimately, the South Esk. Water is diverted from Great Lake in the Derwent catchment to the South Esk catchment, which has significantly increased flows.

2.5 Estuarine circulation, tides and currents

Information on the circulation of the Tamar Estuary is limited and somewhat contradictory. Most sources describe the estuary as partially to well mixed and possibly having salt wedge characteristics in the upper reaches. Strong tidal currents are also suggestive of a partially or well mixed system.

The estuary is tidal to the First Basin on the South Esk and to St. Leonards on the North Esk. Tides are predominantly semi-diurnal (two tides per day of approximately equal magnitude), being influenced by the strong semi-diurnal nature of the tides within Bass Strait (Foster *et al.*, 1986). Tides in the Tamar Estuary are amplified in the upper reaches, with the mean tidal range gradually increasing from 2.34 metres at George Town to 3.25 metres at Launceston (Comalco, 1994; Foster *et al.*., 1986).

Apart from the South Esk and North Esk Rivers, other natural freshwater inputs to the Tamar are minor, and include ground water and a number of rivers and creeks with small catchments (Supply River, Stony Creek, Lady Nelson Creek, Barnards Creek and Egg Island Creek). In places where permanent creek discharges occur, a localised upper layer of fresh water may be created.

2.6 Temperature, salinity and pH

The estuary consists of essentially seawater at the Heads, gradually becoming less saline with distance upstream. Under normal conditions the water at Home Reach is brackish; however, during high river flows, it may be entirely fresh. Salinity has not been regularly monitored in the Tamar Estuary; however chlorinity (measured in surface water as part of the Tamar Estuary Monitoring Program) shows, as expected, a gradual increase with distance downstream (Figure 5).

The temperature in the Tamar Estuary varies according to season, ranging from around 10°C in winter to around 20°C in summer (Foster et al., 1986). The pH in Tamar Estuary water is around 6 to 7 in the upper estuary, and around 8 in the region below the Batman Bridge (Department of Environment, 1971-1988; Launceston City Council, 1988-1996).

2.7 Sediments

The limited data available on sediments in the Tamar Estuary suggest that sediment type and distribution do not appear to conform to those of a typical estuary. While marine sands are present in the lower reaches of the Tamar, the upper estuary is completely lacking in coarse, fluvial sands.

The estuary bed appears to consist mainly of rock, shingle and sand from the Heads to George Town. The sands near the mouth of the estuary are essentially marine and are typically low in organic matter. The sandy material extends up the estuary to Whirlpool Reach and although no mineralogical analysis is available, these sands are assumed to be marine in origin. Above Whirlpool Reach, the sediments are mostly fine mud and are high in organic material, particularly in Home Reach and the lower North Esk River (Foster et al., 1986).

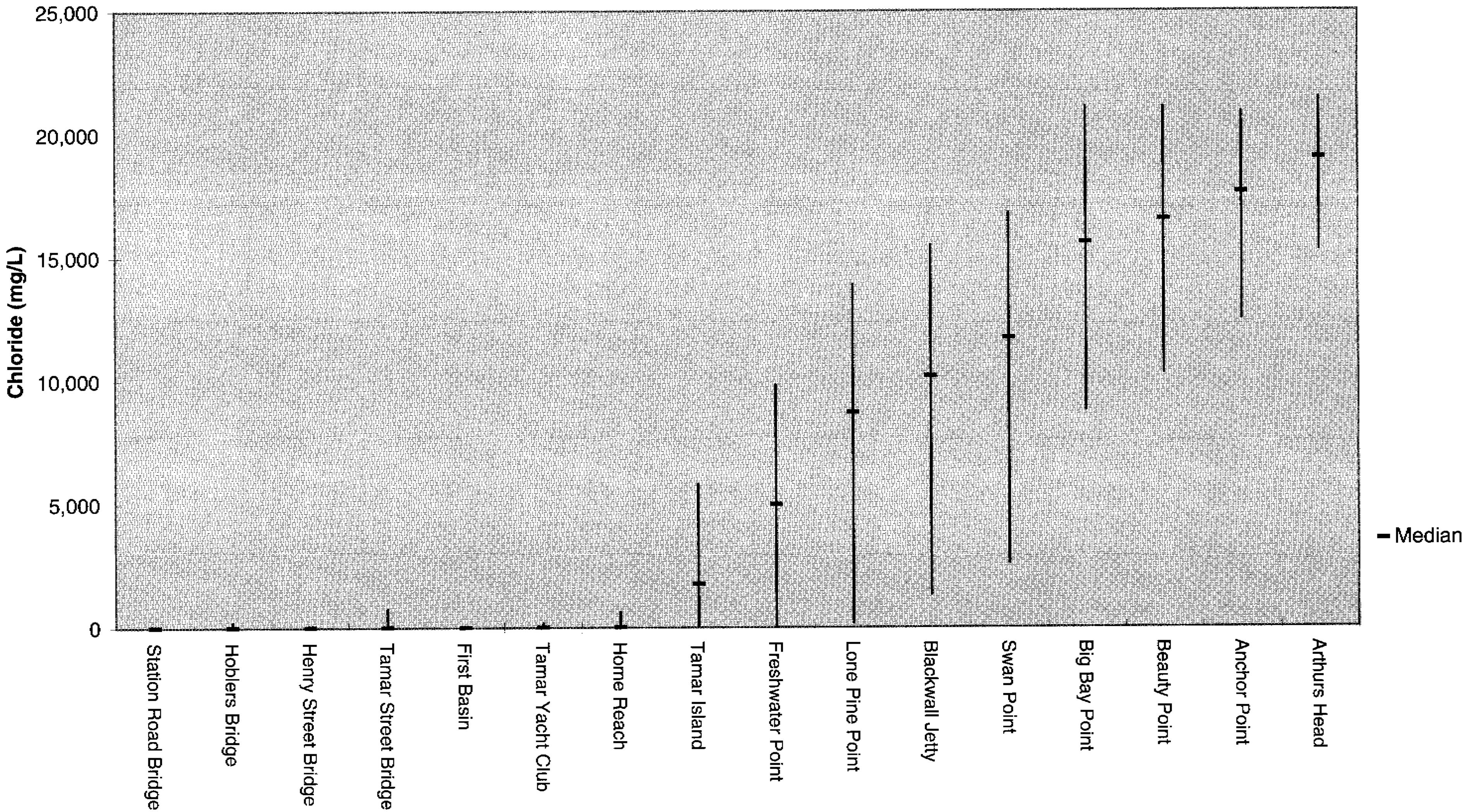


Figure 5 Chloride - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

2.8 Aquatic vegetation

Very little published data on phytoplankton or macroalgae is available for the Tamar Estuary, other than several samples collected in Big Bay and the nearby main channel in 1980 (Ritz et al., 1980).

Seagrass beds of *Zostera muelleri* are known to exist in the lower reaches of the Tamar Estuary and are thought to be quite extensive. This aquatic angiosperm grows on mudflats in the intertidal zone, and represents a rich habitat for animal communities.

Tidal mudflats surrounding Tamar Island and Lucks Flats in the upper estuary are characterised by a reed and rushes community dominated by the species *Phragmites australis, Juncus krausii* and *Schoenoplectus pungens*. Below Tamar Island, the intertidal zone has been colonised by the rice grass *Spartina anglica*, which was introduced into the estuary at Windermere in 1947. The presence of *Spartina anglica* in the Tamar Estuary is now an issue of some controversy as it has spread to cover large areas of tidal marshes from Tamar Island to Kayena. See Section 2.10 for further discussion.

2.9 Macroinvertebrates, fish, birds and other fauna

An investigation into intertidal macro-invertebrate species in the Tamar Estuary by Smith (1995) revealed the presence of 28 different species (Table 3). The distribution of species depends on their tolerance to salinity. In the region between George Town and Low Head, the intertidal fauna is large and varied, typical of fauna in comparable habitats all along the open Bass Strait coast. Open coast species progressively drop out, and in the upper estuary, the intertidal invertebrates form a true estuarine community.

Table 3 Intertidal invertebrate species in the Tamar Estuary

Family	Genus	No. of Species
Mollusca	Gastropoda	15
	Bivalvia	3
	Polyplacophora	1
Arthropoda	Crustacea	7
Echinodermata	Asteroidea	1
Annelida	Polychaeta	1

(Smith, 1995)

Polychaetes constitute the largest group inhabiting the silty sands of the Tamar Estuary, as is common with such sediments. Molluscs are also common benthic organisms. The introduced Pacific oyster (*Crassostrea gigas)* dominates the intertidal areas throughout much of the lower and middle estuary. Other common species inhabiting the littoral zone include the crab *Helograpsus haswellianis*, the gastropod *Bembicium auratum* and the barnacle *Elminius modestus*. In rocky intertidal areas and in rock pools, the chiton *Sypharochiton septentriones* and the limpet *Patella victoriana* are widespread; the starfish *Patiriella exigua* is also common in rock pools (APPM, 1992). Another introduced species, the small bag mussel (*Musculista senhousia*) has been identified in the intertidal zone. This species forms dense mats often completely covering the substrate, and although its numbers are relatively low at present, it is a potential problem species (Smith, 1995).

110 fin-fish species have been documented in the Tamar Estuary (Tasmania Parks, Wildlife and Heritage, 1991). The distribution of fish species depends on their tolerance to salinity changes and available habitat. The most common species of fin-fish known to live in the Tamar Estuary include mullet (*Aldrichetta forsteri*), pufferfish (*Sphareroides hamiltoni*), garfish (*Hemiramphus melanochir*), flounder and cod (APPM, 1992). The Tamar Estuary and its environs also provide habitat, breeding and feeding grounds for a range of water fowl and other bird life (Table 4).

Table 4 Birds observed near Tamar Island, upper Tamar Estuary

Species Habit	No. of Species
Water birds	12
Shore birds	9
Land birds	15
Bush birds	5
Coastal birds of prey	1
Coastal sea birds	1
Vagrant species	21

(Tasmania Parks, Wildlife and Heritage, 1991).

A colony of fairy penguins, comprising several thousand birds, exists at Low Head in the lower estuary. The colony is scattered over the Head, from the Pilot Station in the estuary itself around to East Beach on the coast.

Large aquatic mammals also visit the lower reaches of the Tamar Estuary. Occasional Australian sea-lions and seal have been observed at the mouth of the estuary and cetaceans (dolphins, Humpback whales and Southern Right whales) regularly enter the lower reaches.

2.10 Introduced species

A number of introduced species have been identified in the Tamar Estuary, some of which have or may potentially have serious impacts on the ecology of the estuary; others may affect human health and public amenity as well. Some of these are listed in Table 5 below:

Table 5 Introduced species in the Tamar Estuary

Common Name	*Species Name*	Where Found
Pacific oyster	*Crassostrea gigas*	intertidal shorelines
Small bag mussel	*Musculista senhousia*	intertidal shorelines
Rice grass	*Spartina anglica*	intertidal shorelines

Rice grass

Rice grass *(Spartina anglica)* is a vigorous saltmarsh plant which typically inhabits the upper intertidal zone of temperate estuaries. Its dense growth and root network act as a trap for sediment, significantly altering the natural rate, magnitude and location of sediment deposition and erosion. These processes eventually elevate shorelines and river banks, creating rice grass terraces and marsh islands, which have significant impacts on estuarine hydrodynamics, ecology and amenities. Impacts on biodiversity and integrity of native wetland communities, migratory birds and fisheries are of particular concern. Furthermore, rice grass adversely affects recreational amenities. (Hedge, 1997)

Rice grass was introduced to the Tamar in 1947 with the goal of stabilising mudflats, reclaiming intertidal lands and improving navigation. The plant spread rapidly throughout the estuary, and now represents Tasmania's (and Australia's) largest infestation, covering 415 ha out of a total 590 ha, statewide. The intertidal area between East Arm and Tamar Island is most severely affected, particularly at Pedders Point (see Figures 6 and 7). Rice grass is thought to have achieved some of its original objectives - increasing sedimentation on tidal flats thereby deepening/narrowing navigation channels - however, this has been at considerable ecological cost and loss of amenities. Dense stands of rice grass may inhibit public access to the shoreline, and many private boat ramps/jetties have been rendered non-functional. In some areas (e.g. Gravelly Beach) sandy beaches have been transformed into muddy rice grass meadows. (Hedge, 1997)

As part of a statewide strategy to manage rice grass, the Tasmanian Rice Grass Advisory Group has recommended that efforts be made to contain rice grass in the Tamar to the area above East Arm. The most effective treatment appears to be the herbicide Fusilade. (Hedge, 1997)

Pacific oyster

The Pacific oyster (*Crassostrea gigas)* was first introduced in Tasmania at Port Sorell with the intention of establishing a fishery. This species is thought to have spread to the Tamar, as planktonic larvae, and may have completely displaced the native mud oyster, *Ostrea angas* in the Tamar system (Smith, 1995). The Pacific oyster is extremely prolific. Mature females release millions of eggs each during the spawning season, and the fertilised larvae may be carried long distances by currents before settling as spat along shorelines. Pacific oysters are known to outcompete many species of native shellfish and form dense populations along many Tamar shorelines. In addition to their ecological impacts, Pacific oysters may have serious effects on shoreline access and amenity. Their sharp brittle shells are a hazard to walkers and swimmers, and also damage boat bottoms (E. Turner, pers. comm.).

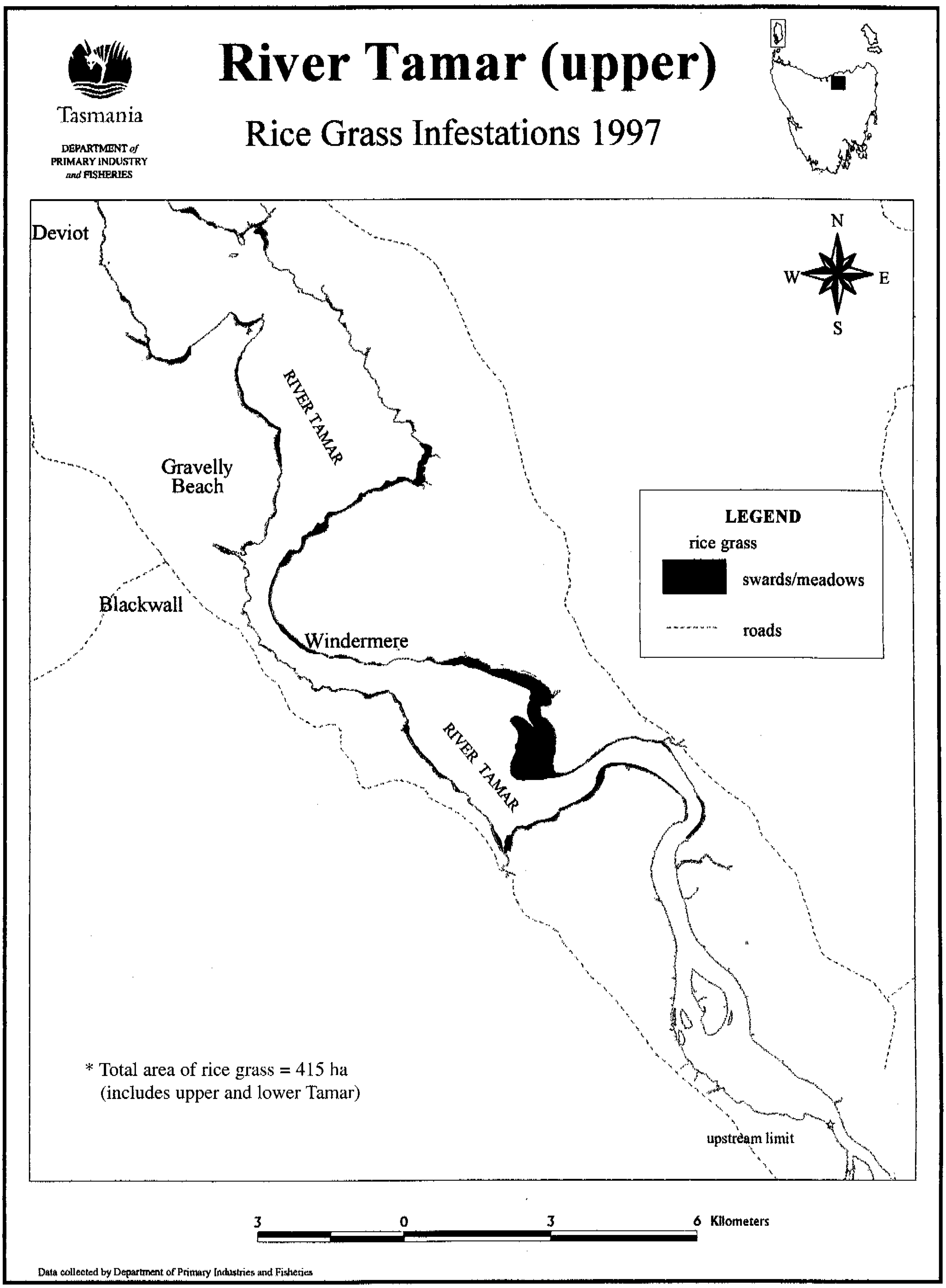


Figure 6 Rice grass distribution in the upper Tamar Estuary (Rice Grass Advisory Group, DPIF, 1997)

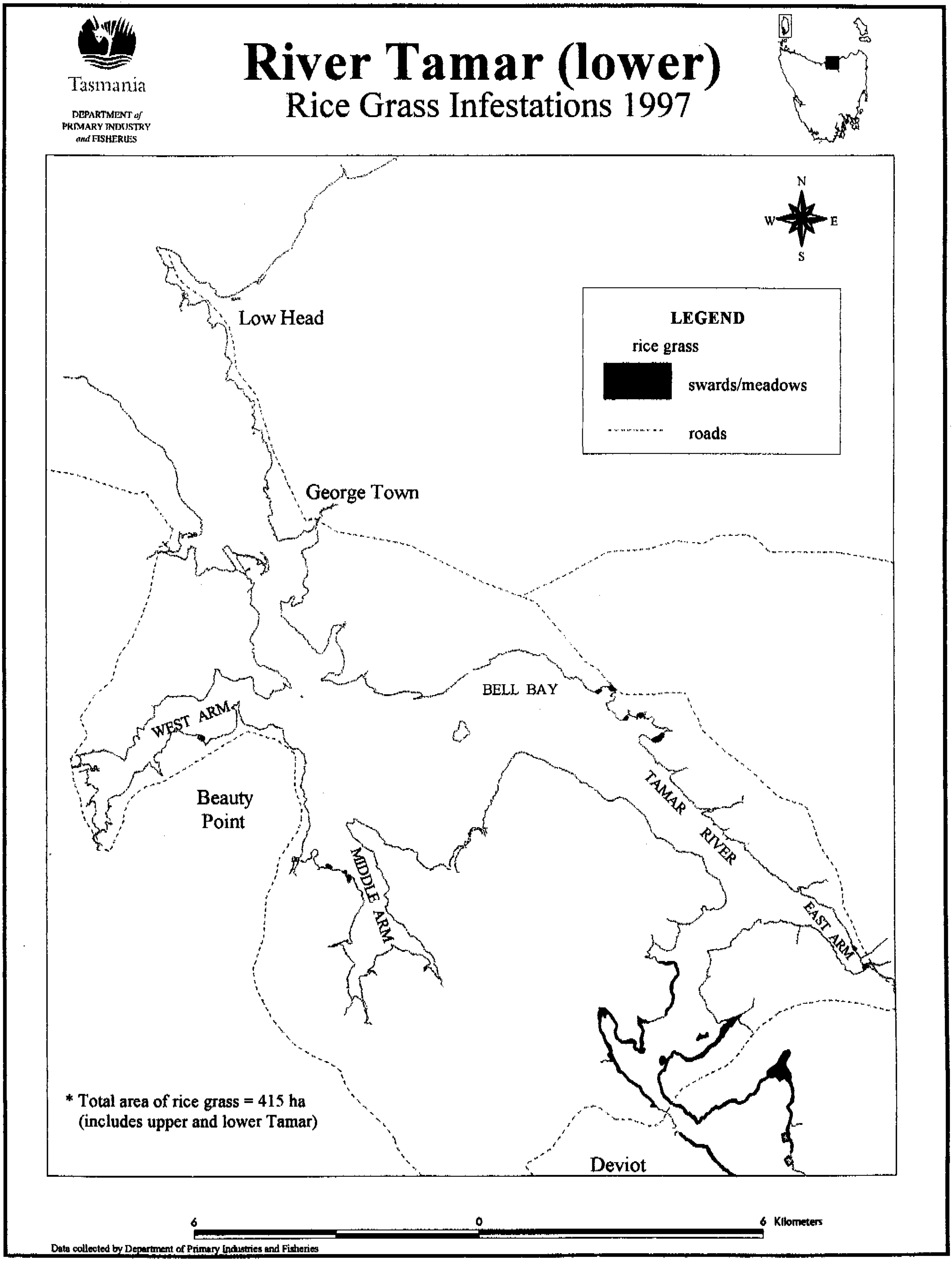


Figure 7 Rice grass distribution in the lower Tamar Estuary (Rice Grass Advisory Group, DPIF, 1997)

3 Uses of the Tamar Estuary

A summary map indicating the major uses of the Tamar Estuary is provided as Figure 8.

3.1 Population centre

The first settlement on the River Tamar was at York Town in 1804 (now known as West Arm), which was established by Lieutenant Colonel W. Patterson. A better water supply and more productive agricultural land upstream encouraged a gradual shift of the population southwards. By 1825, Launceston had become the centre of administrative and commercial activities in northern Tasmania and remains the largest city in the north of the State.

The Tamar Estuary supports the second largest concentration of people in Tasmania, with a total population of 92,260 living in the three separate council areas which border on the estuary (Figure 9, Table 6). The population is scattered down both sides of the estuary; but is concentrated at the southern end, in the metropolitan area of Launceston and extending down the western side of the river into the West Tamar Municipality. Another small concentration is also at George Town near the mouth of the estuary.

Table 6 Local government areas bordering on the Tamar Estuary

Local Government Area	1994 Population	Proportion of State (%)
George Town	7,111	1.5
Launceston	65,832	13.9
West Tamar	19,317	4.1
Total	**92,260**	**19.5**

(ABS, 1996)

With a population of this size, the Tamar Valley region has become a focus for institutions such as the University of Tasmania (Launceston Branch), Australian Maritime College (Launceston and Beauty Point) and the Australian National Underwater Training Centre (Beauty Point).

3.2 Recreation

The Tamar Estuary is widely used for recreation. Swimming in the upper reaches of the Tamar Estuary is mostly restricted to the First Basin in the South Esk River and St. Leonards in the North Esk River, although swimming at St. Leonards has been less common in recent years due to concerns over water quality. Swimming and various other activities such as diving, water-skiing, small boat sailing and windsurfing are also popular at beaches near the estuary mouth and at recreational sites in the middle estuary such as Hillwood, Paper Beach and Gravelly Beach. Recreation in the upper reaches near Launceston is generally restricted to secondary contact activities. Small boat sailing occurs at Rosevears and Home Reach and canoeing and rafting are popular in Cataract Gorge. Rowing and tourist cruises are common in the upper estuary, and large boating is popular throughout the Tamar. Recreational fishing is widespread in the middle and lower reaches, downstream from Tamar Island.

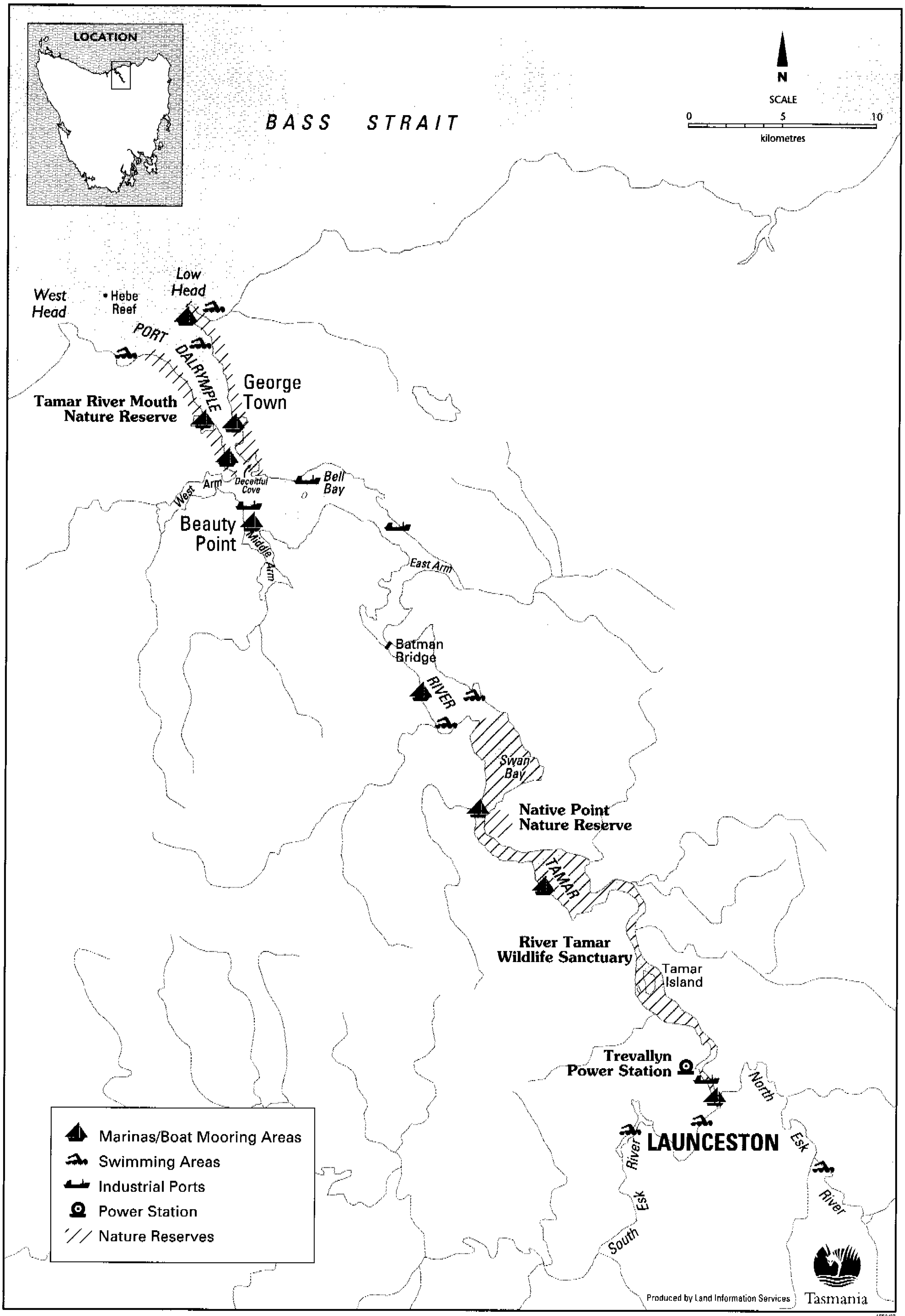


Figure 8 Uses of the Tamar Estuary

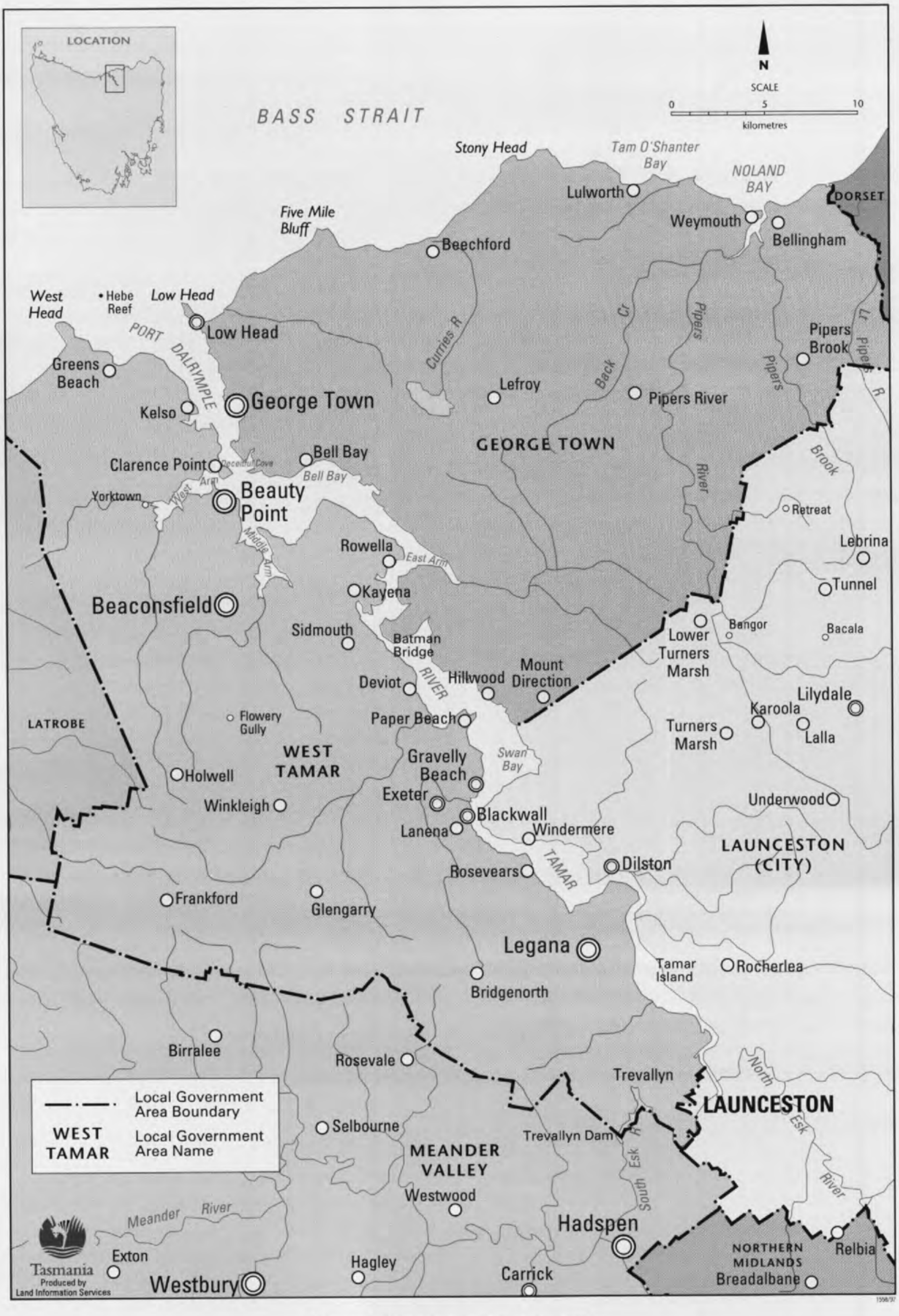


Figure 9 Local government areas

Foreshore recreation at Launceston occurs in areas such as Kings and Royal Parks. Several sporting venues and facilities are situated around this area. Use of the foreshore for picnicking and barbecuing is common in the lower reaches of the estuary at sites such as Batman Bridge, Hillwood, Paper Beach, Greens Beach, Gravelly Beach and Low Head.

Aesthetics are an important feature of any water body; however these values are diminished by the intermittent occurrence of litter and other visual pollution on the river banks and floating in the water near Kings and Royal Parks and by the odour and visual degradation resulting from exposed mud banks, particularly in the upper reaches.

Some regions of the River Tamar have significant tourism value. The Penny Royal and Ritchies Mill sites, situated near Launceston's foreshore are favoured by tourists, as is Cataract Gorge - one of the most visited tourist destinations in northern Tasmania. Several board-walks have recently been constructed in areas around the foreshore of the upper estuary and plans are currently underway to add to the board-walk system and to upgrade facilities at other sites throughout the estuary.

Several annual Tamar-based boating events occur on the estuary. These include the Three Peaks Race, the Bass Strait Challenge, the Top of the Tamar, the Launceston Regatta and the Henley Regatta. As well as attracting national and international competitors, these events promote the Tamar as a central focus for local sporting clubs and the general community.

Heritage values of the Tamar region are focused mainly on natural and European heritage. Investigations of areas immediately surrounding the Tamar Estuary have failed to find evidence of aboriginal inhabitancy, in contrast to the Derwent Estuary in the south of Tasmania. The density of scrub around the foreshores of the Tamar may have meant that food and other necessities were more accessible and more abundant in other areas, such as the Five Mile Bluff, which was inhabited by aborigines.

3.3 Fishing and aquaculture

A limited aquaculture industry operated in the Tamar Estuary for a short period in the 1960s, the legacy of which resides in two disused oyster leases at Deviot. Since the closure of these sites, there have been no other commercial fishing or aquaculture activities in the Tamar. However, the estuary does provide a breeding ground and nursery for many commercially fished species, particularly in the extensive seagrass beds in the lower reaches, which are important sources of food and shelter for juvenile fish. In addition, oyster spat is collected in the intertidal zone at a number of locations, including East Arm and Supply River. Spat collection is sporadic and depends on seasonal conditions. As previously mentioned, the middle and lower estuary is popular for recreational fishing.

3.4 Marine transport

With Launceston as the centre of commerce and industry in the north of Tasmania, the Tamar Estuary serves an important function in the conveyance of goods and services to the city, although the recent downgrading of Launceston port facilities has diminished the function of the upper and middle Tamar as a marine transport route. Bell Bay now serves as the main port in the north east of Tasmania and with major industries located at Bell Bay and Long Reach, large shipping is still frequent in the lower estuary. Approximately 1.2 million tonnes of cargo is imported into the State via the Tamar Estuary annually, and approximately 2.5

million tonnes is exported. The main exports include forest products, ferro-alloys, aluminium ingots and general cargo in shipping containers (Captain Black, PLA, Pers. Comm.). See Table 7 for details on imports and exports.

No cruise ships visit the Tamar at present, and on average, only one naval vessel uses the port per year. Boats using the middle and upper reaches of the estuary are now primarily pleasure craft such as tourist vessels and yachts. A major marina, owned by the Tamar Yacht Club, operates at Beauty Point and another has been proposed at Gravelly Beach. Recreational vessels are also moored up and down the length of the estuary as indicated in Figure 8, for example, at York Cove at George Town, Home Reach near the Tamar Yacht Club, Rosevears, Blackwall to Gravelly Beach, Supply Bay to Deviot, Kelso, West Bay, Pilots Bay at Low Head and Bryants Bay.

Table 7 Ten largest imports and exports to/from Tamar (1995/96)

Export	Mass Tonnes	Import	Mass Tonnes
Woodchips	1,818,163	Manganese ore	386,886
Fe & Si manganese	251,410	Alumina - bulk	185,175
Aluminium	82,392	Coke-bulk-TEMCO	99,988
General cargo	69,720	General cargo	94,642
Pine logs	45,874	Petroleum-petrol	77,386
Timber	35,946	Petroleum-coke-Comalco	50,485
Vegetables	25,502	Coal-bulk-TEMCO	49,729
Newsprint	24,996	Petroleum-oils, distillates	42,728
Manganese ore	22,230	Wheat	29277
Scrap metal	17,236	Empty returns	19,680

(PLA Annual Report, 1996)

3.5 Industrial and sewage discharges

The Tamar Estuary and its tributaries have received inputs of land based pollutants for over a century. These have included urban and agricultural run-off, sewage and industrial discharges (particularly from metal processing, wood processing, abattoirs) as well as drainage from mine sites. The addition of these contaminants to the river system has resulted in localised environmental degradation, particularly in the upper reaches of the estuary, and near industrial outfalls (e.g. Deceitful Cove). In 1995, a 300 tonne oil spill, occurred in southern Bass Strait, resulting in some contamination of the estuary's lower reaches.

3.6 Nature reserves

There are several nature reserves situated along the Tamar Estuary, as indicated in Figure 8. The Tamar River Wildlife Sanctuary, which extends from Tamar Island to the Batman Bridge, is an important wetland habitat and refuge for water fowl and other animals. The Tamar River Mouth Reserve contains a variety of saltmarsh to coastal vegetation habitats and provides a sanctuary for water fowl. Other important reserves include the Four Mile Creek Wildlife Sanctuary and the Native Point Nature Reserve.

4 Inputs to the Tamar Estuary

Inputs to the Tamar Estuary include urban and agricultural run-off, sewage and industrial discharges and drainage from mine sites. These inputs can be broadly categorised as point-sources and non-point (or diffuse) sources.

Point source discharges to the Tamar Estuary are identified in Figure 10 and include ten sewage treatment plants (mostly located in the upper estuary) and several industrial sources in the lower estuary; specifically, two woodchip mills at Long Reach (North Forest Products and Boral Timber) and two metal processing industries at Bell Bay (Tasmanian Electro Metallurgical Company (TEMCO) and Comalco Aluminium (Bell Bay) Limited). Since 1993, TEMCO has treated and discharged the majority of its wastewater to the George Town wastewater treatment plant (WWTP).

Other industries which have historically introduced various forms of pollution into the upper Tamar Estuary include two major tin smelters, several foundries and plating shops, railway yards, ship yards, docks, tanneries, textile industries and fellmongers. These industries were mostly located in the Launceston area. Until recently, abattoir wastes also contributed organic, nutrient and bacteriological loadings to the Home Reach area and the lower North Esk River. Most of these industries no longer exist, and those which do, are now discharging to the Hoblers Bend WWTP. However, a legacy of pollution from these sources may remain in contaminated sediments and ground water.

Inputs from diffuse sources include sediment, organic and nutrient loadings from the North Esk and South Esk Rivers, derived primarily from agricultural run-off from crop lands and pastures, heavy metals leaching from several closed mines in the South Esk River catchment, and urban run-off, particularly from the city of Launceston. The Launceston sewerage system is thought to be a major contributor of pollution during wet weather due to sewage-stormwater cross-connections (National Environmental Consultancy, 1989). Municipal and industrial refuse disposal sites and large industrial stockpiles may also contribute contaminants to the Tamar. Other diffuse sources include atmospheric fall-out and pollutants leached from contaminated sediments within or adjacent to the estuary.

Inputs to the Tamar system have been summarised in the following chapter as accurately as possible on the basis of existing reports and monitoring data. However, it is not possible to quantify many inputs, particularly from non-point sources. These have been identified as possible sources of contaminants and their potential impacts have been discussed.

4.1 Sewage treatment plants

Sewage treatment plants collect and treat wastewater using a variety of treatment technologies, depending on wastewater volume and character, costs and environmental criteria. Effluent from domestic sewage treatment plants usually contains elevated concentrations of total suspended solids (TSS), biochemical oxygen demand (BOD), nutrients and bacteria. Some treatment plants are designed to treat both domestic and industrial wastes (such as the plants at George Town and Hoblers Bridge), in which case, industrial contaminants may also be present. Sewage-derived contaminants may also leach from poorly performing septic systems in several unsewered communities around the Tamar, or may be discharged directly from recreational vessels which often lack holding tanks.

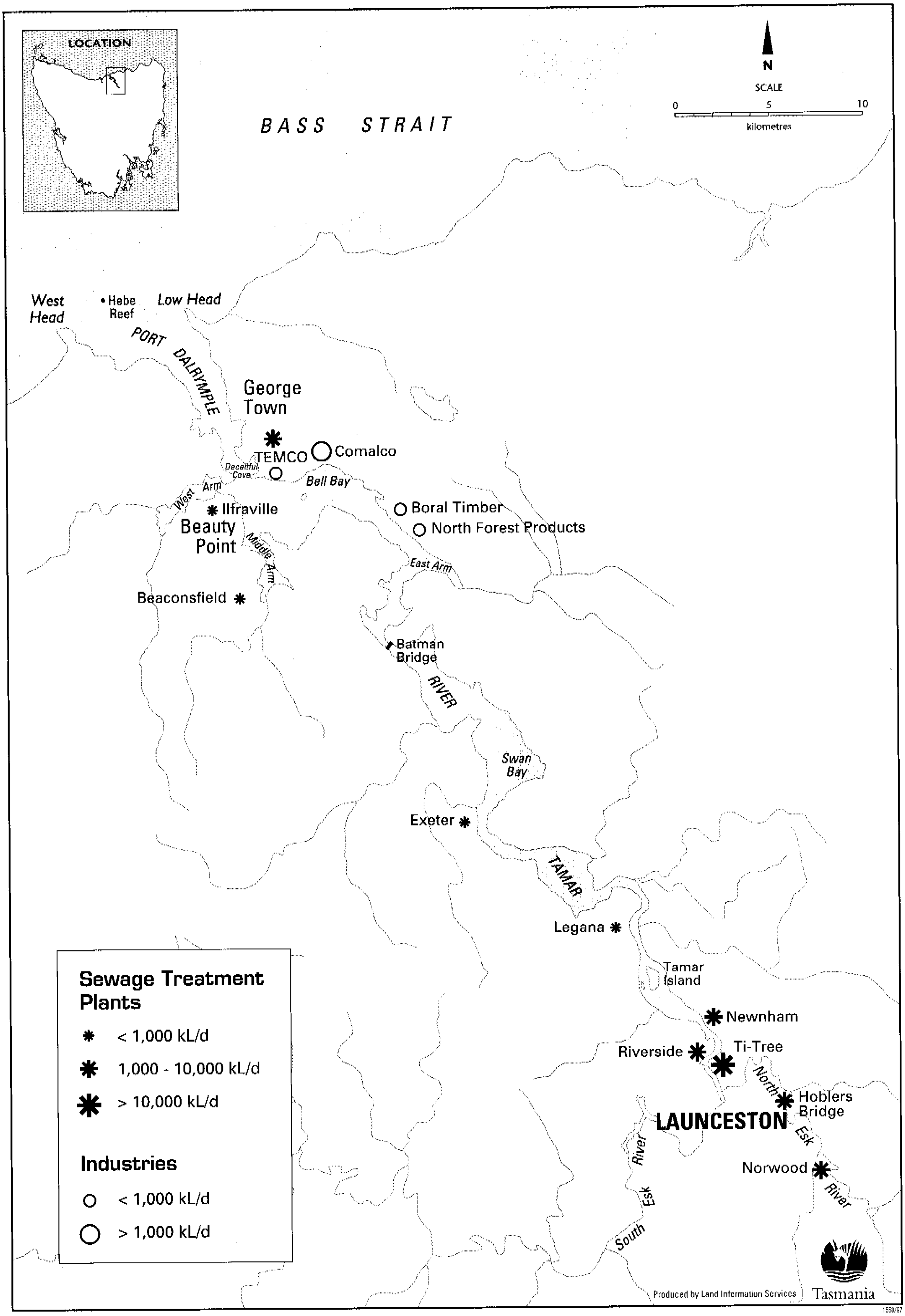


Figure 10 Wastewater discharges to the Tamar Estuary

Sewage treatment plants are not normally designed to treat stormwater. Diversion of stormwater to sewage treatment plants - whether due to infiltration through cracked sewer mains, historical cross-connections of sewer and storm-water pipes or illegal private connections from roofs, etc. - can cause major treatment problems, resulting in the discharge of poorly-treated or untreated sewage to the estuary. Furthermore, it may take some time for operations to return to normal after a major flood event, and effluent quality may continue to be poor during this period. Launceston has a number of historical stormwater connections to the sewer in older parts of the city. Generally, the first flush of stormwater is collected and treated at the Ti-Tree Bend plant. During periods of high run-off, however, overflows of untreated sewage combined with stormwater occasionally enter the estuary. Duplication of the rising main to Ti-Tree Bend would significantly improve the existing system (B. Piesse, Pers. Comm.).

Monitoring requirements

All sewage treatment plants which discharge to the Tamar are required to monitor their effluent on a monthly basis for TSS, BOD and faecal coliform; certain plants also provide data on faecal streptococcus, nutrients and other performance indicators. Maximum permitted levels of contaminants in treated sewage discharged to inland, estuarine and coastal waters are indicated in Table 8.

Table 8 Sewage treatment plant discharge limits under the Environment Protection (Water Pollution) Regulations, 1974

Receiving Waters	BOD_5 (mg/L)	TSS/ NFR (mg/L)	Faecal coliforms orgs/100 ml	Oil & grease (mg/L)	Ammonia (mg/L)	Nitrate+ nitrite (mg/L)	Total phosphorus (mg/L)
Inland waters							
(i)	20	30	200	10	0.5	10	2
(ii)	40	60	200	10	0.5	10	2
Bays and estuaries							
(i)	20	30	1000	10	0.5	10	2
(ii)	40	60	1000	10	0.5	10	2
Coastal waters	N/A	200	N/A	N/A	N/A	N/A	N/A

Notes:

(a) (i) represents where the flow of the receiving waters is <50 times the flow of the emission, and (ii) is where the flow of the receiving waters is > 50 times the flow of the emission;

(b) The oxygen content of the receiving water shall not be reduced below 50% saturation;

(c) The effluent should be visually free of grease and oil;

(d) Where algae are visually detectable in the effluent (i.e. from sewage lagoon systems), there is no limit on the NFR and the BOD level is increased to 40 mg/L.

This data is reported to and reviewed by Environment & Planning and gives an *indication* of typical effluent quality. However, since samples are collected independently of the operation of the plant, this data may not reflect unusual conditions (e.g. high rainfall events, spills, etc.) which may have significant effects on the estuary.

Sewage effluent discharges to the Tamar Estuary

Ten sewage treatment plants discharge effluent directly to the Tamar, or into tributaries in close proximity to the estuary. These are situated at the locations shown on Figure 10. As indicated in Table 9 and Figure 11, average daily flows vary widely from plant to plant, ranging from approximately 110 kL/d at Exeter to 25,000 kL/d at Ti-Tree Bend. The larger treatment plants monitor actual flows; for the smaller lagoon-type systems, flow estimates were provided by the West Tamar Council. The combined total average daily flow from all 10 plants is approximately 40,000 kL - 60% of this is from the Ti-Tree Bend plant, which is the largest in the state.

The type and degree of wastewater treatment varies from plant to plant, as is summarised in Table 10, and consequently effluent quality varies as well (See Figure 12, Table 9). Faecal coliform levels were elevated in effluent discharged by several STPs on a number of occasions in 1996; this may reflect poor plant performance (exacerbated by unusually high rainfall in 1996) or other factors. For example, elevated faecal coliform levels at the Beaconsfield plant, are thought to be related to seagulls and other birds which use the constructed wetlands within the system. A number of improvements have been made to STPs in the past 5 years. For example, the George Town and Hoblers Bridge plants now treat industrial wastes from TEMCO and Killafaddy, respectively. Also, the lagoon systems operated by West Tamar Council have all been recently upgraded and effluent from the Riverside plant is used to irrigate the golf course during summer months. The Ti-Tree Bend plant has also been progressively upgraded between 1971 and 1992 to give full secondary treatment with disinfection.

Annual inputs of TSS, BOD and nutrients (where available) from the 10 sewage treatment plants which discharge to the Tamar were calculated for 1996 on the basis of each plant's average flow rates and effluent concentrations, derived from monthly monitoring records. Results are summarised in Table 9 and are shown graphically in Figure 12. It is interesting to note that although Ti-Tree contributes 60% of total sewage flows, it accounts for only 35% of the TSS load and 28% of the BOD load to the estuary. Total sewage-derived inputs of TSS and BOD are estimated at 345 and 197 t/yr, respectively. Nutrient inputs are more difficult to estimate (data is lacking for Riverside and Newnham Drive plants); total phosphorous inputs were approximately 75 t/yr, while dissolved inorganic nitrogen was approximately 250 t/yr.

Table 9 Tamar sewage treatment plants: average daily flows, mean concentrations and annual inputs - 1996

Name	Licenced Discharge	1996 Discharge	TSS (NFR)		BOD		Ammonia N		Nitrate-Nitrite N		Total Phosphorus		Faecal Coliform *
	kL/day	kL/day	mg N/L	t/yr	mg/L	t/yr	mg N/L	t/yr	mg N/L	t/yr	mg P/L	t/yr	# org./100 ml
Beaconsfield	324	240	59	5.17	19	1.66	2.7	0.24	0.3	0.03	4.0	0.35	481**
Exeter	115	110	33	1.32	29	1.16	6.5	0.26	0.3	0.01	6.2	0.25	108
Beauty Point	540	350	113	14.44	41	5.24	3.7	0.47	0.5	0.06	5.9	0.75	784
Legana	540	340	56	6.95	24	2.98	2.0	0.25	1.1	0.14	4.9	0.61	367
Riverside	2,800	1,480	28	15.13	31	16.75	ns		ns		ns		575
Ti-Tree	25,000	24,864	13	117.98	6	54.45	5.0	45.38	7.4	67.16	3.8	34.49	16
Hoblers Bridge	4,500	4,265	34	52.93	20	31.13	31.6	49.19	0.2	0.31	8.6	13.39	170
Newnham Drive	3,920	2,756	23	23.14	20	20.12	ns		ns		ns		254
Norwood	4,050	3,476	38	48.21	24	30.45	32.7	41.49	0.2	0.25	6.6	8.37	35
George Town	3,600	2,086	33	25.13	10	7.61	0.9	1.18	0.3	0.23	5.0	3.81	275
TOTAL	**45,389**	**39,967**		**310**		**172**		**138**		**68**		**62**	

* geometric mean

** at lagoon outlet; geomean increases to 2911 at wetland outlet

Table 10 Tamar sewage treatment plants: plant type and improvements

Location	Council	Lic. Discharge kL/d	Outfall	Treatment type	Recent/Planned Improvements
Beaconsfield	**West Tamar**	324	Brandy Ck.	5 cell lagoon system plus constructed wetland	upgraded 1992/93
Exeter	**West Tamar**	115	Stony Ck.	5 cell lagoon system	upgraded 1991
Beauty Point	**West Tamar**	540	West Arm	4 cell lagoon system, aerator at inlet	upgraded 1997 (2 lagoons added)
Legana	**West Tamar**	540	Tamar	4 cell lagoon system	upgraded 1995
Riverside	**West Tamar**	2,800	Tamar	M/B secondary with disinfection	upgraded 1990/91
Ti-Tree	**Launceston**	25,000	Tamar	M/B secondary with disinfection	improved disinfection 1992
Hoblers Bridge	**Launceston**	4,500	N. Esk	M/B secondary with disinfection	upgraded 93; Killafady connected in 94
Newnham Drive	**Launceston**	3,920	Tamar	M/B secondary with disinfection	
Norwood	**Launceston**	4,050	S. Esk	extended aeration lagoon (Pasveer)	
George Town	**George Town**	3,600	Tamar	Activated sludge plus 3 lagoons/wetland	TEMCO wastes treated as of 1993

M/B = mechanical/biological

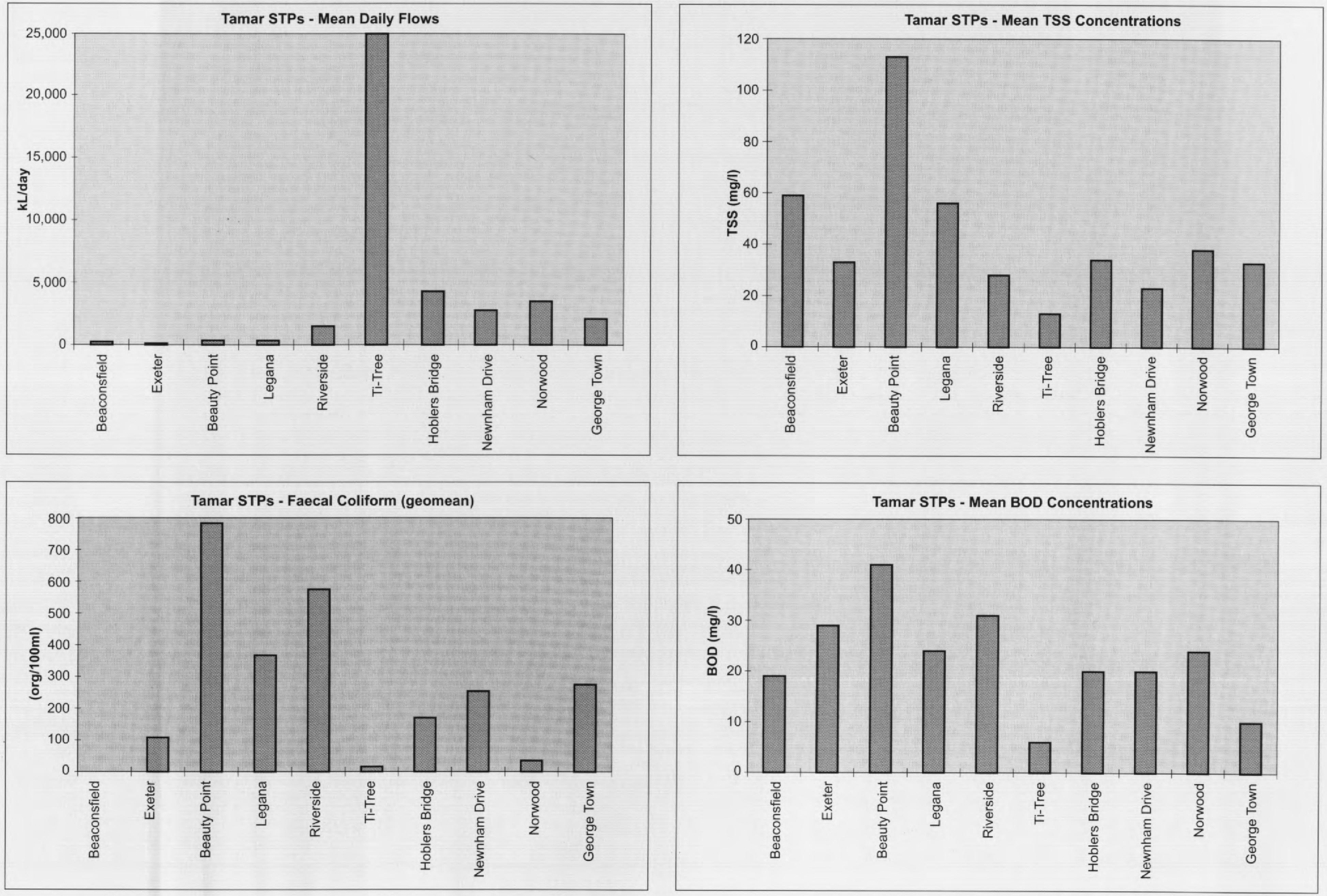


Figure 11 Tamar sewage treatment plants: mean daily flows and concentrations

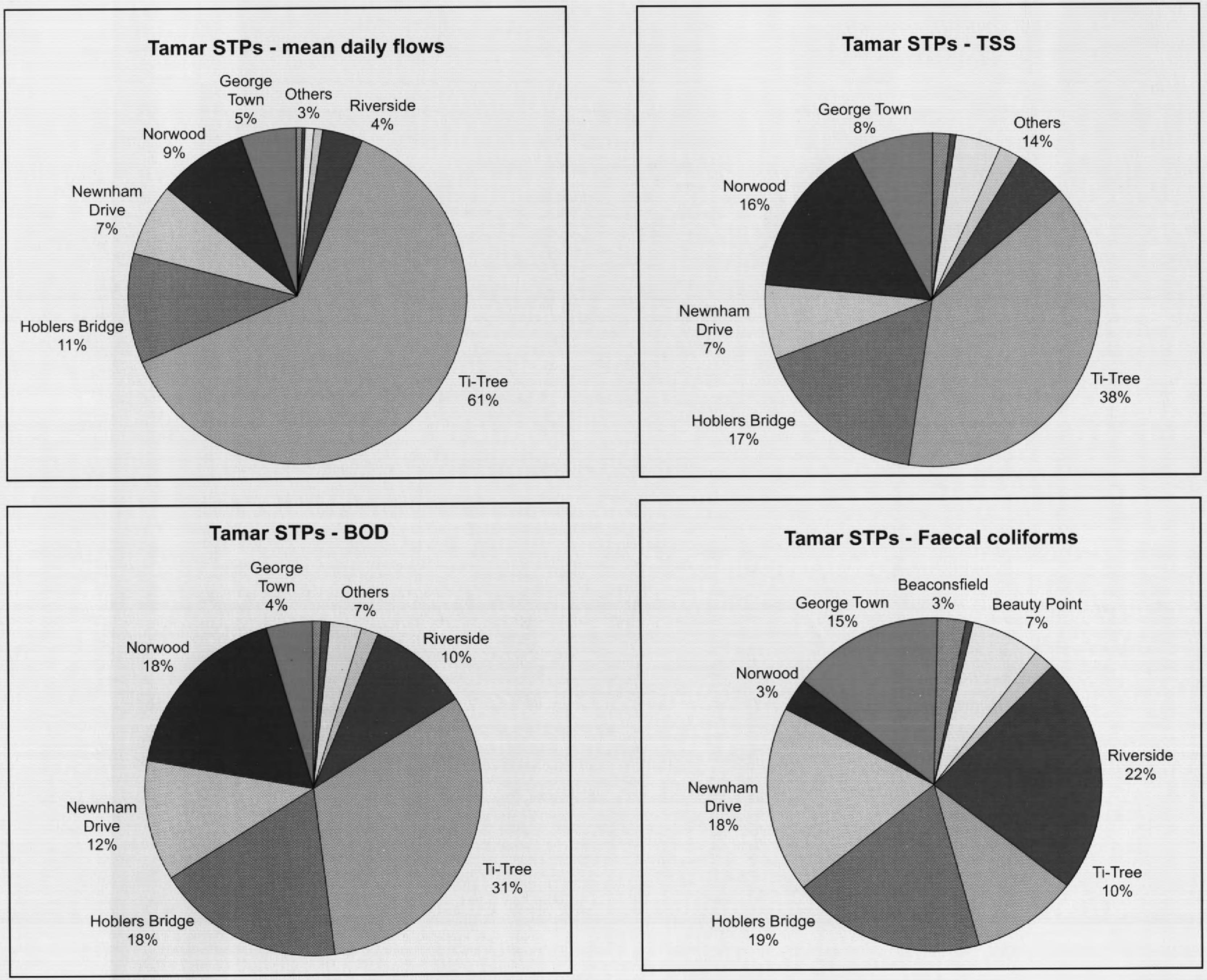


Figure 12 Tamar sewage treatment plants: relative flows and inputs

4.2 Industry

In 1996, several major industries discharged contaminants to the estuary: these include the Comalco aluminium smelter, the TEMCO ferroalloy plant and two large woodchip mills (Boral and North Forest Products). The location of each of these industries is indicated in Figure 10. There have been a number of improvements in the treatment of industrial wastewater in recent years. Since 1993, TEMCO has diverted the majority of its processing wastes to the George Town WWTP, and in July 1994, the Killafaddy abattoir in Launceston began diverting its wastewater to the Hoblers Bridge WWTP. More recently, Comalco encapsulated a large industrial waste stockpile, resulting in significant improvements in effluent quality. All of the above industries operate under licenses from the Department of Environment and Land Management (DELM) and work to targets and objectives outlined in their Environmental Improvement Programs (EIP).

In addition to direct discharges of liquid processing wastes, industrial contaminants may also enter the estuary via other pathways: air emissions, ground water seepage, stormwater run-off and spills. In some cases, mass emission from these indirect and/or infrequent inputs may be greater than average end-of-pipe discharges.

Comalco Aluminium (Bell Bay) Ltd.

Comalco's Bell Bay plant is situated on the eastern shore of the Tamar estuary, approximately 3 km south east of George Town. The plant has been operating since 1955 and has three main process areas: manufacture of carbon products, smelting, and metal alloying and casting. Prior to 1974, the site also operated as an alumina refinery. In 1996, following the negotiation of a new power agreement, Comalco announced a $200 million capital expenditure program which will increase the plant's capacity to 140,000 t/yr and includes significant environmental improvements, including a change to dry scrubbing technology to significantly reduce airborne fluoride emissions.

Features of environmental significance include;

- stacks and other sources of atmospheric emissions;
- stockpiles and landfills, including spent pot liner (SPL) pile;
- sewage treatment lagoon;
- settling/retention pond;
- stormwater detention pond/wetlands.

Emissions

Atmospheric emissions containing particulates, fluoride and sulphur oxides constitute the majority of all emissions from the site. Fluoride has been identified as of particular concern, as at high concentrations, it can damage vegetation and accumulate in animals, weakening bones and teeth. Comalco adheres to the Washington State Standard, which sets limits on ambient fluoride concentrations to protect vegetation and grazing animals. The majority of Comalco's atmospheric emissions are discharged from potroom fume scrubbers. The degree to which atmospheric emissions from the site affect the Tamar estuary is unknown, but is largely influenced by local meteorological conditions, particularly wind direction and precipitation.

Liquid emissions from the site include industrial processing water, some treated sewage effluent and stormwater. These emissions eventually enter the Tamar via four drains (Main Drain, Fringelands Drain, Stormwater Drain and North Drain), however the primary exit point is the main drain. Contaminants in liquid emissions include total suspended solids, fluoride, hydrocarbons, ammonia and cyanide.

Processing water includes cooling waters from the carbon plant and casting shop, treated effluent from the cryolite recovery plant and treated leachate from the recently encapsulated spent potliner (SPL) pile. These effluent streams are pumped to a settling/retention pond before being discharged to the Tamar via the Main Drain. (Note: cryolite recovery will cease with the commissioning of dry scrubbing technology, due for completion in late 1997).

Prior to 1996, stormwater from the industrial site was also directed to the settling pond; this occasionally caused overloads to the settling pond during high rainfall events, resulting in intermittently elevated contaminant concentrations discharged from the Main Drain. In 1996, a wetland system, designed to act as a filter, was constructed on the site of the former SPL pile to reduce loads on the settlement pond. This wetland detains and treats run-off from the site's northern catchment and from the "barkland" area - a former lagoon for red mud wastes from alumina refining, now covered with wood waste and revegetated. Sewage from the plant is treated on-site, and effluent from the sewage lagoon is used for irrigation of the barkland.

A number of existing and former stockpiles/solid waste disposal areas on the site may be associated with surface and/or ground-water contamination. These include the industrial solid waste landfill (6 ha) and the former SPL storage area (8 ha). Groundwater monitoring data indicates that elevated concentrations of fluoride and cyanide are locally present in some of these areas, however, total ground-water emissions/mass loads to the Tamar cannot be ascertained on the basis of existing reports/data.

SPL is the biggest waste disposal issue in the aluminium industry, as it contains fluoride, cyanide and ammonia. Currently there is no known process to treat this waste and Comalco continues to support research into new treatment technologies. Comalco's SPL stockpile contained over 250,000 tons of material accumulated over the life of the smelter, and, until recently, was situated adjacent to the Tamar Valley Escarpment, approximately 200 to 300 m from the estuary. The stockpile was surrounded by a moat to catch and treat leachate, however, it was still identified as the primary source of liquid emission contaminants from the site. In 1995/96 this stockpile was segregated, relocated and encapsulated; residual leachate from the encapsulated stockpiles is collected and treated. The former SPL site has been redeveloped as a wetland to treat/polish stormwater run-off.

Monitoring

Comalco's present monitoring program includes monitoring of processing wastes, treated sewage, stormwater, ground water and air emissions. Land-based ambient monitoring of air, rainwater and vegetation, and ambient monitoring in the Tamar estuary is also carried out. All data is reported to the Department of Environment and Land Management (DELM) under the terms and conditions of the smelter's license and EIP. The main parameters monitored include pH, TSS, oil and grease, F, NH_3, Fe+Mn and cyanide. Atmospheric monitoring includes F, particulates, and SO_2.

Summary of 1996 Emissions

Table 11 summarises mass emissions from Comalco, estimated for 1996 on the basis of 1996 monitoring data, the 1994 Comalco EMP (Environmental Management Plan) and 1996 EIP and other information provided by Comalco.

Table 11 Comalco: summary of 1996 emissions

	Main Drain		**Groundwater**		**Atmosph***
Total Effluent Volume (ML)	1200 ML		?		
	avg. conc. (mg/L)	mass load t/yr	conc. (mg/L)	mass load t/yr	mass load t/yr
TSS/particulates	39	44			1300
Oil and Grease	4.4	5.3			
Metals (Fe+Mn)	1.6	2.0			
Ammonia	1.3	1.5			
Fluoride (soluble)	34	39	<1 - >100	?	
Fluoride (total)	38	44			580
Sulphur compounds					660
CN (total)	1.4	1.8	<1 - >10	?	
CN (WAD)	0.1	<0.1			

* pers. comm., L. Payne, Comalco

Recent and Planned Improvements

- 1994-6 Atmosphere improvement program (new potline hoods, scrubber improvements
- 1995/96 Relocation/encapsulation of SPL stockpile/improvements to SPL management
- 1996/97 Construction of wetlands system for stormwater treatment at SPL site
- late 1997 Dry scrubbers to be installed (reduction of fluoride emissions)

Tasmanian Electro Metallurgical Company (TEMCO)

TEMCO is situated on the eastern shore of the Tamar Estuary, approximately 2 km south east of George Town. The plant has been operating since 1962 and is Australia's only ferroalloy producer, supplying approximately 210,000 tons/yr of manganese alloys to the steel industry. The plant contains 4 electrically heated furnaces which produce ferromanganese and silicomanganese, and one LPG/coke fired sinter plant which produces manganese sinter (mostly consumed as feedstock on site).

Features of environmental significance include;

- TEMCO/George Town wastewater treatment plant (WWTP);
- Stormwater detention pond/wetland system;
- Stacks and other sources of atmospheric emissions;
- Sewage treatment plant ;
- Stockpiles and landfills;
- Fume dams - used to pretreat scrubber effluent.

Emissions

Atmospheric emissions are discharged from 4 furnaces and the sinter plant and are monitored for particulates, sulphur oxides and nitrogen oxides. The sinter plant has been identified as the main source of atmospheric emissions on the site. Mass atmospheric loadings from the sinter plant, estimated on the basis of 1996 monitoring data and average emission rates, suggest that atmospheric sources contribute the majority of mass emissions at the TEMCO site. The degree to which atmospheric emissions from the site affect the Tamar estuary is unknown, but will depend on local meteorological conditions, such as wind direction and precipitation.

Liquid emissions from the site include industrial processing water, stormwater, ground-water discharge/seepage and sewage effluent. Contaminants in liquid emissions from the site include TSS, ammonia, trace metals (particularly barium, iron, manganese, lead, zinc), cyanide, phenols and fluoride. Prior to 1993, all liquid emissions from the site were discharged to the Tamar Estuary at Deceitful Cove. In 1993, the TEMCO/George Town WWTP was commissioned, which now treats all processing wastes from the site, and in 1994, a stormwater treatment system consisting of detention ponds/wetlands was commissioned.

At present, processing water from gas scrubbers (Category 1 Effluent) is pre-treated on site in two large fume dams to remove tars and particulates, before being pumped to the TEMCO/George Town WWTP, along with Category II Effluent (quench and rinse water from alloy/slag operations, blowdown from cooling tower, etc.). Some of the more highly contaminated surface run-off (i.e. first-flush) is also collected and treated at the WWTP. All remaining site run-off, plus the effluent from the package sewage treatment plant (70 kL/day), is diverted to the stormwater detention pond/wetlands treatment system (Category III Effluent), which eventually discharges to the Tamar via the North Drain.

Groundwater quality and discharges to the Tamar are difficult to quantify; contamination may be associated with the numerous stockpiles and liquid/solid waste disposal areas on the site. These include fume dams, stockpiles and industrial landfills (containing manganese fume, silicomanganese slag, tar and solid industrial wastes), which are situated approximately 500 m from the estuary. Groundwater monitoring data indicates that elevated concentrations of thiocyanate and phenols are locally present, however, data is not available to estimate mass loadings to the estuary. Monitoring wells installed adjacent to the Tamar do not indicate significant transport towards the estuary (D. Hassell, TEMCO, pers. comm.).

Monitoring

In 1996, TEMCO's monitoring program included monitoring of Categories I and II effluents, treated sewage, discharges from the stormwater pond/wetlands system, ground water, air emissions and dust fallout. No ambient monitoring in the Tamar estuary is presently being done by TEMCO, however, George Town WWTP conducts ambient monitoring near its outfall. The main parameters monitored include pH, TSS, TDS, NH_3, phenols and free cyanide. Trace metals (Ba, Fe, Mn, Pb, Zn) and other compounds (F, thiocyanate) are monitored at a lesser frequency. Stacks are monitored for particulates, NOx and SOx.

Summary of 1996 Emissions

Table 12 summarises mass emissions from TEMCO, estimated for 1996 on the basis of 1996 monitoring data, TEMCO's 1994 and 1996 EMPs and other information provided by TEMCO.

Table 12 TEMCO: summary of 1996 mass emissions*

	Stormwater North Drain		**Groundwater**		**Atmosph.****
Total Effluent Volume (ML)	92.8 ML		?		4700 m^3/min
	avg. conc. (mg/L)	mass load t/yr	conc. (mg/L)	mass load t/yr	mass load t/yr
TSS/particulates	62	5.75			240
Ammonia (as N)	0.3	0.03			
Zinc	0.06	<0.01			
Manganese	1.8	0.17			
Iron	0.2	0.02			
Fluoride	1.6	0.15			
Phenols	0.004	<0.01	<0.1 - >50	?	
CN (WAD)	0.02	<0.01			
thiocyanate			<0.1 - >200	?	
NOx					850
SO_3					>400

* liquid industrial effluent and some stormwater is treated and discharged via George Town WWTP - not included in this table

** sinter plant only; data provided by D. Hassell, TEMCO.

Recent/Planned Improvements

- 1993 - TEMCO-George Town WWTP commissioned
- 1994 - Stormwater detention pond/wetlands treatment system commissioned

North Forest Products - Tamar Woodchip Mill

The North Forest Products (NFP) Tamar mill is situated on the eastern shore of the Tamar estuary, approximately 10 km south east of George Town. This mill, which commenced operations in 1972, processes both hardwood and softwood pulp logs for export to Japan. During the period 1991 - 1996, annual woodchip production ranged from 0.8 to 1.25 million green tonnes, making it one of the larger woodchip mills in Australia; 1996 production was 825,000 green tonnes. The Company received approval in 1997 to increase production to 1.46 million green tonnes.

Most pulp logs are debarked prior to delivery. A hydraulic debarker is used to debark remaining logs, and all logs are then chipped at the site. Chips are stored in two 50,000 tonne piles located adjacent to Tamar, awaiting transport. Features of environmental significance at the site include:

- settling dam - receives both processing and stormwater run-off;
- chip storage piles;
- former bark disposal area - 3 ha site, presently being revegetated;
- stormwater drain - one minor drain;
- sewage treatment plant - upgraded in 1997.

Both salt and fresh water are used in the production process: saltwater (75%) for debarking and freshwater (25%) for other processing activities. In 1996, total water use at the site was estimated at 359 ML (P. Mineely, NFP, pers. comm.) All process water from the log wash and chipping line is screened to remove gross solids. The finer particulates are settled out in the settling dam and the overflow discharges to the Tamar via subsurface pipe. Most run-off/leachate from chip storage piles, the log yard and other areas of the site (approximately 6 ML per year, according to the 1996 EMP) is also diverted or pumped to the settling pond), bringing the total discharge from the site to 365 ML.

Contaminants in liquid emissions from the site include TSS, BOD, resin acids (when pine is being processed/stored) and faecal coliform. During 1996, water quality monitoring consisted of bimonthly sampling of discharge from the settling dam and monthly monitoring of sewage treatment plant effluent.

Table 13 summarises mass emissions from NFP, calculated for 1996 on the basis of 1996 monitoring data, the 1996 NFP Environmental Management Plan and other information provided by NFP.

Table 13 North Forest Products: summary of 1996 mass emissions*

Total effluent volume	365ML**	
	avg. conc *** (mg/L)	mass load t/yr
TSS	109	39.8
BOD	31	11.3

* settling dam only

** P. Mineely, NFP, pers. comm.

*** 1996 monitoring data

Boral Timber Tasmania Ltd. (Forest Resources)

Boral Timber Tasmania Ltd. is situated on the eastern shore of the Tamar estuary, approximately 10 km south east of George Town. This mill, which commenced operations in 1972, processes eucalyptus logs for export to Japan. The company is currently licensed to produce 1 million tonnes of woodchips/year; 1996 production was 860,000 tonnes.

Pulp logs are debarked prior to delivery and then washed, split and chipped at the site. Chips are stored in a single 150,000 tonne (max) pile located adjacent to Tamar, awaiting transport. Features of environmental significance at the site include:

- series of 3 settling dams - treat and recirculate processing water and stormwater;
- chip storage pile;
- solid waste dump - at separate site >2 km from Tamar. Now closed and revegetated.
- stormwater drain;
- sewage treatment plant and pond;
- olivine burner - burns most wood wastes generated on site.

Liquid emissions from the site include processing water, stormwater run-off and leachate from the chip storage pile. Approximately 50 ML/yr of fresh water (217 kL/day) are used per year. Process water from washing logs and surface water run-off is screened and discharged to a series of three settling dams, prior to discharge to the Tamar Water is recirculated from the second dam for log wash and yard watering. Most run-off/leachate from chip storage piles, the log yard and other areas of the site is also diverted through the settling pond system. Some run-off from roads discharges directly to Williams Creek/Tamar.

Atmospheric emissions from the site include equipment exhaust, airborne fibre and dust and emissions from the olivine burner. This burner is described as a high temperature/smoke free unit. Atmospheric emissions are not monitored.

Contaminants in liquid emissions from the site include TSS, BOD, oil and grease and faecal indicator bacteria. During 1996, water quality monitoring consisted of bimonthly sampling of discharge from the settling dam and monthly monitoring of sewage plant effluent.

Table 14 summarises mass emissions from Boral Timber Tasmania, estimated for 1996 on the basis of 1996 monitoring data and other information provided by Boral.

Table 14 Boral Timber Tasmania Ltd.: summary of 1996 mass emissions*

Total effluent volume	50 ML**	
	avg. conc *** (mg/L)	mass load t/yr
TSS	17	1.3
BOD	4	0.3

* settling dam only

** J. Duncan, Boral, pers. comm.

*** 1996 monitoring data

Total industrial inputs

Estimated industrial inputs to the Tamar from TEMCO, Comalco, Boral and NFP are summarised in Table 15. The Hokushin medium density fibreboard plant (due to commence operations in Sept. 1997) will send wastewater to the George Town WWTP. Several smaller industries also operate in the vicinity of Launceston and the Long Reach/Bell Bay industrial area, such as the Killafaddy Abattoir, Waverley Woolen Mills, N. Edwards Tannery, Southern Aluminium, etc. The majority of these direct their processing wastes to sewer, however, stormwater run-off and spills from some of these sites may eventually enter the Tamar. In most cases, stormwater inputs are not monitored and cannot be readily quantified.

4.3 Urban run-off

Urban run-off represents a significant diffuse source of pollution to urban waterways. Contaminants are washed off roofs, streets, parks, gardens, etc., eventually entering the river system. Typically, urban stormwater contains high concentrations of suspended material, nutrients, organic matter and bacteria, plus significant quantities of litter. In addition, urban run-off often contains high concentrations of metals from exhaust emissions (lead), tyre wear (zinc), and brake linings (copper). Concentrations of arsenic, cadmium, mercury, nickel and chromium are generally low; however they may occur in significant concentrations in urban run-off from areas with a history of heavy industry. Levels of suspended solids, metals and other contaminants frequently exceed water quality criteria designed to protect aquatic life and may cause urban run-off to be an unacceptable discharge to natural waters in many cases.

The upper Tamar Estuary is subject to potential contamination by urban run-off, particularly in the more urban/industrial areas in and around Launceston. A survey of Launceston's stormwater run-off was initiated several years ago, but has not yet been completed. In the absence of more site-specific data, a very rough estimate of urban runoff inputs to the Tamar is presented here. These values are based on an estimated total urban area of 35 km^2 and the typical pollutant loading values presented in Table 16 for high-density residential land use. The results - presented in Table 17 - obviously require further refinement, but may be useful as a "first cut" estimate.

Table 15 Summary of annual industrial inputs to the Tamar Estuary (1996)*

Parameter	Comalco[1]	TEMCO[2]	Boral[3]	NFP[3]
Total effluent volume, 1996 (ML)	1200	93	50	365
Contribution in tonnes				
TSS	44	6	1	40
BOD	ns	ns	0.3	11.3
COD	ns	ns	ns	ns
Ammonia-N	1.5	<0.1	ns	ns
Nitrate+Nitrite N	ns	ns	ns	ns
Ammonia+Nitrate -N	--	--	--	--
Total Nitrogen	ns	ns	ns	ns
Orthophosphate	ns	ns	ns	ns
Total Phosphorus	ns	ns	ns	ns
Cadmium	ns	ns	ns	ns
Copper	ns	ns	ns	ns
Lead	ns	ns	ns	ns
Iron	--	<0.1	ns	ns
Manganese	--	0.2	ns	ns
Iron + Manganese	2.0	ns	ns	ns
Mercury	ns	ns	ns	ns
Zinc	ns	<0.01	ns	ns
Arsenic	ns	ns	ns	ns
Total CN	1.8	ns	ns	ns
WAD CN	<0.1	<0.01	ns	ns
Fluoride (total)	44.0	0.2	ns	ns
Fluoride (soluble)	39.0	ns	ns	ns
Oil and Grease	5.3	ns		ns
Phenols	ns	<0.01	ns	ns
PAHs	ns	ns	ns	ns

ns = not sampled

* liquid effluent only – does not include atmospheric or ground-water inputs

1 Main drain

2 Storm water drain (industrial effluent is treated at George Town STP)

3 Settling dam

Table 16 Typical pollutant loading ranges for various land-use categories

LAND USE	TSS	TP	TN	Pb	Zn	Cu	FC	COD
Road	281	0.59	1.3	0.49	0.18	0.03	7.1E+07	112
	723	1.50	3.5	1.10	0.45	0.09	2.8E+08	289
	502	1.10	2.4	0.78	0.31	0.06	1.8E+08	201
Commercial	242	0.69	1.6	1.60	1.70	1.10	1.7E+09	306
	1,369	0.91	8.8	4.70	4.90	3.20	9.5E+09	1,728
	805	0.80	5.2	3.10	3.30	2.10	5.6E+09	1,107
Single family low density	60	0.46	3.3	0.03	0.07	0.09	2.8E+09	NA
	340	0.64	4.7	0.09	0.20	0.27	1.6E+10	NA
	200	0.55	4.0	0.06	0.13	0.18	9.3E+09	NA
Single family high density	97	0.54	4.0	0.05	0.11	0.15	4.5E+09	NA
	547	0.76	5.6	0.15	0.33	0.45	2.6E+10	NA
	322	0.65	5.8	0.10	0.22	0.30	1.5E+10	NA
Multi-family residential	133	0.59	4.7	0.35	0.17	0.17	6.3E+09	100
	755	0.81	6.6	1.05	0.51	0.34	3.6E+10	566
	444	0.70	5.6	0.70	0.34	0.51	2.1E+10	333
Forest	26	0.10	1.1	0.01	0.01	0.02	1.2E+09	NA
	146	0.13	2.8	0.03	0.03	0.03	6.8E+09	NA
	86	0.11	2.0	0.02	0.02	0.03	4.0E+09	NA
Grass	80	0.01	1.2	0.03	0.02	0.02	4.8E+09	NA
	588	0.25	7.1	0.10	0.17	0.04	2.7E+10	NA
	346	0.13	4.2	0.07	0.10	0.03	1.6E+10	NA
Pasture	103	0.01	1.2	0.004	0.02	0.02	4.8E+09	NA
	583	0.25	7.1	0.015	0.17	0.04	2.7E+10	NA
	343	0.13	4.2	0.010	0.10	0.03	1.6E+10	NA

[a] For each pollutant and land use, loadings are listed as kg/ha-y (except no./ha-y for FC) in the order minimum, maximum, median.

NA Not available

Source :Horner, 1992

Table 17 Estimated inputs from urban run-off - Tamar Estuary

Contaminant	kg/ha	t/yr
TSS	322	1127
BOD	30	105
TP	0.65	2
TN	5.8	20
Dissolved inorganic N (NH_3+NOx)	3.1	11
Pb	0.1	0.4
Zn	0.22	0.8
Cu	0.3	1.1
Faecal coliform	2.6E+10 (org/ha)	9.1E+13 (org/yr)

Notes:

urban area is estimated at 35 km^2

land use is assumed to be high density, residential

most pollutant loading rates derived from Horner (1992) - median values

BOD and dissolved inorganic N rates are from Horner et al, 1994 (Table 2.3)

loading rate for faecal coliform is from Horner (1992) - used maximum value to account for combined sewer overflow issues.

4.4 Refuse disposal sites, industrial stockpiles and contaminated sites

Municipal refuse disposal sites

Refuse disposal sites (RDSs) may contribute pollutants to water bodies in the form of leachate, surface run-off and wind-blown rubbish. In Tasmania, RDSs must meet specified permit conditions, which usually require leachate management together with monitoring of leachate, groundwater and nearby waterways. Parameters which are commonly monitored include nitrate, ammonia, phosphate, pH, BOD, COD, total coliforms, faecal coliforms and metals. Leachate quality varies from site to site depending on the refuse composition, water content, stage of decomposition, temperature and oxygen availability. Some contaminants which may be present in leachate are hazardous even in very low concentrations. These include chlorinated hydrocarbons, aromatic solvents, phenolic compounds, pesticides and herbicides and metals such as cadmium, mercury and lead. In general these pollutants are associated with the uncontrolled landfills of the past, particularly those with commercial and industrial catchments and associated wastes. Municipal solid waste is less likely to contain material which gives rise to such contaminants in the leachate. Appropriate permit conditions and proper management of RDSs help to minimise the risks of such contaminants escaping into the environment.

Permitted RDSs in the vicinity of the Tamar Estuary are shown in Figure 13. Active sites in the Tamar Valley include George Town, Launceston and Beaconsfield; two closed sites are located at Exeter on the West Tamar and Churchill Park in Launceston. In addition to permitted sites, it is likely that many unknown sites have been used for the illegal dumping of relatively small volumes of refuse. A new site, located near Beaconsfield on the West

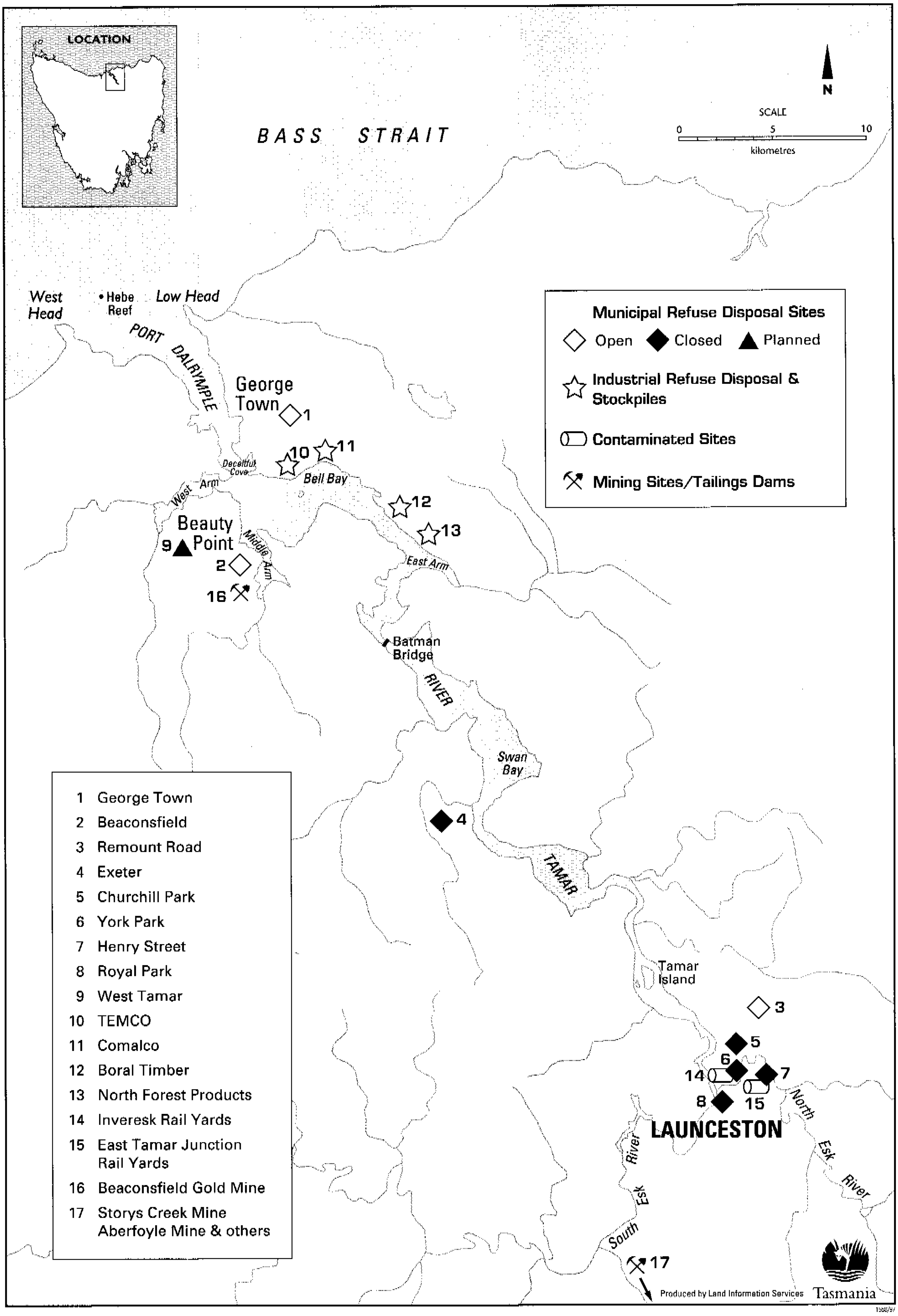


Figure 13 Refuse disposal sites, industrial stockpiles, contaminated sites and mines

Summary of Figure 13

1. George Town (Mt. George)

- Active municipal refuse disposal area.
- Landfill/trenching.
- Primarily domestic waste.
- Licensed capacity - 7,000 tonnes per year.
- Occasional monitoring of surface waters (York Creek), groundwater and leachate.
- No leachate collection or treatment. No liner but natural clay base.
- Progressive revegetation as areas are filled.
- Unknown contaminants.

2. Beaconsfield (Bowens Jetty Road)

- Active municipal refuse disposal area.
- Landfill/mounding.
- Primarily domestic waste.
- Licensed capacity - 10,000 tonnes/year.
- Quarterly monitoring of surface waters (Brandy Creek), groundwater and leachate.
- No leachate collection or treatment. No liner.
- Screening by trees and progressive rehabilitation.
- Contaminants largely unknown - possibly iron, manganese and coliforms.

3. Launceston (Remount Road)

- Active municipal refuse disposal area.
- Landfill.
- Primarily domestic waste.
- Estimated filling rate of around 130,000 tonnes/year.
- Regular monitoring of leachate before and after treatment and groundwater monitoring at bores.
- Leachate drainage system - diverted to sewerage system and treated at Ti- Tree Bend wastewater treatment plant.
- Unknown contaminants - unlikely to be significant.

4. Exeter

- Closed municipal refuse disposal area (closed 1989).
- Landfill.
- Primarily domestic waste (some agricultural chemicals and chemical containers).
- Licensed capacity 4,000 tonnes per year.
- Surface water, groundwater, soil and sediment monitored in late 1980s. Currently no monitoring.
- Complete rehabilitation and revegetation to help reduce leachate production.
- Leachate evaporation lagoon and drainage pipe system constructed as part of rehabilitation.
- Uncontrolled dumping prior to 1985.
- Unknown contaminants (allegedly organo-pesticides in the past).

5. Launceston (Churchill Park)

- Closed municipal refuse disposal area (1964-1984)
- Municipal waste (uncontrolled site before license).
- Approx. 1,320,000 cubic metres of waste over a 21 year period.
- Intermittent monitoring was carried out while site was operational. No monitoring currently carried out.
- No leachate system. Levees to contain pollutants. Uncontrolled dumping prior to 1985.
- Site converted to sports grounds but is now slipping.
- Proposal to dump sewage sludge on site and cover with loam. Site will then be used as recreational area.
- Unknown contaminants.

6. York Park (Invermay Road)

- Closed municipal landfill (1887-1920).
- Unknown volume.
- Currently used for sport and recreation

7. Henry Street

- Closed municipal landfill (1955-1964).
- Approximately 300,000 cubic metres of waste.
- Currently pasture.

8. Royal Park

- Closed municipal landfill (1920-1942).
- Unknown volume.
- Currently used for sport and recreation

9. West Tamar (York Town Road, Beaconsfield)

- Planned municipal landfill.
- No development has yet started on the site.
- Licensed capacity 8400 tonnes per year.
- To be constructed: Impermeable liner, leachate pond and drainage pipes, surface run-off to be diverted.

10. TEMCO

- Large areas of industrial landfills and stockpiles.
- Groundwater monitoring.

11. Comalco

- 250,000 tonnes of SPL stockpile recently moved and encapsulated.
- Approximately 10-20 ha other landfills/stockpiles.
- Groundwater monitoring.
- Leachate from the new SPL stockpiles is collected/treated

12. Boral Timber Tasmania

- 150,000 tonne chip storage pile.
- Most run-off is diverted/treated in settling dam.

13. North Forest Products

- two 50,000 tonne chip storage piles.
- Most run-off is diverted/treated in settling dam.

14. Inveresk Rail Yards (Inveresk)

- Contaminated site (rail yard)
- Severe hydrocarbon (diesel) contamination in groundwater
- Heavy metal contamination in soil.
- Ongoing monitoring
- Remediation program underway. Removal of contaminants from groundwater. Containment wall bordering North Esk River.

15. East Tamar Junction Rail Yards (Hoblers Bridge Rd)

- Contaminated site (rail yard)
- Contamination of soil and apparent contamination of groundwater by petroleum hydrocarbons.
- Ongoing extensive site assessment being carried out.
- Remediation -removal of contaminated soils.

16. Beaconsfield Gold Mine

- Closed gold mine (closed early 1900s).
- Possible contamination of estuary by heavy metals.
- Tailings reworked some years ago.
- Mine site/tailings dams rehabilitated.
- Investigation into recommencing mining in underground shaft currently underway.

17. Storys Creek Mine and Aberfoyle Mine

- Closed mine sites (Aberfoyle and Storys Creek)
- Contamination of South Esk River and Tamar by cadmium, copper, zinc and lead previously recorded.

Tamar, has received environmental and planning permits; however, development on the site has not yet begun.

It is very difficult to quantify the amounts and types of contaminants which enter the Tamar Estuary from RDSs. However, it is likely that 'old-type' municipal landfills such as the George Town site, existing Beaconsfield site and the old Launceston RDS at Churchill Park may contribute contaminants to the estuary via ground-water seepage or surface run-off, as these sites have no leachate management systems. The new Beaconsfield site will be much improved in terms of design, with a subsurface liner and leachate treatment system.

The Churchill Park RDS was operational for 20 years until 1984. During this era there was minimal control over materials being put into landfills, so the contents of the site are largely unknown. It is also unknown whether the site is likely to contribute contaminants to the Tamar Estuary as it has not been monitored since the site was closed. The southern border of Churchill Park is very close to the North Esk River and while levee banks have been constructed on this side, their effectiveness in containing pollutants is not known. Given the proximity of Churchill Park to the North Esk River, the unknown status of its contents and the absence of a leachate collection system or monitoring program, it is certainly a possibility that the abandoned RDS contributes contaminants to the North Esk River/Tamar Estuary.

The Beaconsfield and George Town RDSs are also typical of older sites. These landfills have no leachate collection or treatment systems, increasing the potential for contaminants to enter the wider environment including Tamar tributaries. Regular monitoring at the Beaconsfield RDS has indicated slightly elevated iron and manganese downstream in Brandy Creek (which flows into the Tamar) and also high *E. coli*, although this could also be attributed to a sewage treatment plant upstream. Intermittent monitoring at the George Town site has shown little difference upstream and downstream of the site in York Creek (a tributary of the Tamar) which flows near the RDS (Department of Environment and Land Management, Unpublished Data). Very little leachate is generated at the George Town site unless there is heavy rainfall.

The Exeter RDS (now closed) came under scrutiny in the late 1980s, when it was alleged that seepage from the site was the source of contamination of nearby farmland. The site has since been rehabilitated, which included the installation of a leachate evaporation pond and subsoil drainage. Subsequent groundwater monitoring has failed to detect contamination from the site (Ray Wright, West Tamar Council, Pers. Comm.; DELM, Unpublished Data).

It is unlikely that the existing Launceston RDS contributes significant contaminants to the Tamar Estuary as it is at least 3 to 4 km from the Tamar Estuary and has a comprehensive leachate system where the leachate and run-off are collected and diverted to a wastewater treatment plant. The treated leachate is monitored and is found to be of acceptable quality. The groundwater and surface water around Remount Road RDS is monitored quarterly and results to date (from 1983) indicate that the site is having no effect on water quality.

Other closed municipal landfills include York Park RDS in Invermay, Royal Park RDS at the top of the estuary in Launceston and Henry Street RDS, which is situated on flood prone land adjacent to the North Esk. Little is known about the potential of these landfills to introduce contaminants to the Tamar Estuary as there is virtually no information available prior to 1960 (David Doyle, Launceston City Council, Pers. Comm.). The Westbury Road old landfill situated in South Launceston is some distance from the North Esk River and is unlikely to contribute contaminants. None of the above sites have leachate control.

Contaminated sites

Several contaminated site assessments have been carried out in the vicinity of the Tamar Estuary, including two railway yards on the lower North Esk River. The Inveresk Rail Yard was identified as being significantly contaminated, with groundwater at the site found to be polluted with diesel (petroleum hydrocarbons). This has been largely cleaned up through a remediation program in which groundwater was pumped out over a period of time, the contaminants removed and the water treated through an oil/water separator. Monitoring is being continued at the site. Elevated heavy metals were also found in the soil at Inveresk Rail Yards; however they do not appear to be a problem in the groundwater. A containment wall has been installed adjacent to the North Esk to prevent contaminants seeping into the river; its effectiveness is uncertain (DELM, unpublished material).

Extensive ongoing site assessment is also being undertaken at the East Tamar Junction Rail Yards on Hoblers Bridge Road. Testing for total petroleum hydrocarbons, volatiles, cyanide and heavy metals is being carried out (DELM, unpublished material).

The types and amounts of inputs of contaminants from such sites is unquantified.

Industrial landfills/stockpiles

A number of industrial landfills and stockpiles are present on the East Tamar, in the vicinity of the Bell Bay Industrial Estate and Long Reach, as indicated in Figure 13. Ground-water monitoring at some of these sites (Comalco, TEMCO) has indicated elevated concentrations of certain contaminants (see Section 4.2 for further information).

4.5 Mines

Beaconsfield

Gold mining has been carried out intermittently at Beaconsfield for almost a century. The initial mining operation, which ceased in the early 1900s, dumped a large volume of tailings into the Tamar Estuary, containing unrecovered gold and associated metals. Some evidence suggests that the mining activity may have resulted in significant metal contamination at Middle Arm (Ayling, 1974). However, it is not known whether a pollution problem still exists in the area. Several years ago, some of the tailings were retrieved and reworked. Cyanide used to extract the gold in this process was recovered and the mine site and tailings dams have been rehabilitated (Ray White, West Tamar Council, Pers. Comm.). Investigations into the feasibility of recommencing mining at Beaconsfield are currently underway. Redevelopment of the Beaconsfield site will comply with 'best practice' and will require council approval. At present it seems likely that mining will go ahead.

Rossarden/Storys Creek

Mining operations near the township of Rossarden in Tasmania's north east are generally regarded as the source of high levels of metals detected in the South Esk River (Norris et al., 1981 and 1982). Two major tin and wolfram mines operated in the catchment between 1892 and 1982: the Storys Creek mine and the Rossarden Aberfoyle mine. Both mines discharged their tailings and associated pollutants directly into Storys and Aberfoyle Creeks until 1959, when they were required to impound their fine tailings in settling ponds. After the addition of lime, the supernatant was discharged into Storys and Aberfoyle Creeks. The coarse tailings were dumped near the mines, still in close proximity to the creeks. Acid mine drainage continues to be discharged from the site. Further information about environmental effects of the Storys Creek/Rossarden mines is provided in DELM, 1993.

Norris et al. (1981) found elevated concentrations of cadmium, zinc, copper and lead associated with TSS, in sediments and in solution in the South Esk River below Storys Creek (Table 18). These concentrations were well above natural background levels recorded upstream of Storys Creek mouth. The metals were found to be elevated for the remaining length of the South Esk River (130 km) to the Tamar Estuary.

A more recent water quality survey of the river (DPIF, 1996) suggests that heavy metal concentrations remain elevated, as indicated in Figure 14.

Table 18 Concentration ranges of metals in the South Esk River

Metal (μg/g)	Range in sediments	Range associated with NFR	Range in solution
Cadmium	0.1-51.8	0.01-0.7	0.2-113.0
Zinc	23-1249	1.3-51.8	18.9-3680.0
Copper	6.8-524.0	0.4-15.8	2.5-76.2
Lead	4.6-76.3	0.1-2.1	2.3-20.5
Manganese	280-2490	1.5-9.8	-
Iron	9580-22800	68-186	-

(Norris et al., 1981)

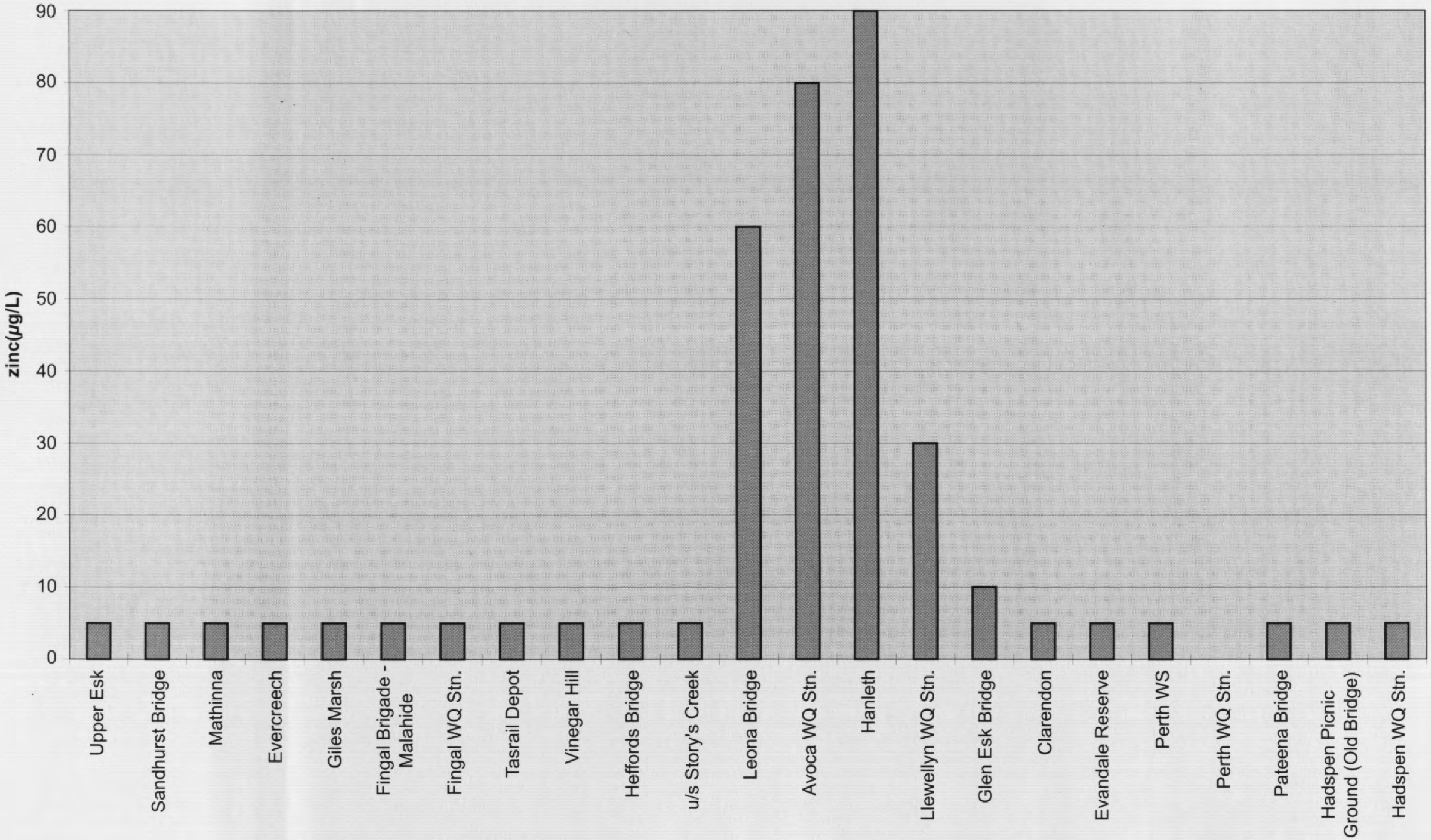


Figure 14 Zinc concentrations, South Esk River (1995)
(DPIF, 1996)

4.6 Tributaries

The South and North Esk Rivers are the main tributaries of the Tamar, contributing the majority of flows, sediments and nutrients to the estuary.

The Department of Primary Industry and Fisheries (DPIF) has recently completed a study of the South Esk Basin which estimates nutrient exports from the South Esk, Macquarie and Meander Rivers. On the basis of 2 to 3 years of monitoring data, annual exports of nutrients from the South Esk Basin are estimated at 80 t/yr total phosphorus and 1000 t/yr total nitrogen (DPIF, 1996). Dissolved nutrients, turbidity and a number of other parameters were also monitored as part of this study, however, total exports of these variables were not determined.

Sediment discharge from the South Esk basin was estimated by Foster et al. (1986) on the basis of suspended sediment samples collected in the river under a range of flow conditions. They estimate that for the period 1924 to 1979, annual sediment discharge from the South Esk to the Tamar estuary averaged 39,300 tonnes, with much higher loads discharged in wet years.

For the North Esk, flow data was not available to enable detailed calculations of sediment load, however, Skirving (1986) estimated silt loads from the North Esk at 3550 to 4700 tonnes/year. No data on nutrient exports from the North Esk River are available.

4.7 Sediments

Many contaminants have an affinity with particulate material, therefore sediments are often a reservoir of pollutants. While contaminants associated with sediments may be relatively immobile, chemical and physical changes may result in them being released back into the environment and they may thus enter the ecosystem.

Information concerning the physical and chemical characteristics of Tamar sediments and associated contaminants is patchy and incomplete. It is therefore difficult to speculate on the significance of Tamar sediments as a source of contaminants. In highly polluted areas of the estuary such as Deceitful Cove, it is possible that manganese, zinc, cadmium, lead and copper may be released into the water column when the sediments are dispersed (TEMCO/Comalco, 1992). Cadmium, particularly was found to be likely to leach into Tamar water from the highly contaminated sediments at the head of the cove. However, the solubility of polycyclic aromatic hydrocarbons (PAHs) in Deceitful Cove sediments was found to be low. It is possible that disturbance of sediments by dredging in the upper reaches may result in remobilisation of contaminants from sediments to the water column. Dredged sediments deposited in prepared silt deposit ponds adjacent to the estuary may also be a potential source of contaminants.

4.8 Atmospheric inputs

Substantial quantities of pollutants can enter estuaries directly in the form of precipitation or as dry fall-out from the atmosphere. Atmospheric inputs are derived from a variety of sources, such as emissions from vehicles, industry and wood heaters. The atmosphere has been found to contribute a substantial proportion of pollutants to many urbanised estuaries. In Port Phillip Bay, for example, atmospheric inputs of inorganic nitrogen contribute approximately 800 to 1300 tonnes of nitrogen to the system each year, accounting for 10 to 20% of total nitrogen inputs (Carnovale and Saunders, 1988; CSIRO, 1996).

Most monitoring of atmospheric pollution focuses on contaminants which represent a risk to human health, such as ozone, carbon monoxide, nitrogen oxides, sulphur dioxide, particulates, lead and other air toxics. Compounds which are most likely to affect estuarine water quality include nutrients (particularly ammonia and nitrate-N), lead and air toxics (e.g. PAHs and fluoride).

The main sources of atmospheric pollution in the Tamar region are:

- industries at Bell Bay (Comalco, TEMCO);
- urban inputs (traffic, wood heaters);
- Bell Bay power plant (when operating, i.e. prior to 1994); and

Specific data on air quality in the Tamar region are limited. In the Launceston area, monitoring of particulates has been carried out at up to 5 sites since 1991 (Carnovale, 1997). Monitoring of sulphur dioxide in the George Town area has also been done over various years. More recently, the Tamar Airshed Study monitored the air quality at 15 sites in the Tamar Valley (Department of Environment and Land Management, 1995) and established an inventory of point and diffuse sources of emissions with in the study region. These sources included domestic wood heaters, vehicles in the Launceston area, aircraft at Launceston airport and scheduled industrial premises. The main emission species which were studied included carbon monoxide, sulphur dioxide, nitrogen oxides, hydrocarbons and particulates. Industries in the Bell Bay area, specifically TEMCO and Comalco, also routinely monitor stack emissions (for particulates, nitrogen oxides, sulphur oxides and fluoride) and conduct ambient air quality monitoring in their immediate vicinity, as part of their license conditions.

Although this data may give some indication of the types of airborne contaminants which are present in the region, it is not possible to estimate what proportion ultimately enters the Tamar. Airborne contaminants of particular concern with respect to the Tamar estuary would include ammonia and nitrate, lead, PAHs and fluoride. The degree of atmospheric fallout will depend largely on local meteorological conditions and can only be quantified through the collection and analysis of representative dust fall-out and rainwater samples at sites immediately adjacent to or over the estuary. This type of monitoring has not been done in the Tamar region, with the exception of some fluoride measurements on rainfall samples collected in the Bell Bay area.

4.9 Spills

The grounding of the transport bulk carrier *Iron Baron* on Hebe Reef on the 10th July in 1995, resulted in an oil spill of around 300 tonnes of fuel oil and some diesel. It is estimated that approximately 155 tonnes of oil impacted the northern Tasmanian coastline from Five Mile Bluff to Port Sorell, contaminating primarily the Tamar and Port Sorell estuaries (Department of Environment and Land Management, 1996). See Section 6.7 for further discussion.

4.10 Summary

Table 19 and Figure 15 attempt to summarise inputs to the Tamar from industries, sewage treatment plants, urban run-off and the South Esk Catchment. The data suggests that the South Esk River contributes the majority of flows, TSS and nutrients - as would be expected for a river/catchment system of its size. Sewage treatment plants contribute the next largest proportion of flows, TSS and nutrients, probably followed by urban run-off. Liquid emissions from industrial sources are not very large, reflecting the considerable improvements in waste management/processing over recent years as well as transfer to municipal/industrial WWTPs.

Table 19 is limited in its usefulness, however, as the full range of parameters has not been measured for most sources; thus, cumulative inputs cannot be accurately determined and intercomparisons are of questionable value. Furthermore, inputs from municipal and industrial sources have undoubtedly been underestimated, as these values were based on monitored end-of-pipe liquid emissions, and do not include diffuse sources (e.g. air emissions, groundwater inputs, spills and sewage overflows). In highly contaminated areas of the estuary, sediments may also be an internal source of contaminants, particularly for metals. Table 20 provides an alternative, qualitative overview of inputs from all sources.

Table 19 Summary of estimated annual inputs to the Tamar Estuary (1996)

Parameter	Industry	Sewage	Urban Runoff	South Esk
Total effluent volume (ML)	1708	14,588	?	2,200,000
Contribution in tonnes				
TSS	91	310	1127	40,000
BOD	12	172	105	na
COD	ns	ns	na	na
Faecal Coliform*		1.42E+13	9.1E+13	na
Ammonia-N	>2	138	na	na
Nitrate+Nitrite N	ns	68	na	na
Ammonia+Nitrate -N	--	206	11	na
Total Nitrogen	ns	ns	20	1000
Orthophosphate	ns	ns	na	na
Total Phosphorus	ns	62	2	80
Cadmium	ns	ns	na	na
Copper	ns	ns	1.1	na
Lead	ns	ns	0.4	na
Iron	ns	ns	na	na
Manganese	ns	ns	na	na
Iron + Manganese	>2	ns	na	na
Mercury	ns	ns	na	na
Zinc	ns	ns	0.8	na
Arsenic	ns	ns	na	na
Total CN	>2	ns	na	na
WAD CN	<0.1	ns	na	na
Fluoride (total)	44	ns	na	na
Fluoride (soluble)	39	ns	na	na
Oil and Grease	6.6			
Phenols				
PAHs				

ns = not sampled, na = not available

* as total number of organisms

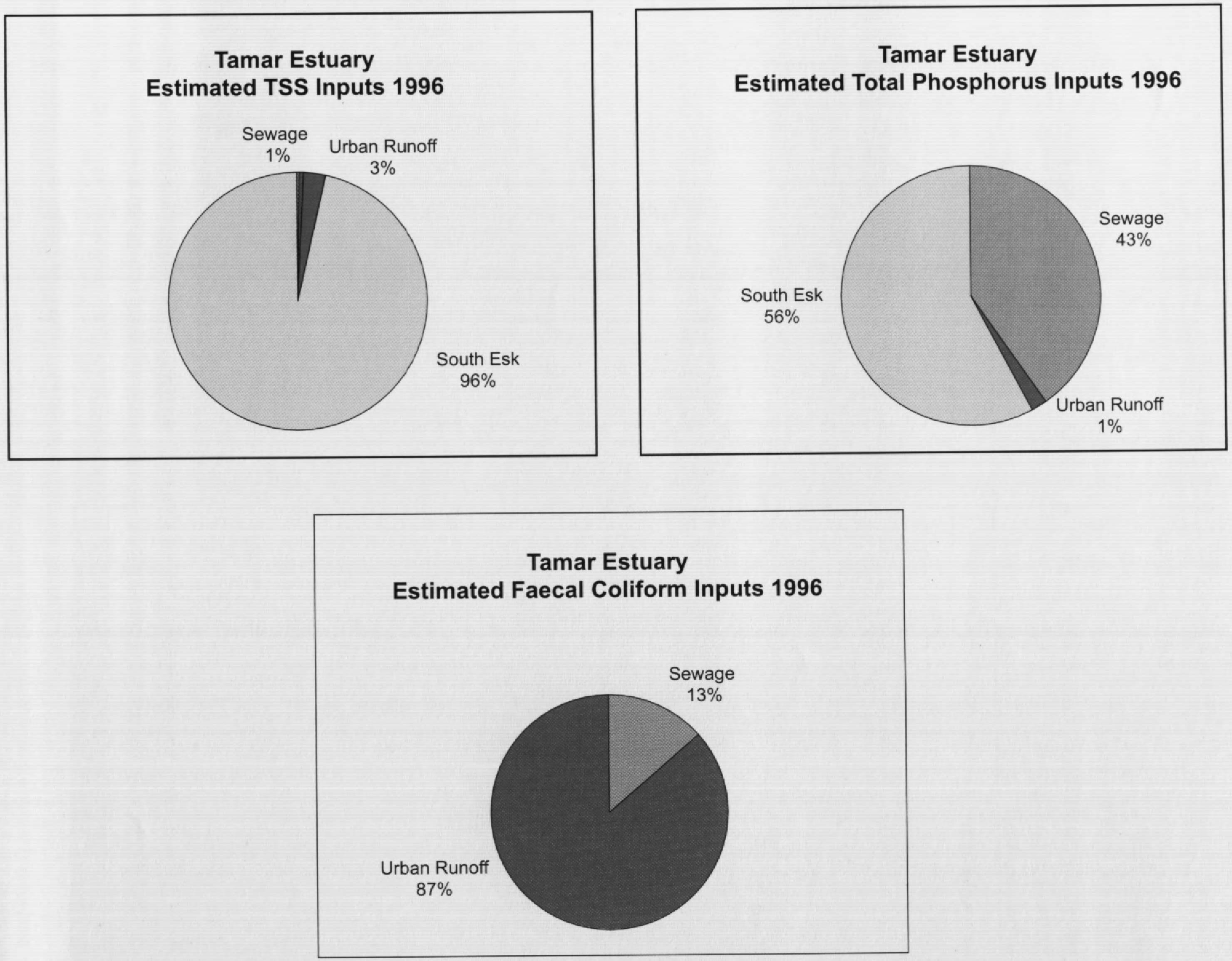


Figure 15 Cumulative inputs to the Tamar Estuary from all major sources

Table 20 Qualitative assessment of mass inputs to the Tamar

Source	TSS	BOD	Nutrients	Bacteria	Metals
STPs	M/L	M/L	L	M/L	S/M
Industry - metals	S/M	S	S	S	M
Industry - wood	S/M	S/M	S	S	S
Mining	S	S	S	S	M/L
N. and S. Esk Rivers	L	L	L	M	M/L
Urban air pollution	S/M	S	S/M	S	S/M
Estuarine sediments	?	?	?	?	?
Urban Run-off	L	M	S/M	M/L	S/M

L = Large, M = Medium, S = Small

5 Previous studies and monitoring programs

Data on the contamination status of the water, sediments and biota of the Tamar Estuary is sketchy at best. However, intermittent surveys which have been done over the past twenty five or so years do provide a general indication of environmental quality in the Tamar Estuary. The most pertinent, recent studies include a long term water monitoring study by the Department of Environment (1971-1988) and the Launceston City Council (1988-1996) and a reasonably extensive examination of the lower part of the estuary by Gawne and Richardson (1992a; 1992b). An older study of some significance is the research into the metal concentrations in sediments and oysters throughout the estuary, done by Ayling (1974). These and other studies are summarised below.

The most pertinent studies on the Tamar Estuary to date include the following:

- Co-operative monitoring between the Department of Environment and Land Management (DELM), Launceston City Council (LCC), Port of Launceston Authority (PLA) and Department of Primary Industries and Fisheries (DPIF) from 1971 to present.
  Parameters in water (DO, TSS, secchi depth, pH, salinity, temperature, phosphate, arsenic, faecal indicators, fluoride, pesticides).

- Ayling (1974)
  Metals in Oysters and Sediments (Cd, Cu, Cr, Pb, Zn).

- DELM (1986)
  Tamar River Report; a water, sediment, bacteriological and oyster survey - Water (DO, salinity, pH, temperature, NFR, Cd, Cu, Pb, Zn, faecal indicators), Sediments (LOI, Cd, Cu, Pb, Zn, Hg), Oysters (Cd, Cu, Pb, Zn).

- TEMCO/Comalco (1992)
  Survey of Deceitful Cove - Sediments (Pb, Zn, Mn, Cd, Ni, Fe, Cu, Hg, Mo, Sn, Cr, Co, As, Ba, Se, Bi, Ur, Th, PAHs), Biota (Cd, Pb, Zn, Mn, Cu, Cr, Ni, PAHs in crab, algae, fish, oyster).

- Gawne and Richardson (1992a)
  Survey on Lower Tamar Estuary - Water (N as ammonia, fluoride, phenols, Al, Ba, Fe, Pb, Mn, Hg, Zn), Sediments (Al, Ba, Fe, Pb, Mn, Zn, PAHs), Oysters (Al, Ba, Fe, Pb, Mn, Zn, PAHs).

- Gawne and Richardson (1992b)
  Survey of Deceitful Cove - Water (N as ammonia, fluoride, phenols, PAHs, Al, Ba, Fe, Pb, Mn, Zn), Sediments (Al, Ba, Fe, Pb, Mn, Zn, PAHs), Oysters (Al, Ba, Fe, Pb, Mn, Zn, PAHs).

Other studies which have been conducted on the Tamar Estuary include:

- Thrower and Eustace (1973a; 1973b)
  Metals in Oysters (Cd, Cu, Zn).

- Ratkowsky et al. (1974)
  Metals in Oysters (Cd, Cu, Zn).

- Dix et al. (1975)
  Mercury in Sand Flathead.

- DELM (1986)
  Lab Report - Metals in Oysters (Cd, Cu, Pb, Zn, Hg).

- DELM (1988)
  1987/88 Tamar Water Monitoring Program - Parameters in water (TSS, DO, secchi disc, phosphate, faecal indicators).

- DELM (1989)
  Bacteriological water monitoring program - *E. coli* in water.

- DELM (1996)
  Hydrocarbons in bivalves and fish (also examined tissue damage relating to hydrocarbon contamination).

6 Environmental quality of the Tamar Estuary

This chapter provides an overview of the existing data on the Tamar Estuary. This review helps to establish the environmental quality of the estuary and to identify which areas are in need of remediation. In addition, the review highlights areas where data is lacking and where future monitoring would be beneficial. Discussions about specific parameters measured in the Tamar Estuary indicate why high levels are of concern, and compare levels of contaminants in the water, sediment and biota with relevant guidelines.

Since 1971, an ongoing monitoring program by the Department of Environment and Land Management has measured temperature, chloride, dissolved oxygen, pH, total suspended solids, secchi depth as well as phosphate, fluoride, pesticide-related compounds and faecal indicator bacteria in surface waters 2 to 6 times per year at 16 sites throughout the estuary (Figure 16). This monitoring program provides the basis for much of the following discussion as most other Tamar studies have been one-offs and many are limited in geographical extent. These are useful in determining conditions at a point in time; however in assessing long term trends and persisting pollution problems, the data are limited compared with long term monitoring data.

6.1 Dissolved oxygen

Dissolved oxygen (DO) concentrations in estuarine waters are dependent on a number of factors, including temperature, salinity, biological activity and turbulence and mixing. DO may therefore fluctuate widely over periods of hours, weeks or months. Oxygen dissolves more readily at low temperatures and low salinities, causing DO levels to be significantly higher in cold freshwater than in warmer seawater. Aquatic plants are net producers of oxygen during daylight hours, but are net consumers at night, therefore DO levels also vary diurnally, with the lowest concentrations occurring near sunrise. Saturated levels of DO in a healthy estuarine environment generally lie between 6.5 and 9 mg/L. Levels of DO below 5 mg/L are known to be stressful to many species of fish (ANZECC, 1992). Unusually high DO levels, on the other hand, may be indicative of large plant biomass and eutrophic conditions. ANZECC (1992) has recommended that dissolved oxygen levels should not fall below 6 mg/L (or 80-90% saturation), as measured over at least one diurnal cycle.

Dissolved oxygen depressions may be contributed to by elevated water temperatures, stratified conditions (i.e. poor vertical mixing) and a high organic loading. Although considerable vertical mixing occurs in the upper Tamar, the area does have a high organic loading as a result of urban run-off, sewage effluent and until recently, abattoir wastes.

Monitoring of dissolved oxygen (DO) in the Tamar Estuary by the Department of Environment and Launceston City Council (1971-1996) has shown that levels in the middle and lower estuary generally fall within the guidelines recommended by the Australian and New Zealand Environment and Conservation Council (ANZECC, 1992). Observed dissolved oxygen ranges are indicated in Figure 17. Several sites in the upper reaches of the estuary have historically shown low DO levels, in some cases well below the recommended guidelines, suggesting localised organic pollution. Areas which, in the past, were consistently low in DO include the lower North Esk River and the Tamar at Home Reach. Between 1975 and 1988, DO levels ranged from 3.9 mg/L to 9.9 mg/L at these sites, with

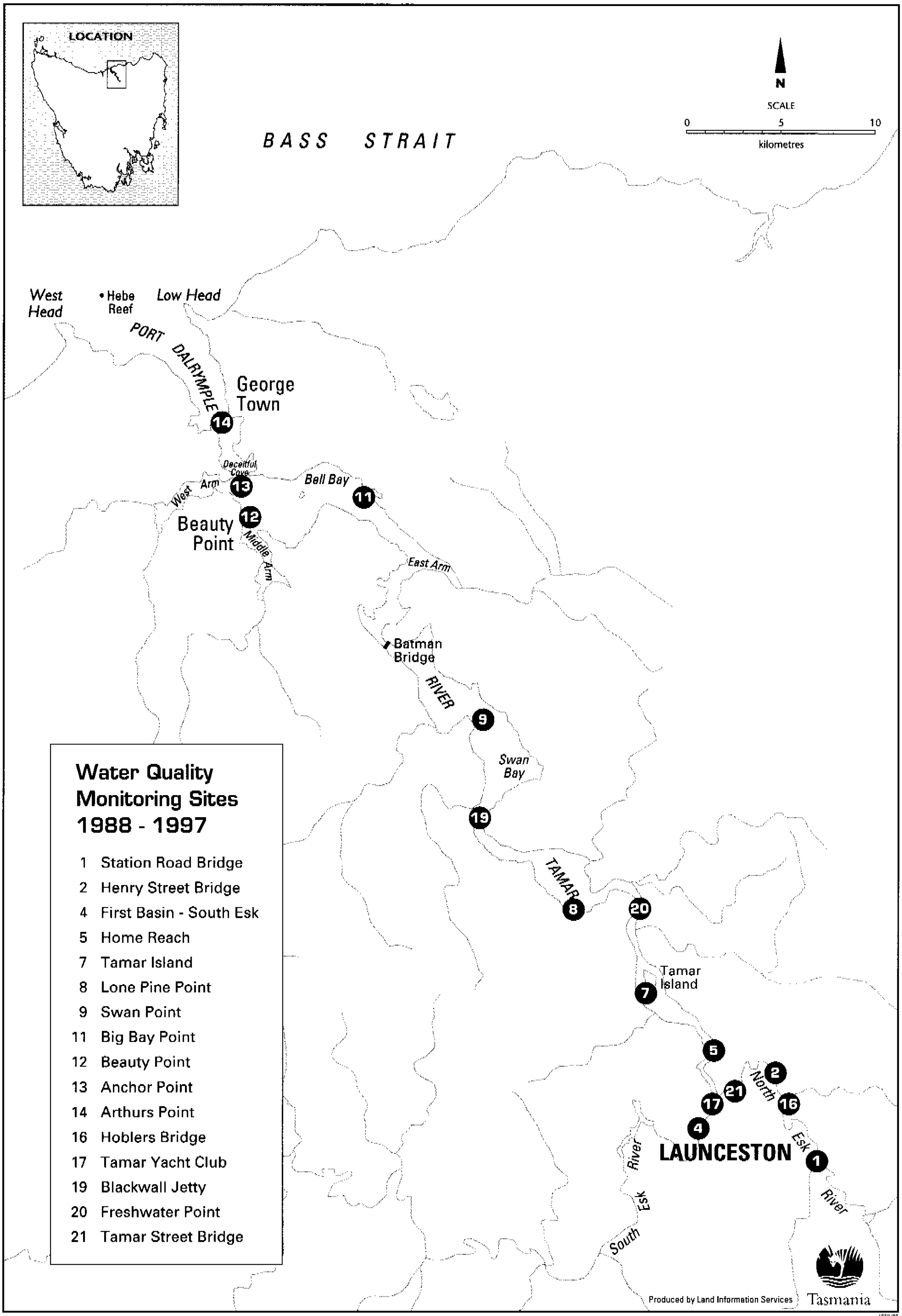


Figure 16 Water quality monitoring sites - Tamar estuary monitoring program

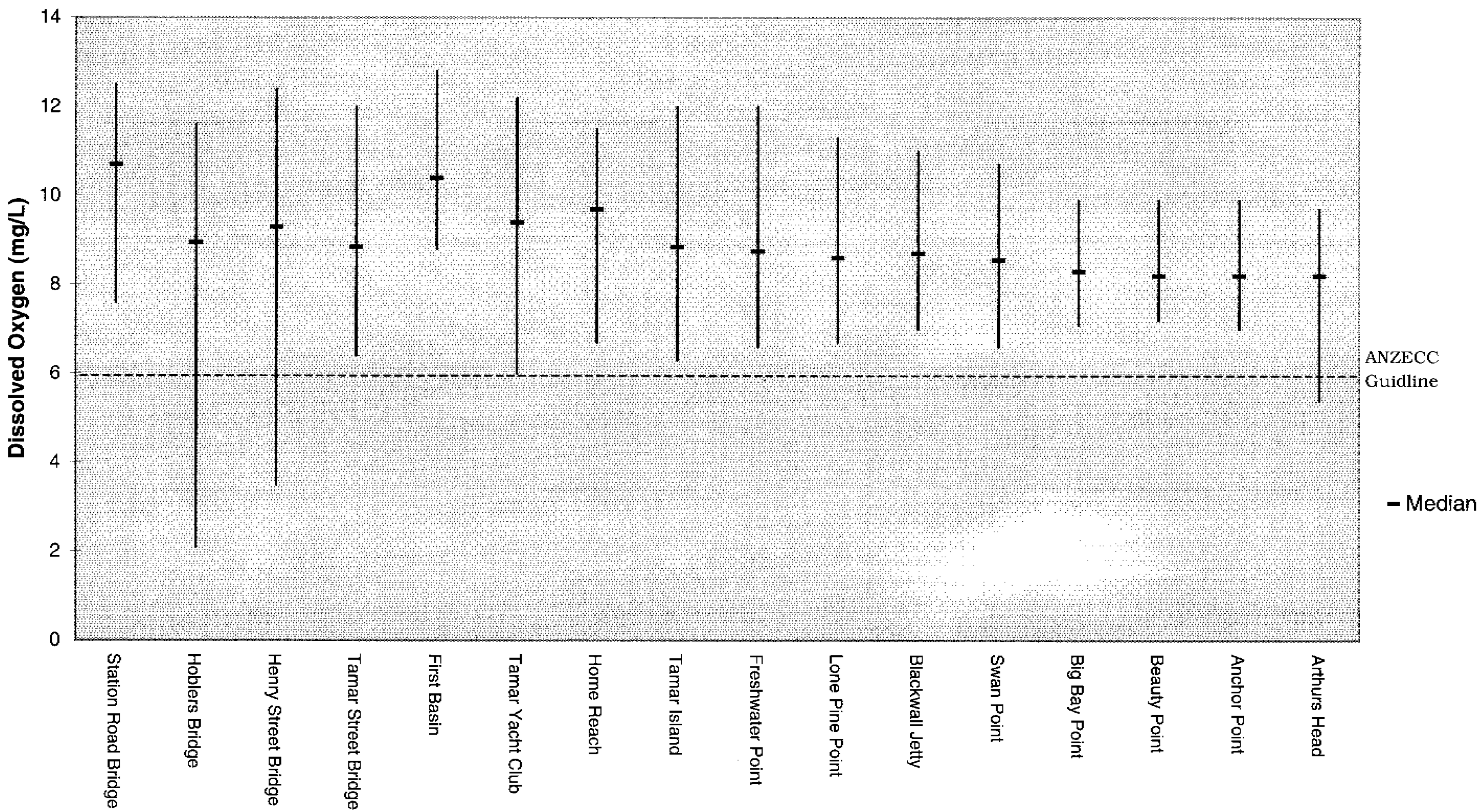


Figure 17 Dissolved Oxygen - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

values commonly around 5 or 6 mg/L. Levels have improved recently, with all recorded values since mid 1992 being above 6 mg/L.

It should be noted that the current monitoring program consists of spot sampling, carried out during daylight hours, when DO levels tend to be higher. Therefore, the data probably do not reflect the lowest oxygen levels which may occur.

6.2 Suspended particulate matter and Secchi depth

Suspended particulate matter (also termed non-filterable residues or total suspended solids) consists of silt and clay, phytoplankton, decaying organic matter and other particles derived from both natural and anthropogenic sources. The level of suspended particulate matter (SPM) in estuaries often varies widely in response to river discharges, wind and tidal mixing, phytoplankton blooms and other factors. Typically, SPM tends to accumulate (and is thus highest) at the interface between salt and freshwater.

High levels of SPM may adversely affect aquatic ecosystems both when in suspension and during settling. In suspension, high SPM levels may reduce light penetration, affecting primary production. As particulate matter settles out, it may also smother sessile organisms, clog the gills of finfish and change the nature of the substrata. ANZECC guidelines recommend that increases in SPM should be limited such that optical guidelines are maintained (for optical guidelines see ANZECC, 1992) and that the seasonal mean nephelometric turbidity does not change by more than 10%.

Regular monitoring since 1971 at 16 sites throughout the Tamar Estuary, has established highly variable levels of SPM (Department of Environment, 1971-1988; Launceston City Council, 1988-1996). In the earlier monitoring data, highest concentrations were often observed near Green Hillock and Haystack Points in the upper-middle estuary. In recent years, high levels of SPM have also been recorded at Henry Street Bridge and Tamar Street Bridge in the Lower North Esk River (Figure 18). SPM ranges from around 10 - 20 mg/L in the upper estuary and around 5 - 10 mg/L in the lower reaches. Compared with the Derwent Estuary, SPM levels in the Tamar are somewhat elevated.

Secchi depth measurements indicate the light penetration in a water body. Secchi depth readings were taken at sites in the Tamar Estuary as part of the Tamar River Monitoring Program. As expected, the results show greater light penetration from the head of the estuary towards the mouth (Figure 19).

6.3 Pathogens/bacteria

Outbreaks of ill health associated with contaminated water are usually attributed to disease-causing micro-organisms (pathogens). Pathogens cause ailments in humans, often as a result of primary contact recreation in contaminated areas. Such diseases are commonly eye, nose and throat infections, skin diseases and gastrointestinal disorders. Consumption of contaminated seafood, particularly shellfish, may also cause gastrointestinal disorders, hepatitis and other diseases. While a higher risk is associated with primary contact recreation, in severely contaminated areas, there may be risks associated even with secondary contact recreation (i.e. fishing, rowing, etc.). Common pathogens include salmonellae,

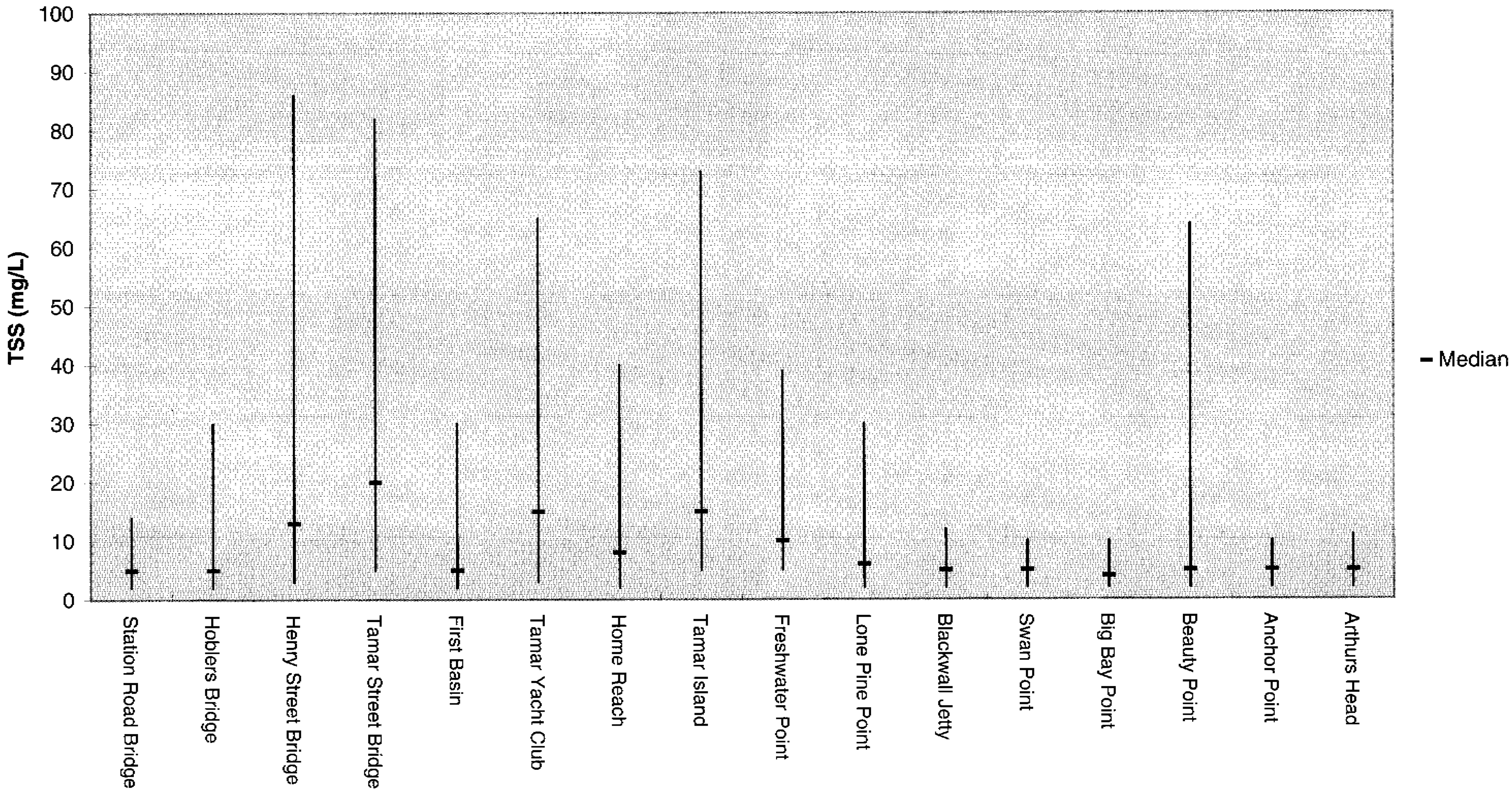


Figure 18 Total Suspended Solids - Tamar Estuary Monitoring Prog. 1988-96
Bar represents range of values measured.
See Figure 16 for sampling locations.

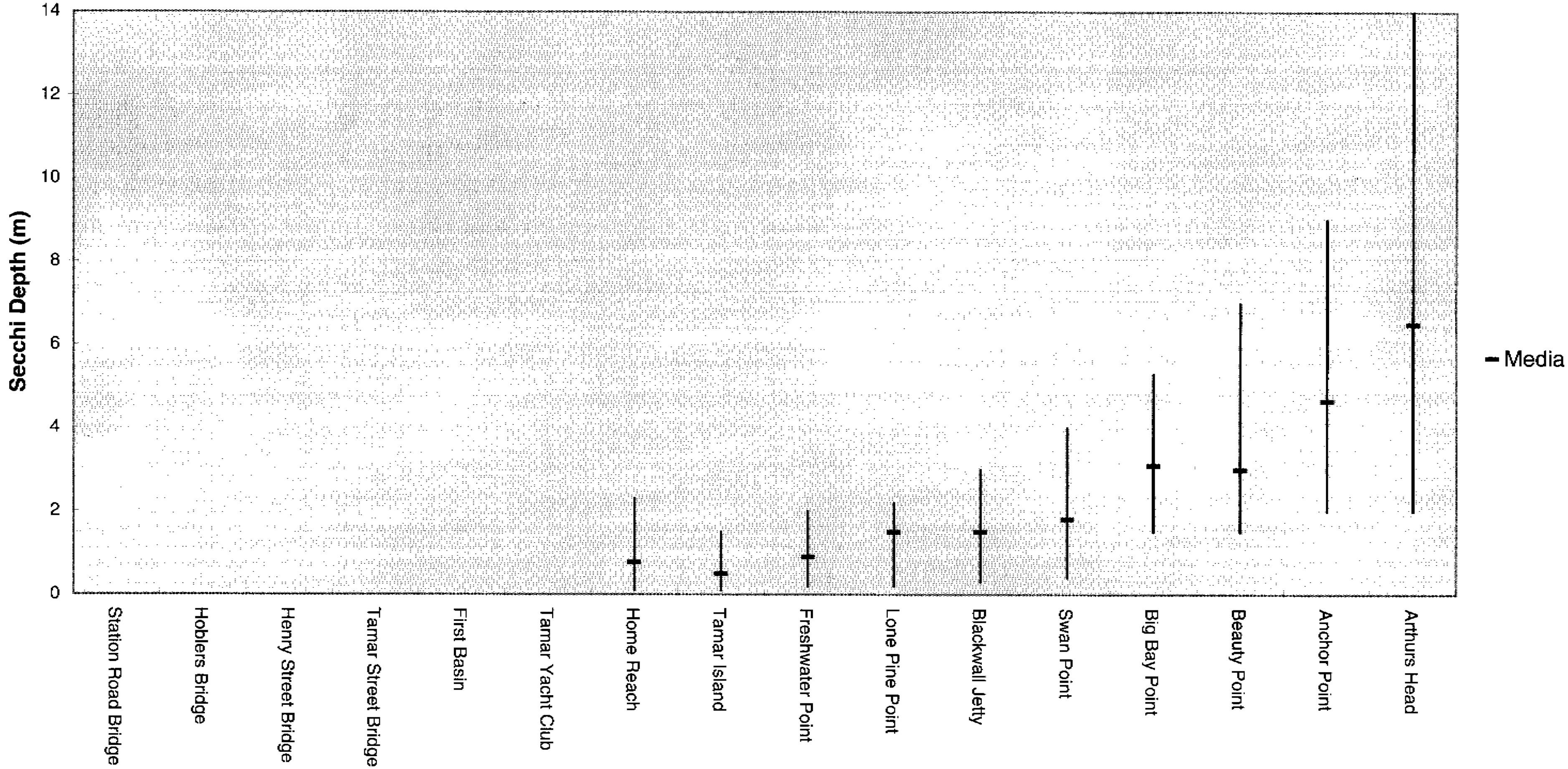


Figure 19 Secchi Depth - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

shigellae, enteropathogenic *Escherichia coli*, cysts of *Entamoeba histolytica*, parasite ova, enteroviruses and infectious hepatitis (ANZECC, 1992). Pathogens occur intermittently and are difficult to recover from water, therefore direct detection of pathogens is not a feasible option for routine assessments. For this reason, 'indicator' micro-organisms are generally used to estimate the health risks associated with pathogens in recreational waters. Several different micro-organisms are used as indicators of health risks. The National Health and Medical Research Council (NH&MRC) favours the use of faecal coliforms, a subgroup of the total coliform population that are easy to measure and are present in virtually all warm blooded animals. Faecal coliform bacteria in human faeces comprise about 97% *E. coli*, 2% *Klebsiella* and 2% *Enterobacter* and *Citrobacter* together.

McBride et al. (1991, *cited in* ANZECC, 1992) have documented a number of deficiencies with the use of faecal coliforms as indicator organisms of health risks in recreational waters and waters used for shellfish growing. Recent studies have shown poorer relationships between faecal coliform densities and illness rates in bathers than are obtained using enterococci in marine waters and either enterococci or *E. coli* in fresh waters. In addition, there is now considerable evidence that faecal coliforms die off more quickly than pathogens under certain circumstances; therefore they may go undetected during beach monitoring programs, resulting in the disease risks being underestimated. Because of this, New Zealand, Canada and the USA now recommend guidelines for recreational waters based on either *E. coli* or enterococci. To minimise risks, ANZECC recommends the use of both the NH&MRC guidelines for faecal coliforms and guidelines recommended by McBride et al. (1991) for enterococci. See Table 21 for specific levels.

Table 21 ANZECC guidelines for bacteria in recreational waters

Primary contact recreation	The median bacterial content in fresh and marine waters taken over the bathing season should not exceed: • 150 faecal coliform organisms/100 mL, with four out of five samples containing less than 600 organisms/100 mL.* • 35 enterococci organisms/100 mL, with a maximum number in any one sample 60-100 organisms/100 mL.
Secondary contact recreation	The median bacterial content in fresh and marine waters should not exceed: • 1,000 faecal coliform organisms/100 mL, with four out of five samples containing less than 4,000 organisms/100 mL.* • 230 enterococci organisms/100 mL, with a maximum number in any one sample 450-700 organisms/100 mL.

* These guidelines are based on a minimum of five samples taken at regular intervals within a thirty day period.

Levels of faecal coliforms and faecal streptococci in Tamar water have been measured by the Department of Environment and the Launceston City Council at 16 sites since 1972, as part of the Tamar Monitoring Program. See Figure 20 and Figure 21 for results. This is not a comprehensive bacterial monitoring program, as samples are normally collected only 4 times per year. Comprehensive bacterial monitoring programs usually focus on bathing beaches and other areas used for primary contact recreation, with samples collected weekly during the swimming season.

Unsatisfactory bacterial levels have historically been recorded in the upper reaches of the estuary - particularly above Lone Pine Point and below the First Basin - and in freshwater areas of the North Esk River (Department of Environment, 1971-1988). Until recently, median faecal coliform levels at Hoblers Bridge, Henry Street Bridge, Tamar Yacht Club and Home Reach were in excess of guidelines for secondary contact recreation. Lower bacterial levels have usually been observed in the middle and lower estuary probably due to fewer sewage/stormwater inputs, better dilution and bacterial die-off.

Since July 1994 (when Hoblers Bend WWTP was upgraded and began receiving wastes from the Inveresk area), a significant drop in bacterial levels has been recorded in the upper Tamar. Bacteria levels are now consistently in the range of 100-1000 *E. coli*/100 mL, and median values at all sites are < 1000. However, median values at all sites between Hoblers Bridge and Freshwater Point still exceed guidelines for primary contact recreation, presumably reflecting inputs from urban runoff.

Bacterial levels in the Tamar Estuary indicate the extent of pollution by sewage in the river and are also indicative of other animal wastes. Sources of contamination are varied and may include direct discharges of untreated sewage, inadequate disinfection of treated sewage, illegal or poorly designed septic systems and faecal material washed into the estuary during rainfall events. Wastes from abattoirs (in the past) and animal faeces washed down from sale yards and truck washing facilities may also contribute to bacterial levels in the estuary.

While the apparent bacterial pollution in the upper estuary is disturbing, a short term monitoring program carried out from January to March in 1989 at recreational areas throughout the estuary, found that the levels of bacteria at most sites were in compliance with the ANZECC guidelines for primary contact recreation. Occasional high concentrations were recorded at Lagoon Beach in the lower estuary, and First Basin on the South Esk. Rotary Park at Evandale which is located above the estuary on the North Esk River, was the only site which had unacceptable levels of bacteria.

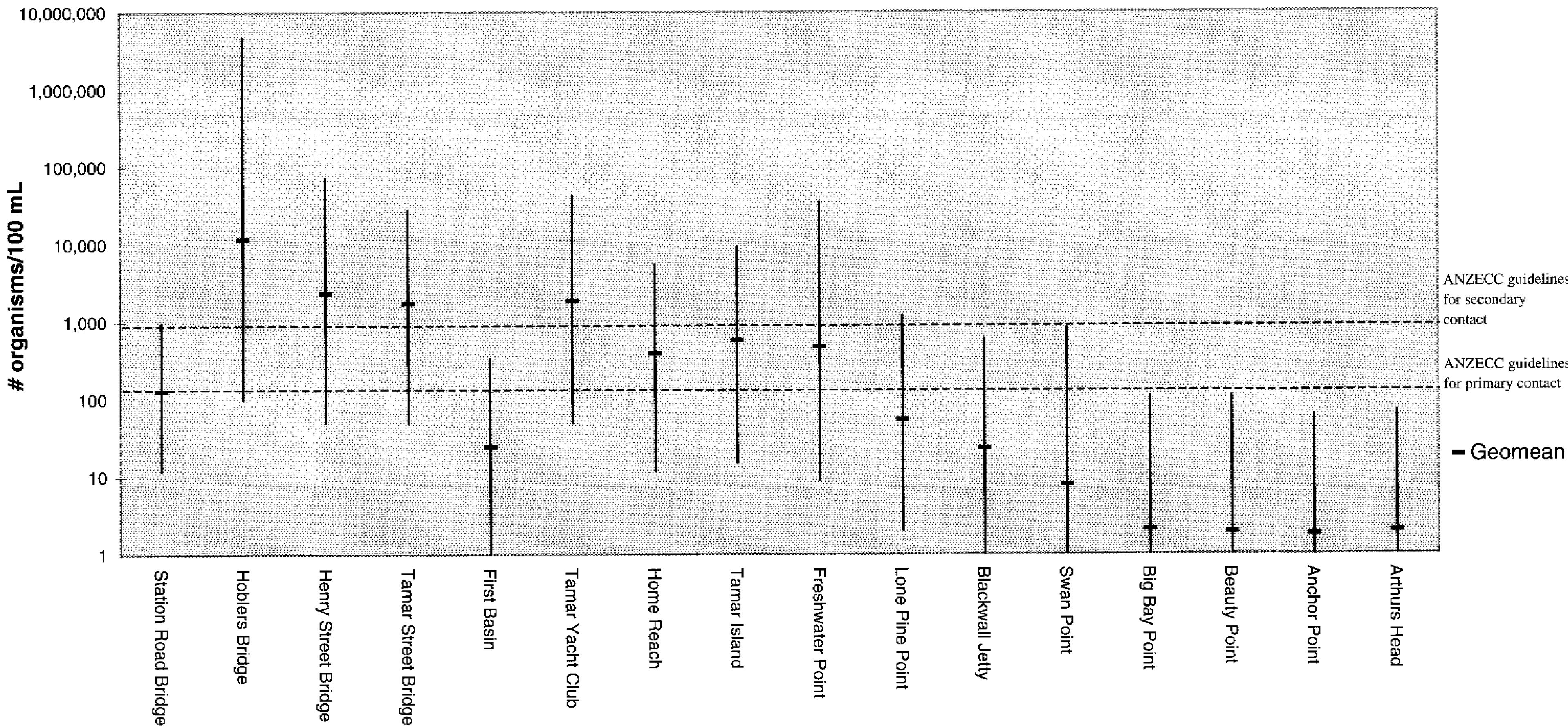


Figure 20 E. Coli Tamar - Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

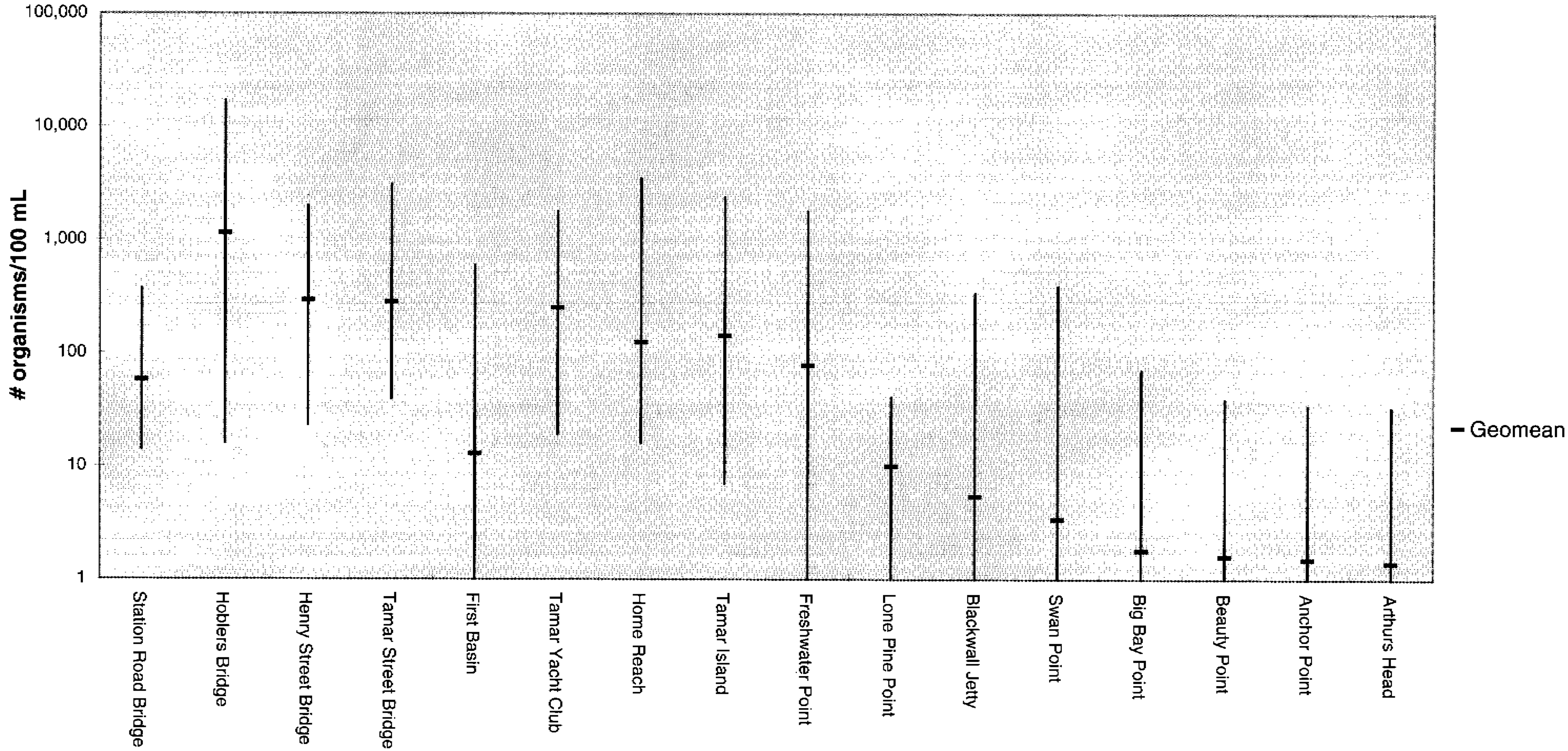


Figure 21 Faecal Streptococci - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

6.4 Nutrients

A number of water quality problems have been attributed to elevated nutrient levels in estuaries, particularly the excessive growth of algae, which in extreme cases can become algal blooms. Excessive algal growth can have a number of adverse effects on estuarine ecosystems, including the following:

- gradual and often undesirable changes in the species and numbers of aquatic flora and fauna in the estuary;
- fluctuating oxygen levels in the water mass. Algae, like all plants, are net producers of oxygen during the daytime and net consumers at night. Excessive algal growth thus results in high oxygen levels during the day, but low levels at night, which can cause physiological stress to fish and other organisms. If the algal biomass is sufficiently high, oxygen levels may fall low enough to cause the death of fish and other organisms;
- blooms of certain toxic species of algae may result in the contamination of aquatic organisms, endangering human health (e.g. paralytic shellfish poisoning) and closing down aquaculture operations;
- diminished aesthetic appeal due to odours, scum, rotting algae and fish, and discolouration of the water.

Algal growth is broadly dependent upon four factors: light, temperature, salinity and nutrient supply. However, of these, only the nutrient supply can be controlled. Thus strategies to control algal problems have usually focused on the major nutrients (nitrogen and phosphorus), in particular reducing the loads entering the system. The most biologically available form of phosphorus is orthophosphate (PO_4) and the most bioavailable forms of nitrogen are ammonia (NH_3) and nitrate (NO_3). Silica has also been identified as a limiting nutrient for diatom growth.

Nutrient Sources and Guidelines

Nutrients are derived from a variety of natural and anthropogenic (human) sources in the watershed and may be transported to the estuary via rainfall, rivers and streams, ground water, surface run-off and direct discharges. In addition to watershed sources, significant quantities of nutrients may be derived from internal sources within the estuary (e.g. sediments) and from coastal waters. Major anthropogenic sources of nutrients include sewage, industrial effluent, urban run-off, air pollution, agricultural and residential fertilisers, rubbish tips and numerous lesser sources.

No absolute guidelines have been established for what constitutes safe or acceptable levels of nutrients in all estuaries, nor is this a feasible goal, given the unique characteristics of individual estuaries. Nuisance algal growth can be the result of a number of factors, including water temperature, salinity, circulation, water transparency and nutrient concentrations. Levels of nutrients which may induce nuisance algal blooms in a brackish, tropical estuary may have no effect on a well-flushed, temperate system.

ANZECC guidelines (1992) have identified a range of nutrient concentrations at or above which problems have been known to occur in estuaries and coastal waters (see Table 22), however, they strongly recommend that site-specific studies be undertaken to determine appropriate concentrations for specific systems.

Table 22 ANZECC guidelines for nutrients and chlorophyll *a* in estuarine and coastal waters

	Estuaries	Coastal Waters
PO_4-P	5-15 μg P/L	1-10 μg P/L
NO_3-N	10-100 μg N/L	10-60 μg N/L
NH_4-N	<5 μg N/L	<5 μg N/L
Chlorophyll *a*	1-10 μg/L	<1 μg/L

There is very little data on the nutrient status of the Tamar Estuary. The data which has been gathered is patchy, infrequent and not all forms have been measured.

Nitrogen as ammonia

Relatively consistent concentrations of nitrogen as ammonia were recorded at 26 sites throughout the lower Tamar Estuary by Gawne and Richardson (1992b). The concentration was reported as ranging from 70 to 140 μg/L, with a high level of 14,900 μg/L recorded in Deceitful Cove. These values seem anomalously high compared with typical seawater concentrations, as reflected in the ANZECC guidelines. Given the frequent contamination problems associated with ammonia-nitrogen, further sampling is recommended to confirm or disprove this data.

Orthophosphate

Since 1972, orthophosphate (PO_4-P) levels in the Tamar Estuary have been monitored at 16 sites, several times per year by the Launceston City Council and the Department of Environment and Land Management. Orthophosphate in the Tamar Estuary has been historically high, with recorded concentrations well above the levels indicative of problems as recommended by ANZECC (see Table 22). PO_4-P concentrations of > 300 μg/L have been recorded at Hoblers Bridge. An improvement over the entire estuary was observed in 1979-80, which may have been due to the upgrading of sewage treatment facilities and improved in-plant controls in local industries. However, elevated phosphate levels are still recorded intermittently at sites in the upper estuary, particularly at Hoblers Bridge and Henry Street Bridge (Figure 22).

6.5 Chlorophyll *a* and phytoplankton

High levels of chlorophyll *a* in water bodies can be indicative of eutrophication associated with high phytoplankton biomass. The concentration of chlorophyll *a* in water bodies is primarily dependent on the light input and the supply of biologically available nitrogen or phosphorus. Algal blooms and high chlorophyll *a* in estuaries usually occur in the upper and lower estuarine areas. Algal blooms are uncommon in the middle reaches of many estuaries due to light limitation from high turbidity. Some literature has recommended limits on the concentrations of chlorophyll *a* in estuaries to prevent phytoplankton blooms. ANZECC (1992) lists 1-10 μg/L of chlorophyll *a* as being indicative of levels at which problems have been known to occur in estuaries and embayments.

Recurrent nuisance algal blooms have not been a problem in the Tamar Estuary, and very little chlorophyll *a* data has been gathered. Chlorophyll *a* was measured by Ritz et al. (1980) at two sites in Big Bay and nearby in the main channel of the lower Estuary. Depending on

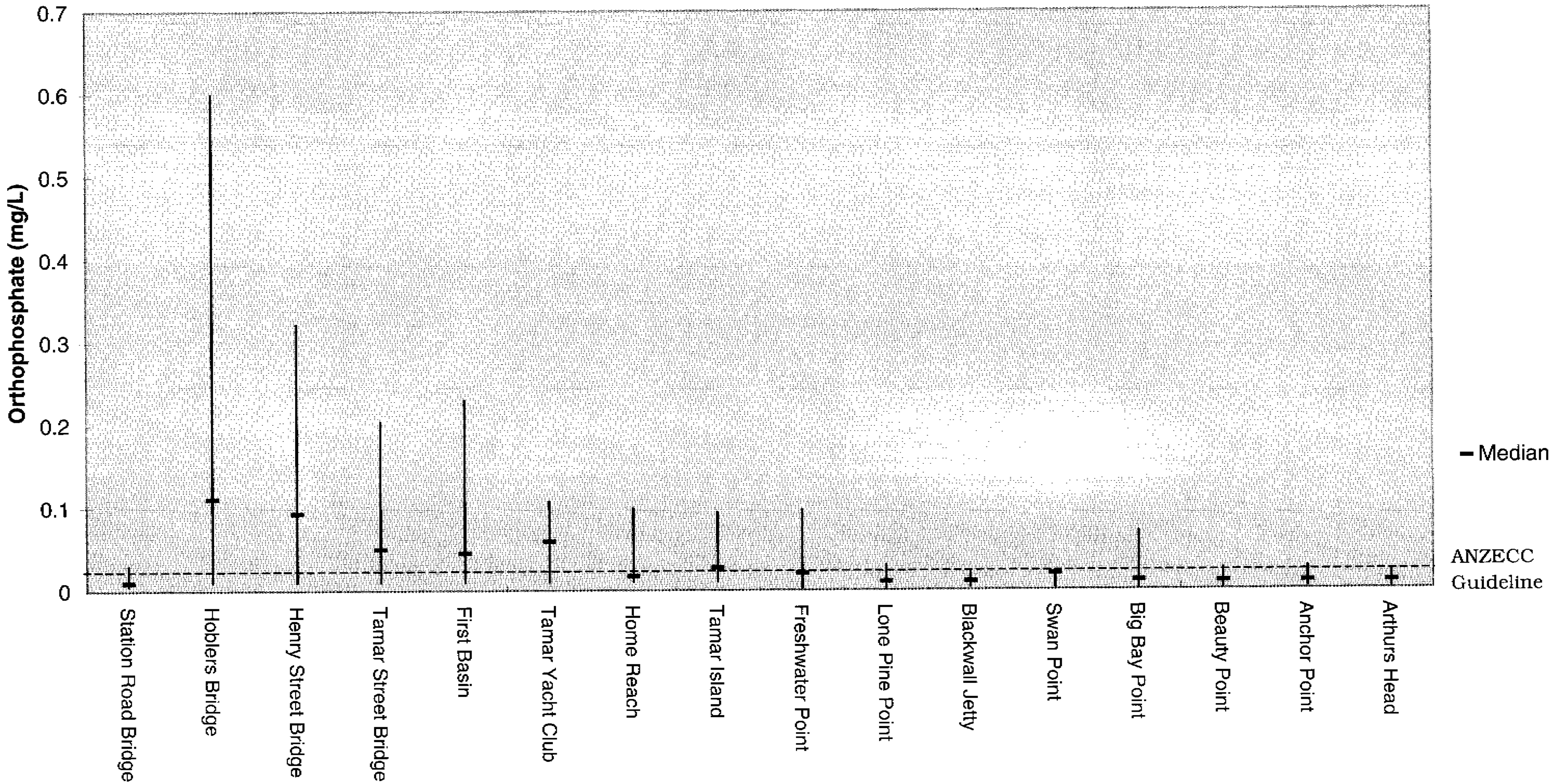


Figure 22 Orthophosphate - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

tides, concentrations ranged from around 3-5 µg/L in the main channel, to around 5-9 µg/L in Big Bay. However, as the measurements were taken on a single day in winter at only at two sites, there is insufficient data to draw any strong conclusions from these results.

6.6 Inorganic toxicants

Heavy metals

Heavy metals may enter the aquatic environment from a number of sources, both natural and anthropogenic. The main anthropogenic sources of metals are generally industry, mining and urban run-off. Some heavy metals are essential to aquatic life and are used by organisms in trace quantities; however, these and other metals can be toxic to organisms if concentrations exceed certain levels. Physicochemical conditions in the sediments and the water column influence the specific form or 'species' of metals, which in turn determines their potential to enter the ecosystem. Species in solution are generally more bio-available and more toxic than metals bound to particulate material. Heavy metals have a strong affinity with particulate material and have a tendency to accumulate in the sediments, therefore sediments in contaminated areas are usually very high in heavy metals. Sediment concentration and bioaccumulated metals tend to be better indicators of heavy metal pollution in the environment as they are more stable than metals in solution, which tend to be somewhat transient.

A number of heavy metals, particularly cadmium, zinc, copper, lead and mercury are toxic to aquatic organisms, some at very low concentrations. Sources of cadmium to the aquatic environment are mostly anthropogenic. On a global scale, it has been estimated that approximately 20% of released cadmium occurs as a by-product of zinc mining and smelting operations and another 30% from the manufacture, use and disposal of cadmium products (Bertine and Goldberg, 1971 *cited in* Hanslow, 1994). Cadmium is also introduced into aquatic environments via urban run-off and sewage effluent. In the case of the Tamar, it is probable the main source of cadmium is historic tin and tungsten mining in the upper South Esk catchment and possibly from previous industrial activity. Concentrations of 103 µg/g of cadmium were reported in sediments from the South Esk River by Norris et al. (1981), as the result of tin mining in the South Esk River catchment. In contrast, uncontaminated sediments generally show a cadmium concentration of <0.5 µg/g. Testing on effluent from wastewater treatment indicates that heavy metal concentrations are low, particularly cadmium which is below the detection limit of 1 µg/g (B. Piesse, Launceston City Council, Pers. Comm.).

Although zinc is an essential element for animals and plants, high concentrations in water exceeding 50 µg/L can produce toxicity in some aquatic organisms. The occurrence of toxic forms of zinc in the aquatic environment is particularly dependent on the pH, concentrations of complexing ligands and the hardness of the water. Zinc occurs naturally as an abundant element in most rocks and soils. Anthropogenic inputs of the metal include mining operations and metallurgical processes, wood combustion, urban run-off, waste incineration and municipal waste water. It is likely that zinc present in the South Esk River results from mining activity in the catchment of the tributary (Norris et al., 1981). Other possible anthropogenic sources of zinc in the Tamar Estuary include previous industrial activities and urban run-off.

Metals in Tamar water

It is difficult to draw accurate conclusions about the heavy metal status of the water in the Tamar Estuary, due to a lack of continuous monitoring data and the transient nature of metals in the water column. Only two significant surveys have been conducted to date (Department of Environment, 1986a; Gawne and Richardson, 1992a; 1992b). The ranges of metal concentrations in Tamar Estuary water found in the 1986 and 1992 investigations are shown below in Table 23 and in Figure 23, as compared with expected background levels and established guidelines.

Table 23 Ranges of heavy metals in Tamar Estuary waters compared with ANZECC guidelines

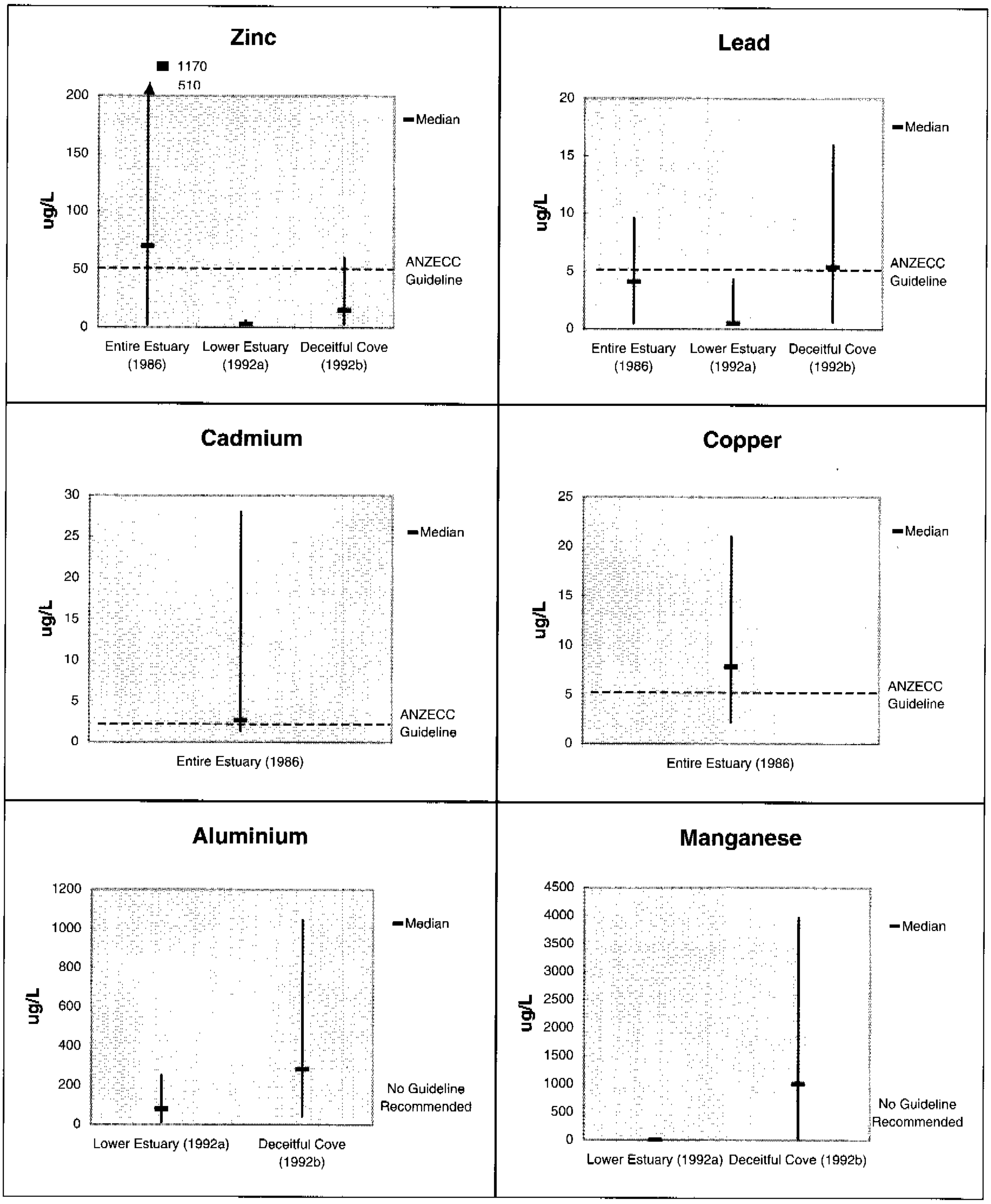
Total metals µg/L	Department of Environment 1986a Entire Estuary 16 Sites	Gawne & Richardson 1992 Lower estuary 26 Sites	Gawne & Richardson 1992 Deceitful Cove 6 Sites	ANZECC Marine Guidelines 1992	Unfiltered, unpolluted seawater range (Gawne & Richardson 1992a)
Aluminium		9-510	44-1940	*NGR	1-8
Barium		6-11	7-207	*NGR	2-63
Cadmium	1.4-28			0.2-2	-
Copper	2.2-21			5	-
Iron		8-211	42-1430	*NGR	0.03-70
Lead	<0.5-9.6	<0.2-9.8	0.6-18	5	0.03-2.4
Manganese		2-510	14-9,000	*NGR	0.03-21
Mercury		0.00042-0.00048		**0.01	0.01-0.22
Zinc	<2.0-1170	<3-8	<3-197	50	0.02-48

* NGR = No guideline recommended

** If <10% is methylmercury

The Tasmanian Department of Environment surveyed the concentrations of four metals in water in 1986 (at the surface and five metres down the water column) at 16 sites throughout the entire estuary, and in the surface waters at an additional four sites in the North and South Esk Rivers. Just prior to the sampling period there was heavy rainfall, and during sampling the South Esk River was in moderate flood which may have resulted in anomalous concentrations. The Department of Environment (1986a) recorded moderately elevated levels of copper and lead and highly elevated concentrations of cadmium and zinc. The current ANZECC guidelines were exceeded at sites throughout the estuary (Table 23). Highest concentrations of copper tended to occur in the lower estuary, while cadmium and zinc levels were higher in the upper estuary. Lead concentrations varied little throughout the estuary. Metal levels were generally higher at 5 metres depth than they were at the surface.

Gawne and Richardson (1992a; 1992b), surveyed metal concentrations (7 metals) in the surface waters of the Lower Tamar Estuary and Deceitful Cove in 1990/91. Four surveys were conducted which varied in the number of sites sampled. The number of sites varied



1986	Department of Environment (1986)
1992a	Gawne and Richardson (1992a)
1992b	Gawne and Richardson (1992b)

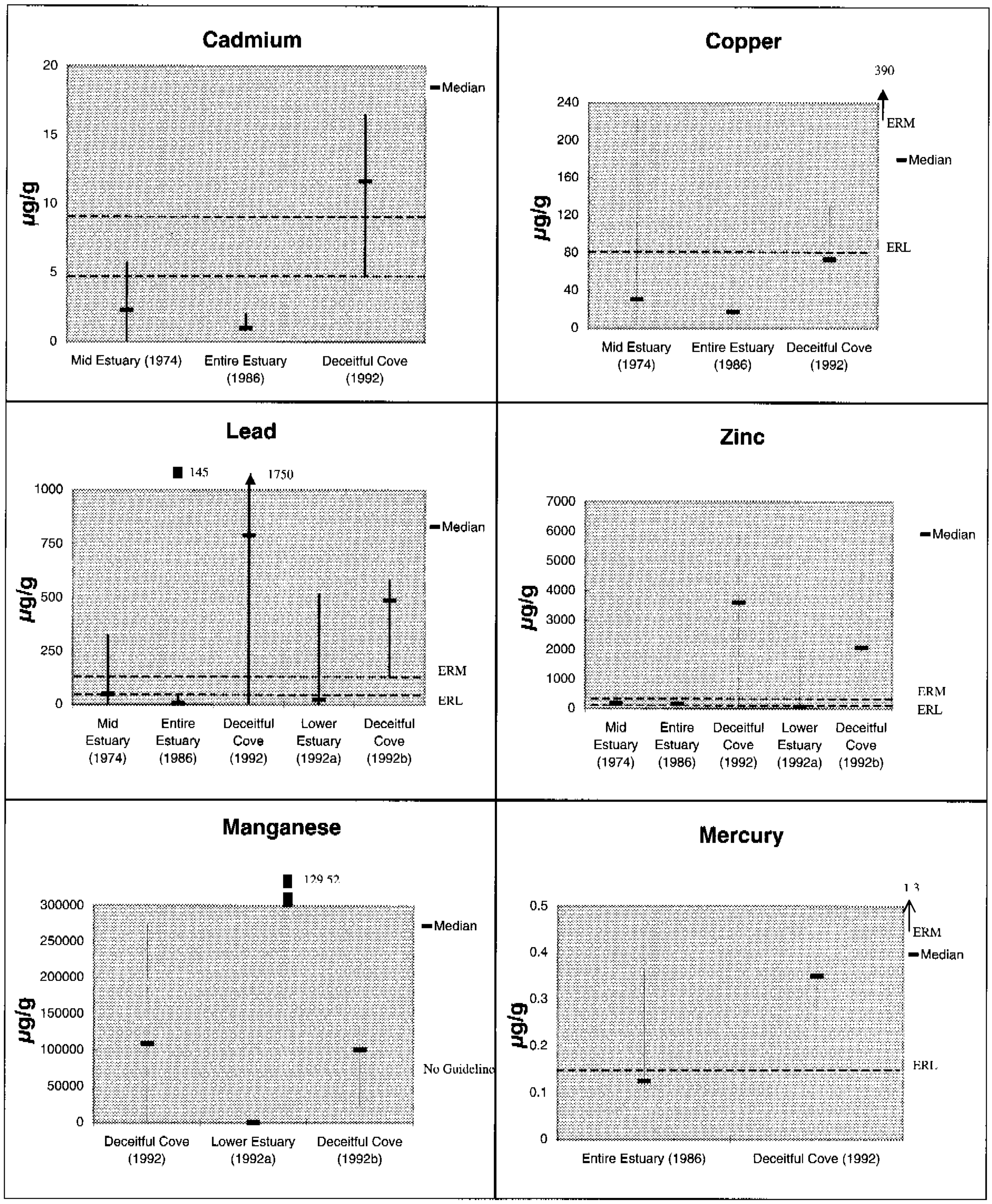
Figure 23 Metals in Tamar Estuary Waters from 6 to 26 in the lower Tamar Estuary and from 3 to 6 in Deceitful Cove. Low to moderate levels of barium, iron, mercury and zinc were recorded. Levels of aluminium were somewhat elevated throughout the lower estuary, as were levels of lead in the vicinity of Deceitful Cove. Manganese concentrations were highly elevated particularly in the area near Deceitful Cove, and although no ANZECC guideline exists for manganese, concentrations of this metal were well above the normal range expected in seawater. With the exception of a few sites, barium, lead, zinc and mercury concentrations were generally below background levels and ANZECC guidelines and were spatially quite consistent. Aluminium, iron and manganese increased upstream, with elevated iron and aluminium at the Batman Bridge suggesting a source of these metals further south (Gawne and Richardson, 1992a). The low concentrations of zinc found by Gawne and Richardson may appear to be surprising in comparison to the results recorded by the Department of Environment (1986a); however, the high levels found in 1986 were in the upper estuary and concentrations in the lower estuary were lower, corresponding with Gawne and Richardson's findings in the same region (Gawne and Richardson, 1992a).

Metal concentrations in Deceitful Cove waters were found to be almost an order of magnitude higher than in the main channel of the Tamar (Gawne and Richardson, 1992b). Iron and zinc concentrations exceeded the ANZECC values for marine waters. With the exception of barium, those metals which are not listed in the ANZECC guidelines were also elevated, being well above the expected range in unpolluted seawater. Metal levels tended to be higher in the low energy areas in the upper reaches of the cove, while concentrations in the deeper high energy regions were comparable with those in the Tamar itself. This distribution reflects the intertidal nature of Deceitful Cove. At low tide, the channel which runs through the inlet consists of a freshwater effluent flow from the Bell Bay industrial estate, when the tide is high the Cove is flooded and a dilution effect occurs.

In conclusion, the estuary as a whole has shown high levels of cadmium, zinc and manganese, with somewhat elevated levels of copper, lead and aluminium. Levels of some metals are higher near Launceston and Deceitful Cove also appears to be an area of concern. However the data is too sparse to conclude this strongly. The data suggests that cadmium, zinc and copper may be of concern, this should be confirmed particularly as cadmium has high toxicity to biota and to humans.

Metals in Tamar sediments

No comprehensive evaluation of sediments in the Tamar Estuary has been carried out to date; however the work which has been done has been mostly concerned with heavy metal contamination. Two surveys were undertaken in 1973 and 1986, however, these studies are now over ten years old and, while helpful in establishing historical patterns of metals, they cannot be used to assess the current state of the Tamar Estuary. More recent studies by John Miedecke and Partners Pty. Ltd. (TEMCO/Comalco, 1992) and Gawne and Richardson (1992a; 1992b) were area-restricted, covering only Deceitful Cove and the lower estuary. Results of these studies are presented in Table 24 and Figure 24.



1974 Ayling (1974)
1986 Dept. of Environment (1986)
1992 TEMCO/Comalco (1992)
1992a Gawne & Richardson (1992a)
1992b Gawne & Richardson (1992b)

Figure 24 Metals in Tamar Estuary surface sediments

There are currently no sediment quality guidelines in place in Australia. It is thus necessary to rely on criteria established in other countries, primarily the United States and the Netherlands, and background levels such as the Global Shale Standard (Förstner and Wittmann, 1979). The criteria used in this report are quality standards developed for marine and estuarine sediments by National Oceanic and Atmospheric Administration, US Department of Commerce (NOAA). The criteria focus on biological effects of contaminants in sediments (Long and Morgan, 1990).

Table 24 Ranges of heavy metals in Tamar Estuary surface sediments compared with sediment quality guidelines

Metal	Ayling	DEP	TEMCO/ Comalco	Gawne & Richardson	Gawne & Richardson	Long & Morgan	
	1974	1986a	1992	1992a	1992b	1990	
	Mid Estuary	Entire Estuary	Deceitful Cove	Lower Estuary	Deceitful Cove	Sediment Quality Standards	
(μg/g)	15 Sites	4 Sites	44 Sites	10 Sites	6 Sites	ERL	ERM
Aluminium				600-11,500	1600-27800		
Arsenic			30-50				
Barium			520-4200	150-4200	200-7400		
Bismuth			7.8-19				
Cadmium	0.1-5.7	<1-2	4.9-16.5			5	9
Chromium	10.3-87.8		30-50			80	145
Cobalt			15-26				
Copper	3-224	2-52	42-130			70	390
Iron			13,000-24,000	750-12,700	850-11,300		
Lead	4.4-1457	3-37	5-1,750	6-515	130-580	35	110
Manganese			10-270,000	<1-129,520	21,340-147,667		
Mercury		0.1-0.43	0.25			0.15	1.3
Molybednum			8-64				
Nickel			110-320				
Selenium			0.24-0.76				
Tin			3-5				
Thorium			2.6-3.8				
Uranium			1.8-4.4				
Zinc	19-494	15-460	20-6050	9-2040	563-4717	120	270

ERL = effects range low - adverse effects 10% of the time

ERM = effects range median - adverse effects 50% of the time

In 1973, the Department of Environment tested surface sediments for metal content (5 metals) at 15 sites through the middle reaches of the Tamar Estuary. The results were reported by Ayling (1974). Cadmium, copper and zinc were generally highest in the sediments closer to Launceston. Zinc and copper were highly elevated at Gravelly Beach in the upper-middle estuary, and exceeded published criteria at several other sites. Concentrations of lead and copper were also somewhat elevated at Middle Arm. Cadmium levels near Launceston and chromium levels near West Arm were also approaching the criteria. The overall metal distribution is indicative of a source or sources of metals near Launceston, possibly related to urban run-off or to past industrial or mining activity. An additional source of metals also appears to be present in the vicinity of Middle Arm. Ayling (1974) reported the use of Middle Arm as a dump for mining wastes and tailings during the gold era and suggested that high metal concentrations in the sediments in this area are a legacy of past mining activity.

In 1986, the Department of Environment surveyed cadmium, copper, lead mercury and zinc concentrations in sediments from four sites throughout the Tamar Estuary. Although sample sites were limited, these results indicated slightly elevated levels of cadmium and highly elevated levels of zinc in the sediments near Launceston. Concentrations of zinc well in excess of the criteria established in the USA (Long and Morgan, 1990) were recorded at Home Reach. Zinc was also elevated in sediments from the middle estuary and in the lower North Esk River. The highest concentrations of copper and lead were at sites in the upper estuary, but were below the published criteria.

In 1990-91, an investigation of metals in the sediments downstream from the Batman Bridge (10 sites), including Deceitful Cove (6 sites), also suggested elevated levels of some metals in the upper estuary, with higher concentrations near Batman Bridge decreasing downstream (Gawne and Richardson 1992a). Concentrations of lead and zinc significantly exceed the published criteria for metals in sediments (Long and Morgan, 1990). The highest individual values of aluminium, iron, manganese, lead and zinc were recorded in Bell Bay.

Gawne and Richardson (1992b) found that with the exception of iron, levels of heavy metals in Deceitful Cove sediments were generally greater than those recorded in sediments from the main estuary. Concentrations of all metals in Deceitful Cove were elevated over background levels and indicative of contamination (Gawne and Richardson, 1992b). Levels of metals were higher in sediments near the top of the cove than at the mouth and in this respect, reflected the concentrations in the waters of Deceitful Cove. Similar values for barium, iron, lead, manganese and zinc in Deceitful Cove sediments were also recorded by John Miedecke and Partners Pty. Ltd. (TEMCO/Comalco, 1992). This study identified significantly elevated levels of lead, zinc, cadmium and manganese over background levels. In comparison with sediment quality criteria, concentrations of lead and zinc in Deceitful Cove significantly exceed the criteria implying severe contamination, particularly in the upper reaches of the cove.

John Miedecke and Partners Pty. Ltd. also examined the stability of the metals in the sediments (TEMCO/Comalco, 1992). The study found the metals to be relatively stable with the exception of cadmium which was observed to leach from highly contaminated clay material at the head of the cove. The study concluded that the silty sediments are unlikely to contribute significantly to the metal load in the Tamar River. However the high solubility of cadmium in the clay material could result in significant input of cadmium during periods of flushing (high rainfall or king tides). In addition, Miedecke detected concentrations of manganese, zinc, cadmium, lead and copper in pore waters of sediments in Deceitful Cove which were significantly greater than metal concentrations in the overlying water column. This concentration differential suggests that a general upward flux of metals into the overlying water column is likely during high tide. Dispersal of sediment into seawater also results in metal release from solids into solution. Concentrations of manganese, zinc, cadmium, copper and lead are elevated in pore water from the sediments; however the concentrations recorded are at or only slightly exceed the ANZECC water quality guidelines.

The existing sediment data is suggestive of historical metal contamination in the upper estuary near Launceston, with high concentrations of metals recorded in sediments from the upper reaches in 1973 and 1986. This is supported by the more recent data from 1990/91 which suggests that this trend is persisting with higher concentrations recorded at upstream sites (Gawne and Richardson, 1992a). In addition, the recent studies indicate significant metal contamination in sediments from Deceitful Cove, which is the receiving environment for effluent run-off from the Bell Bay industrial estate (Gawne and Richardson, 1992a; TEMCO/Comalco, 1992). Past studies have identified another possible 'hot-spot' of metal contamination at Middle Arm possibly as a result of the historical operation of a gold mine at Beaconsfield (Ayling, 1974). It is also possible that high metal concentrations in sediments are linked with areas of high industrial and shipping activity such as Bell Bay (Gawne and Richardson, 1992a). In general, sediments in the Tamar appear to be contaminated in various regions by high levels of lead and zinc and possibly also cadmium and manganese.

Metals in Tamar biota

Filter feeders filter large volumes of water, and in doing so can accumulate significant amounts of toxins. A number of investigations have been carried out in the Tamar Estuary using biota, particularly filter feeders, as indicators of the heavy metal contamination. However most of these studies were carried out over a decade ago, thus the data does not indicate present conditions in the Tamar Estuary. In addition, accumulated metals may remain in the tissues of biota long after the contaminant has disappeared from other parts of the environment (i.e water). Most studies on metals in biota have been concerned with metals in oysters. Oysters accumulate zinc, copper and cadmium to high relative levels. Zinc may produce emetic symptoms (vomiting) in humans if consumed in high enough concentrations and may accumulate to levels which are toxic to aquatic organisms, adversely affecting the ecosystem.

National Food Authority guidelines for metals in oysters, established by the National Health and Medical Research Council (NH&MRC), are shown in Table 25 below. These criteria are food standards rather than environmental guidelines, they are, however, the most suitable available guidelines with which to compare contaminants in biota. Table 25 and Figure 25 also show the ranges of metals in oysters recorded in the Tamar Estuary.

Table 25 Ranges of heavy metals in Tamar Estuary oysters compared with National Food Standards

Metal (µg/g)	Thrower & Eustace 1973a; 1973b Mid-estuary 3 Sites	Ayling 1974 Entire estuary 15 Sites	Ratkowsky et al. 1974 Mid-Estuary 3 Sites	DOE 1974/75 Deceitful Cove 5 Sites	DOE 1986a Mid-Lower Estuary 3 Sites	DOE 1986b Mid-Lower Estuary 6 Sites	*Gawne & Richardson 1992a Lower Estuary 17 Sites	*Gawne & Richardson 1992b Deceitful Cove 1 Site	TEMCO /Comalco 1992 Deceitful Cove 2 Sites	National Food Standard (metals in oysters)
Aluminium							10-76.3	33.5-44.3		
Barium							<2.5	<2.5		
Cadmium	3.8-14.6	1.0-19.2	2.29-14.59	0.4-0.9	1-7.8	0.8-47			0.37-0.42	2.0
Chromium		0-5.4		0.3-0.4						
Cobalt				0.1						
Copper	99-124	34-386	87.4-192.2	6.5-33	67-388	74-340			82-143	70
Iron				33-353			43-147	82.5-92.5		
Lead		0-29.5		0.3-0.5	<0.5	<0.5-0.9	0.05-0.4	0.15-0.4	0.29-0.47	0.5
Manganese				3.1-10			7.8-134	25.5-134		
Mercury				0.4-0.5		0.04-0.22				0.5
Nickel				0.2						
Zinc	802-1600	394-2086	451-1602	284-386	557-2037	320-1570	663-3050	1435-2247	484-678	1,000

* Gawne and Richardson reported results on a dry weight basis. To allow comparison between studies and the National Food Standards, the results were converted to a wet weight basis. The oysters contained around 75% moisture (Gawne and Richardson, 1992a) therefore the DMF was 0.25. Dry weight values were multiplied by DMF to determine wet weight results.

** Oyster species *Ostrea angasi* rather than *Crassostrea gigas*.

Commercial leases of the oyster *Crassostrea gigas* were set up in the Tamar Estuary in the mid 1960s and in the Derwent Estuary a few years later. Concern in the early 1970s over the quality of oysters grown on leases in the Derwent, prompted several investigations into levels of metals in oysters around the state. Three studies in the early 1970s (Thrower and Eustace, 1973a; 1973b; Ayling, 1974; Ratkowsky, 1974) obtained similar results for metal concentrations in oysters taken from the Tamar Estuary. Thrower and Eustace (1973a; 1973b), Ayling (1974) and Ratkowsky et al. (1974) all reported levels of cadmium, copper and zinc in excess of the current Australian Food Standards throughout the estuary, but particularly in the upper reaches. Ayling (1974) also found levels of lead in the upper estuary which exceeded the food standards, and elevated concentrations of lead and zinc at Middle Arm. A tentative correlation was established between concentrations of metals in oysters and sediments. Ayling concluded that on the basis of these results, the region upstream from Middle Island, and Middle Arm were unsuitable for the production of shellfish due to high levels of cadmium, zinc and lead.

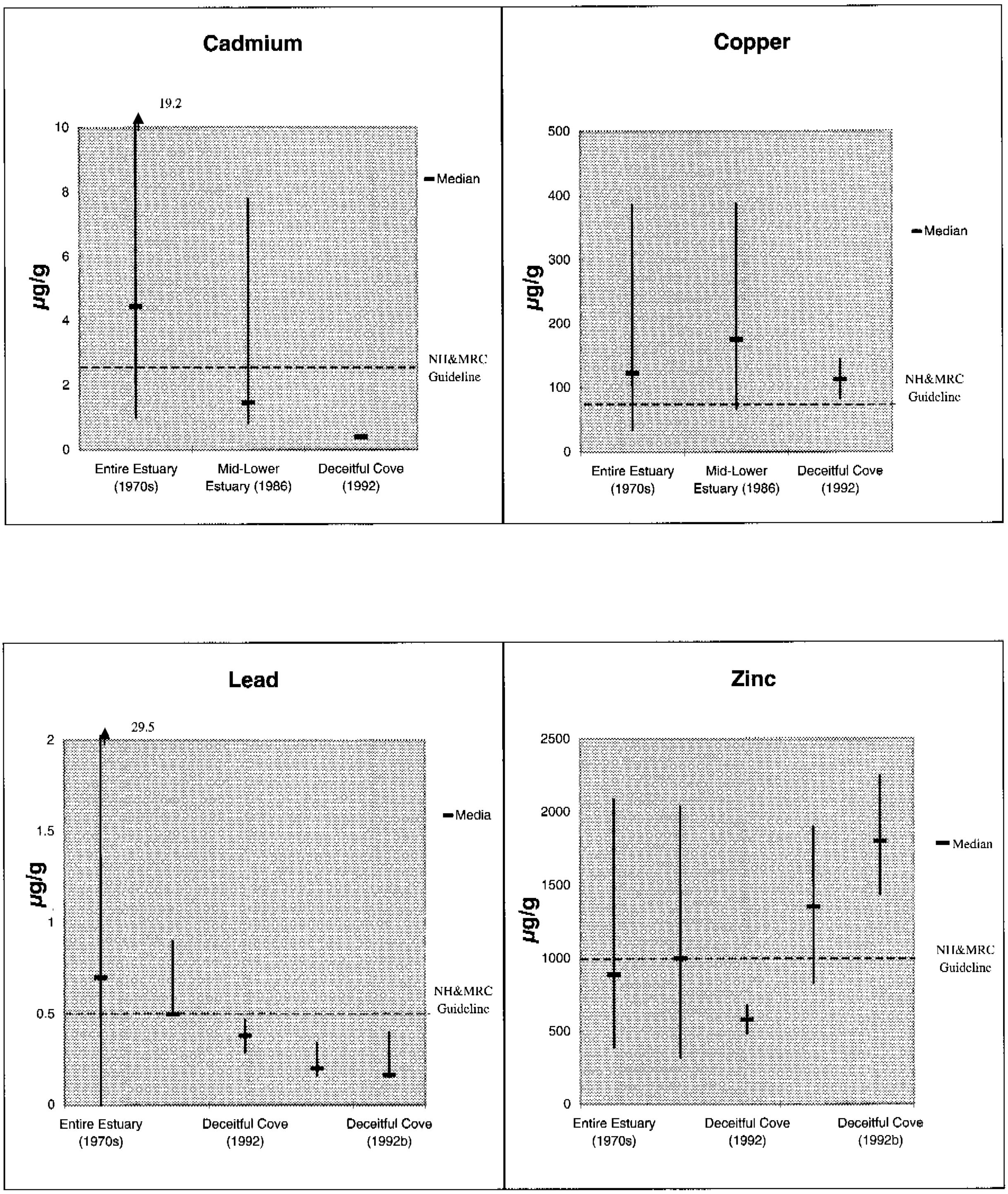
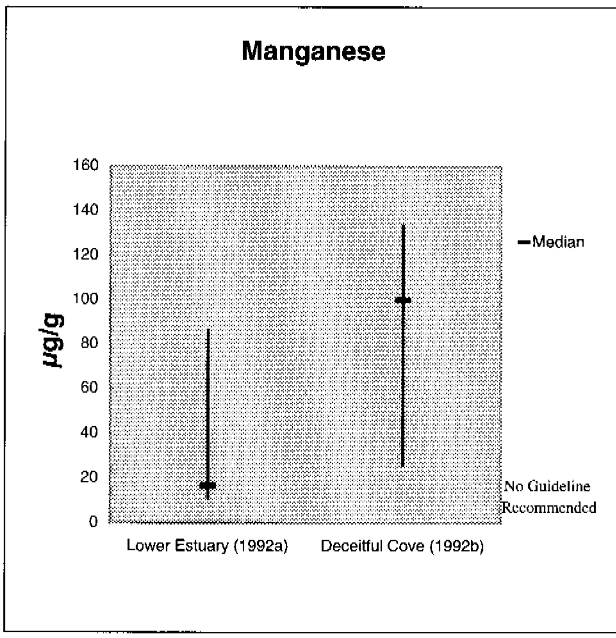
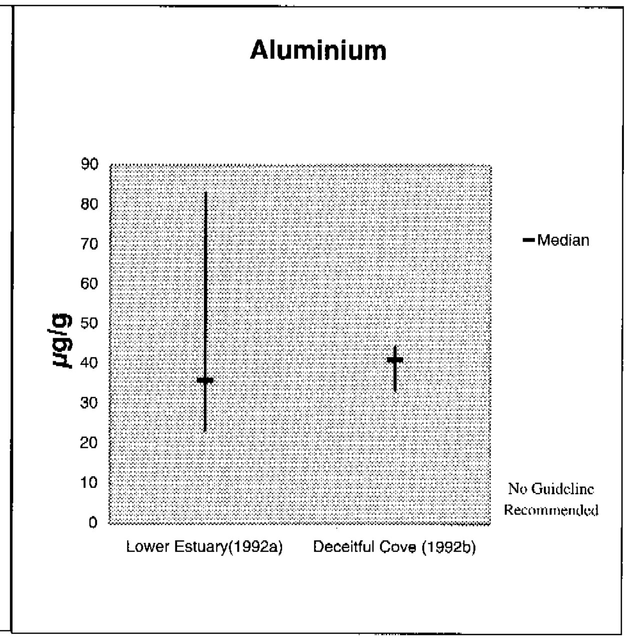
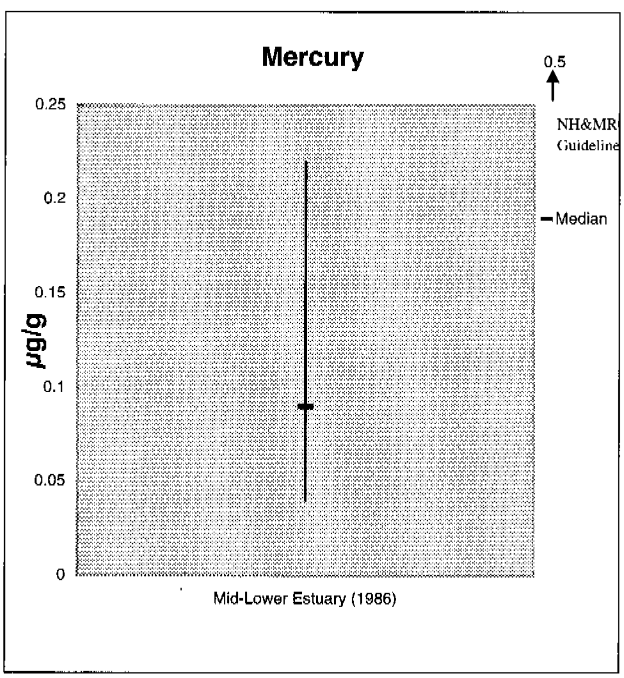


Figure 25 Metals in Tamar Estuary Oysters







1970s	Thrower and Eustace (1973a; 1973b)
	Ayling (1974)
	Ratkowsky et al. (1974)
1986	Department of Environment (1986a)
	Department of Environment (1986b)
1992	TEMCO/Comalco (1992)
1992a	Gawne & Richardson (1992a)
1992b	Gawne & Richardson (1992b)

Figure 25 Metals in Tamar Estuary Oysters

In 1974, a study was completed which examined the use of sand flathead as an indicator species for mercury in Tasmanian waters (Dix and Martin, 1975). The range of mercury in sand flathead in the Tamar Estuary was 0.02-0.1 mg/kg, with an increase in mercury concentrations from the top of the estuary to the mouth. The concentrations were well below the NH&MRC Food Standard level of 1 mg/kg for mercury in flathead.

The Department of Environment conducted a survey of metals in the native oyster *Ostrea angasi*, in Deceitful Cove in 1974. The results indicated levels of lead and mercury equaling the current National Food Standards for metals in oysters. Other metals were below the current guidelines.
Two separate surveys (6 sites and 3 sites) of metals in oysters in the Tamar Estuary were carried out in 1986 by the Department of Environment (Department of Environment, 1986a; 1986b). The results revealed significantly elevated levels of cadmium and copper in the middle estuary and also highly elevated copper concentrations in the lower estuary. Zinc levels exceeded the National Food Standards in oysters from several sites in the estuary, while levels of lead and mercury were found to be well within the guidelines.

A more recent investigation into metals in oysters was carried out by Gawne and Richardson (1992a; 1992b) at 17 sites in the lower Tamar Estuary and 1 site in Deceitful Cove. Gawne and Richardson (1992a) observed that the metal content of oysters in the lower Tamar Estuary fluctuated characteristically with season and with the sexual cycle of the animal. In comparison with world data, the concentrations of manganese and zinc were very high, particularly near Deceitful Cove. Zinc levels exceeded the National Food Standards by up to three times. In Deceitful Cove oysters, manganese and zinc were higher than in oysters from the Tamar Estuary, while other metals remained similar. The principal finding of the study by Gawne and Richardson (1992a; 1992b) was that concentrations of zinc in oysters from the lower Tamar Estuary caused them to be unfit for human consumption. The findings also suggest greater bio-availability of zinc and manganese within the cove and indicate a probable source in the vicinity of Deceitful Cove (Gawne and Richardson, 1992a).

John Miedecke and Partners Pty Ltd (TEMCO/Comalco, 1992) found similar concentrations of lead in Deceitful Cove oysters to those recorded by Gawne and Richardson (1992b); however concentrations of zinc were lower. Both these metals were below the National Food Standards. Concentrations of cadmium and copper were also tested by Miedecke. Copper was the only metal found to be significantly elevated in oysters. John Miedecke and Partners Pty. Ltd. (TEMCO/Comalco, 1992) also investigated bio-accumulation of metals in crabs, fish and algae (ranges shown in Table 25). Elevated levels of some metals were evident in crabs and algae; however fish caught in the area did not show significant accumulation.

It appears that zinc and also possibly cadmium, copper and lead are a concern in terms of accumulation by aquatic organisms in the Tamar Estuary. Historical studies show that metals have generally been higher in biota in the upper estuary near Launceston. More recent investigations are indicative of significant bio-accumulation of metals in the lower estuary, particularly in the vicinity of Deceitful Cove. Studies have shown that certainly zinc, and possibly cadmium, lead and copper are reaching levels in bivalves in the lower estuary and possibly other regions of the estuary also, which may be harmful to consumers and to the ecosystem.

In summary, metals which appear to be high in the waters, sediments and biota of the Tamar Estuary include zinc, manganese, aluminium and possibly cadmium, lead and copper. Areas which appear to be most affected include Deceitful Cove and the Bell Bay area, the upper reaches of the estuary near Launceston, and possibly Middle Arm. The most significant problem identified appears to be the elevated concentration of zinc in oysters in the lower estuary. It is recommended that metals in the estuary be fully investigated in biota, water and sediments, and sources be identified.

Fluoride

Although fluoride is known to adversely affect terrestrial ecosystems at high concentrations - damaging vegetation and weakening bones and teeth of animals, effects on the marine environment have not been well documented, and ANZECC (1992) does not list any guideline for fluoride concentrations for the protection of aquatic ecosystems. According to Gawne and Richardson (1992b), concentrations recorded in the lower Tamar Estuary in 1990/91 are comparable with background levels (1.35 mg/L in average oceans). Monitoring by the Department of Environment recorded lower fluoride levels in the upper regions of the estuary, compared with slightly higher concentrations in the lower reaches; however the results were generally similar to those in average oceans. Concentrations were found to be elevated at Big Bay Point, near Bell Bay (Figure 26).

6.7 Organic toxicants

Hydrocarbons

In response to the grounding of the *Iron Baron* in 1995 (see Section 4.9), the Department of Environment and Land Management investigated hydrocarbon levels in wild and sentinel oysters from the Tamar and Port Sorell Estuaries. A histopathological assessment of oysters and fish was also done to determine damage such as lesions and tissue damage which may result from oil residue toxicity (DELM, 1996). The long term monitoring program was initiated 6-7 weeks after the oil spill.

In the Tamar Estuary, hydrocarbon concentrations in wild oysters (*Crassostrea gigas*) ranged from 1 mg/kg to 27 mg/kg (wet weight). In comparison to world data (Table 26), these levels do not indicate significant long term effects resulting from the *Iron Baron* spill (DELM, 1996). Maximum values measured early in the monitoring program, shortly after the spill, approached levels which could be classified as representative of a polluted system

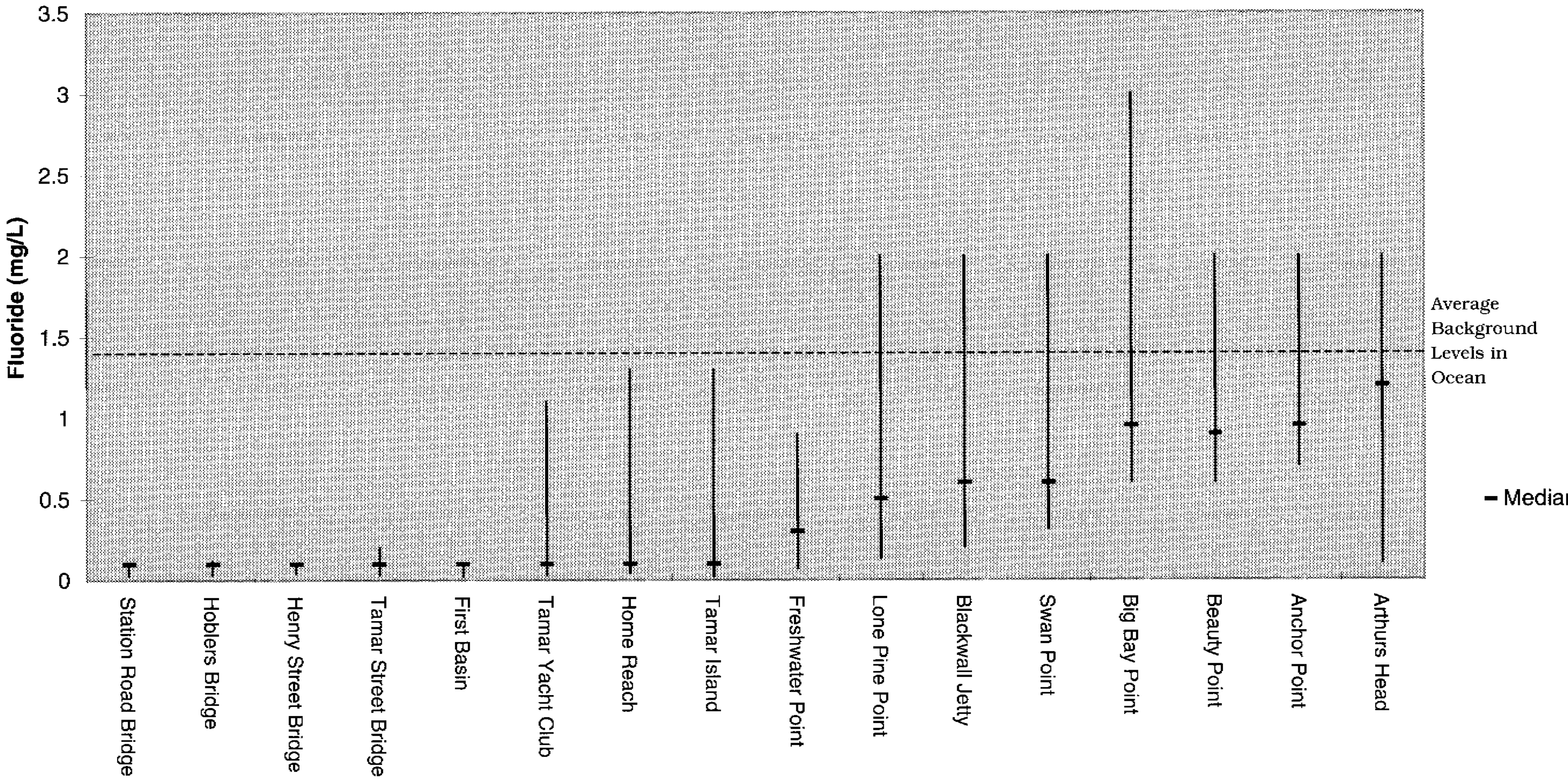


Figure 26 Fluoride - Tamar Estuary Monitoring Program 1988-1996
Bar represents range of values measured.
See Figure 16 for sampling locations.

Table 26 Hydrocarbon concentrations in Tamar Estuary bivalves compared with values reported elsewhere

Location	**Species**	**Total Hydrocarbons** (mg/kg wet weight)	**Reference**
Port Sorell and Tamar Estuaries	*Crassostrea gigas*	1-41	Department of Environment and Land Management (1996)
Amoco Cadiz oil spill Brittany (France)			Laubier (1978)
polluted	*Crassostrea gigas*	150-400	
unpolluted	*Crassostrea gigas*	30-40	
North-western Australia			Pendoley (1992)
unpolluted	*Saccostrea cucculllata*	1-4.9	
Kuwait	*Pincutada margaratiera*	5.6	Anderlini *et al.* (1981)
Spain			Risebrough *et al.* (1983)
unpolluted	*Ostrea edulis*	4.5	
unpolluted	*Mytilus galloprovinciatis*	3.7	
polluted	*Mytilus galloprovinciatis*	33.5-806	
California			Risebrough *et al.* (1983)
unpolluted	*Mytilus californianus*	0.8-2	
polluted	*Mytilus edulis*	35-61	
Western Australia			Burt & Ebel (1995)
unpolluted	*Mytilus edulis*	>0.001-1.0	
Eleni V oil spill Norfolk (England)			Blackmann & Law (1981)
polluted	*Mytilus edulis*	80-265	
unpolluted	*Mytilus edulis*	6	

(Department of Environment and Land Management, 1996)

The histological report did cite some findings of damage in the reproductive and digestive organs of oysters consistent with the type of damage induced by petroleum products, however, the degree of damage was considered to be within the natural variability of an uncontaminated oyster population. Similarly, the liver and gills in fish examined were consistent with oil residue toxicity, but within the normal physiological variation of the species (DELM, 1996).

The low level of hydrocarbon contamination would at first seem surprising after a fairly major oil spill. It is probable that the timing of the grounding at high water spring tide, coupled with a prompt clean-up, minimised contamination in the intertidal zone. Most of the grounded oil was within the supra-littoral zone and was removed before it could be washed back into the lower intertidal areas. Where the cleaning operation was not immediate, as at North Lagoon Beach, a small amount of *Iron Baron* oil was detected. It appears that the impact of the oil spill both immediate and in the long term on the wild benthic bivalve population, as assayed through their hydrocarbon content, was not significant (DELM, 1996).

Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) occur naturally in the environment; however their main sources are related to human activities. PAHs are introduced into the environment via spillages of petroleum hydrocarbons (i.e. shipping operations) or more frequently, by combustion or as a result of urban run-off. As such, high concentrations are usually found near population centres and industrial operations. Concern over PAHs relates to the fact that some are known to cause cancer in man and higher animals, although not all are carcinogenic. The most well known carcinogen is benzo (a) pyrene. The toxic effects of PAHs in the aquatic environment may be either acute or immediate toxicity to aquatic life, caused by PAHs with 2-3 rings, or chronic long term effects such as cancer which are caused by 4, 5 and 6 ringed compounds. PAHs with more than 6 rings are generally inactive (Gawne and Richardson, 1992a).

Water solubility of most PAHs is extremely low and they are usually sorbed onto particles soon after entering a water body. However PAHs are very soluble in animal fat and tend to bio-accumulate in the tissues of organisms. Oysters and mussels are good bio-indicator species for PAHs in the environment, as they do not excrete PAHs as metabolites and they can accumulate PAHs without the deleterious effects suffered by fish (Gawne and Richardson, 1992a). The concentrations of PAHs are generally lowest in the water column, intermediate in biota and highest in the sediments (ANZECC, 1992). According to the current Australian guidelines, concentrations of polycyclic aromatic hydrocarbons in fresh and marine waters should not exceed 3 µg/L (ANZECC, 1992).

PAHs are introduced into the Tamar Estuary in wastes from TEMCO and other industrial and urban sources (Gawne and Richardson, 1992b). PAHs in the waters of Deceitful Cove were tested in 1990-1991 and were found to be range from <0.02 to 11.81 µg/L. The ANZECC guideline was exceeded in several instances, mostly by the lower molecular weight PAHs. The highest concentrations tended to occur in the upper reaches of the cove where the effluent is first received. Levels of benzo (a) pyrene in the upper reaches and in TEMCO effluent occur at concentrations which are typical of industrial run-off. However during high tide, concentrations near the mouth of the cove are below the detection limit, demonstrating that effective dilution occurs. Gawne and Richardson (1992b) concluded that PAH concentrations in the effluent itself are below the level which is directly lethal to marine life, but conceded that the concentrations could cause a range of sublethal effects in sensitive species if sufficient dilution did not occur.

ANZECC has no established guidelines for contaminants in sediments. However criteria established in the USA for PAH levels in sediments are given by Long and Morgan (1990). The level stated in this literature for acceptable concentrations of benzo (a) pyrene is an ERL of 400 µg/kg, and the ERM value is 2500 µg/kg.

The levels of PAHs in sediments in the lower Tamar Estuary, including Deceitful Cove, were tested in 1990/91 by Gawne and Richardson (1992a; 1992b). The highest PAH levels were recorded in areas where shipping or boating activity is common and where urban and industrial run-off is likely. Concentrations of benzo (a) pyrene in the lower Tamar Estuary ranged from <1 µg/kg to 300 µg/kg and <10 to 200 µg/kg in Deceitful Cove, although some PAHs ranged up to 1140 µg/kg (fluoranthene). Compared with USA criteria for benzo (a) pyrene in sediments, the concentrations in the Lower Tamar Estuary and Deceitful Cove are quite low. No values of benzo (a) pyrene exceeded either the ERL or the ERM criteria. On the basis of the ratings suggested in Table 27 (Murray et al., 1989 *cited in* Gawne and Richardson, 1992a), no severely PAH contaminated sediments were identified in the Tamar Estuary and concentrations typical of urban areas occurred only near the Comalco Wharf.

Table 27 Benzo (a) pyrene levels which indicate extent of pollution in estuaries

Degree of contamination	Concentration of Benzo (a) pyrene (μg/kg)
Pristine sediments	<20
Urban sediments	100-1,000
Severely contaminated sediments	>1,000

(Murray et al. 1989 *cited in* Gawne and Richardson, 1992a)

The survey by John Miedecke and Partners Pty. Ltd. (TEMCO/Comalco, 1992) found much higher concentrations of benzo (a) pyrene, ranging from 550 μg/kg to 12,220 μg/kg. These values exceeded the ERL criteria at all sites; however the ERM value was exceeded in only two samples which were taken from the very head of the cove where the effluent enters. Despite elevated levels in some areas, the PAHs in Deceitful Cove sediments were found to be stable, with little risk of them entering the Tamar Estuary via leaching. Dispersion of sediment into the Tamar Estuary is also unlikely to significantly increase the dissolved concentration of total PAHs (TEMCO/Comalco, 1992).

It has been suggested that PAH levels in oysters exceeding 20 μg/kg are indicative of contamination (Murray et al., 1989 *cited in* Gawne and Richardson, 1992a). Gawne and Richardson (1992a) discovered PAH concentrations ranging from <1 to 38.3 μg/kg in the Lower Tamar Estuary and Deceitful Cove (Gawne and Richardson, 1992a; 1992b). The benzo (a) pyrene concentrations which ranged from <1 to 13 μg/kg remained below the level indicative of contamination in all samples. Levels nearing 20 μg/kg were only rarely found, and while some of the lower PAHs exceeded the value, none were indicative of large scale contamination. PAH concentrations were highest in January close to spawning, when oysters contain high concentrations of lipids. Based on these findings, it is unlikely that PAHs exert an influence in the lower Tamar Estuary or Deceitful Cove (Gawne and Richardson, 1992a; 1992b). However John Miedecke and Partners Pty. Ltd. (TEMCO/Comalco, 1992) did find evidence of PAH accumulation in oysters, crabs and seaweed in Deceitful Cove. Concentrations of PAHs in Deceitful Cove oysters ranged from <1 to 1810 μg/kg, with the PAH content in several samples being highly elevated. PAH levels in crabs, algae and fish in Deceitful Cove were similar when compared with samples collected from other areas of the estuary, although slight elevation in crabs and algae was noted. Fish caught in the areas showed no significant accumulation in the tissues (TEMCO/Comalco, 1992).

Phenols

Phenols are used in large quantities as raw materials in the manufacture of plastics, dyes, drugs, wood preservatives, herbicides and other chemicals. Phenolic wastes are also produced during the coking of coal, distillation of wood, in oil refineries and in pulp and paper industries. Effluents from these processes represent obvious sources of phenolic contamination in the aquatic environment; however phenols may also be present as a result of natural processes such as the degradation of complex organic substances (Australian Water

Resources Council, 1984). The persistence of phenols in the aquatic environment is variable. However some phenols have been shown to degrade in natural waters. Individual phenolic compounds vary widely in their toxicity to aquatic organisms (ANZECC, 1992). Toxicity may arise as a result of direct toxic action or through low oxygen levels brought about by the BOD of the phenol. The toxicity is increased by low dissolved oxygen levels and also increases with salinity (Australian Water Resources Council, 1984). ANZECC guidelines for the protection of the aquatic ecosystem recommend that levels of phenols in marine waters should not exceed 0.2 to 50 µg/L, depending on the specific compound.

Phenol concentrations in water measured at 26 sites in the lower Tamar Estuary by Gawne and Richardson (1992a) were found to range from <10 to 255 µg/L (see Table 28). Values exceeding the high range of the current ANZECC guidelines for phenols were recorded near the Batman Bridge, north and south of the Comalco outfall and Bell Bay beacon. The latter three sites are in areas with high shipping activity which may account for the elevated concentrations. High phenol values at Batman Bridge reflect the distribution patterns of several heavy metals, suggesting an upstream source of these contaminants. However as no monitoring has been undertaken in the region upstream from the Batman Bridge, this is purely speculative. Phenol levels were also found to be elevated and well above the ANZECC guidelines in the upper reaches of Deceitful Cove (range from <10 to 3450). Substantial differences in concentrations occur at high and low tides in the cove, indicating that considerable flushing takes place during high tide periods.

Table 28 Phenol concentrations in lower Tamar Estuary and Deceitful Cove (1990/91)

Gawne & Richardson 1992 Lower Estuary	Gawne & Richardson 1992 Deceitful Cove	ANZECC Guidelines 1992
<10-255 µg/L	<10-3450 µg/L	0.2-50 µg/L

Pesticides

The presence of pesticides is generally due to direct application to the environment through agricultural, forestry or domestic activities. Pesticides find their way into natural waters via accidental spillage, spray drift, run-off after rain or via atmospheric deposition (ANZECC, 1992). DDT and Dieldrin are organochlorine pesticides, with low water solubility but high solubility in animal fat, and have high chemical and biological stability. The general persistence of organochlorines in the environment results in a greater chance of contact with non-target organisms. In addition to accumulation through direct contact, organochlorines may also bio-accumulate along the food chain. ANZECC guidelines for DDT in water are set at 1 ng/L and for Dieldrin, the suggested guideline is 2 ng/L.

DDT and Dieldrin levels in Tamar Estuary water were monitored by the Department of Environment from 1971 to 1981 (Department of Environment, 1971-1981) and were found to be well below the recommended maximum guidelines and approaching detection limits. Monitoring failed to detect these pesticides after 1978 and was eventually discontinued.

7 Sedimentation and dredging

7.1 Siltation in the Tamar Estuary

The Tamar Estuary has a high sedimentation rate, which results in the build-up of extensive intertidal mud-banks in the upper reaches near Launceston. This siltation seriously affects the navigation channel, limiting the size of ships which can safely pass up-river and making access to areas of the estuary beyond Rosevears more difficult. The rapid deposition of sediments has also reduced recreational opportunities and has become a major concern to the boating public and to communities surrounding the estuary, with many people considering the mudbanks unsightly. To provide for recreational boating and to maintain the aesthetic appeal of the Tamar environs, extensive dredging has been carried out in Home Reach. The natural regime of siltation and flushing in the Tamar Estuary results in a low capacity channel, which reduces the ability of the estuary to pass major flood flows (Tamar River Improvement Projects Committee, 1995).

Although the Tamar Estuary has a high rate of siltation, it is related more to the hydrology of the estuary than to the amount of sediment input - which is considered to be relatively small, for such a large catchment. Much of the problem stems from the redistribution of previously deposited silts by tidal and river flows. Sources of particulates to the Tamar Estuary include sediment supplied by the rivers, scour of old silt deposits by tide and floods, drainage from mud flats and biochemical sources of particulates within the estuary.

According to Foster et al. (1986), the tributaries of the Tamar Estuary have relatively low sediment yields, characteristic of catchments with mainly forested and pastoral land. Little coarse material enters the Tamar from the South Esk River, as the majority of the bedload is trapped by the Trevallyn Dam. The mean annual sediment load from the South Esk River has been estimated at 39, 300 tonnes. Skirving (1986) estimated that sediment loads from the smaller North Esk Basin were in the order of 3500 to 4700 tonnes.

In addition to sediments introduced to the Tamar by freshwater flows, previously deposited silts also provide a major sediment source as they are redistributed by the combined action of river flow and tides (Tamar River Improvement Project Committee, 1995). Redistribution occurs mostly in the main channel where sediments are relatively unconsolidated. An indirect estimate of the scour and deposition in the Tamar Estuary indicates that river flows in excess of 150 m^3/s will induce bed scour in the upper reaches. In general, floods flush out the upper reaches of the river, only for the sediments to be returned later by tides under conditions of low flow. The pattern of siltation or erosion throughout the estuary is therefore very dependent on the variability of river flows. Diversion of water from Great Lake in the Derwent catchment to the South Esk catchment (via Poatina Power Station) has reduced the incidence of low river flows and, as a consequence, the rate of siltation has decreased significantly. The build up of silt in Home Reach is generally around 30,000 cubic metres each year; however it may reach 100,000 cubic metres during years when flushing floods in the estuary are absent or infrequent (Tamar River Improvement Program Committee, 1995).

It is possible for tidal mudflats to act as sources of sediment to the estuary as a result of tidal drainage during the falling tide and freshwater run-off after rainfall. However intertidal sediments tend to show a high resistance to scouring due to constant wetting and drying. Mud banks are not considered to be a major sediment source to the main river channel except under conditions of severe wave action, which may destroy the surface structure and allow more rapid scour to occur. This effect is found to be relatively small compared with tides and floods (Foster et al., 1986). Biomass growth and the 'salting out' of dissolved solids are two biochemical siltation mechanisms which occur in the Tamar Estuary, however, the contribution to siltation from these sources is expected to be low (Foster et al., 1986).

7.2 Dredging

Prior to the 1950s, the main problem resulting from siltation was related to maintaining sufficient depth and channel width for navigation purposes. However, since the relocation of primary port facilities from Launceston to Bell Bay, the principal issues have been increased risks of flooding to Launceston and the effect of siltation on the aesthetics and recreational uses of the estuary. In an attempt to minimise these problems, the area of the estuary near Home Reach has been dredged at varying levels of intensity since 1890. Initially, dredging was limited to the vicinity of Queens Wharf and the bar at the mouth of the North Esk River. There was little need for dredging in the main channel at that time, as depths were sufficient for the size of boats using the Launceston Port. As access for larger vessels became necessary from the early to mid 1900s, extensive maintenance dredging of the main channel was required. Regular maintenance dredging of the river was discontinued in 1965 when road and rail links virtually eliminated the need for large ships to use the upper reaches of the river. As a result, the estuary began to revert to its natural state with a low capacity channel and extensive intertidal mud-flats. Maintenance dredging in Home Reach recommenced over a decade ago.

The Tamar River Improvement Project Committee (TRIPC) was formed in 1988 with representation from the Tasmanian Government, the City of Launceston, the Municipality of Beaconsfield and the Port of Launceston Authority (PLA). The participating bodies agreed to contribute appropriate funds to implement a program of dredging, silt trapping and stabilisation of mudflats (Tamar River Improvement Project Committee, 1995).

Currently, the primary objectives of dredging in Home Reach are:

- to enlarge the waterway area so that peak floods are kept as low as possible thus minimising the risk of overtopping the flood levees;
- to ensure that the mud-banks do not rise above mean tide level and become too dry for scouring to occur during floods;
- to maintain the navigation channel for commercial and recreational users and maintain the access to maritime facilities - principally Kings Wharf and the Yacht Basin; and
- to improve visual amenity and access to the river.

(Tamar River Improvement Projects Committee, 1995)

Dredging and silt deposition sites

From 1987 to December 1996, the Tamar River Improvement Projects Committee has commissioned the dredging of approximately 750,000 m^3 of material from the river banks and channel upstream from Stephensons Bend (see Figure 27, Table 29) at a total cost of around $4 million. These dredging operations are predominantly maintenance dredging, removing freshly deposited silt from the river banks and channel.

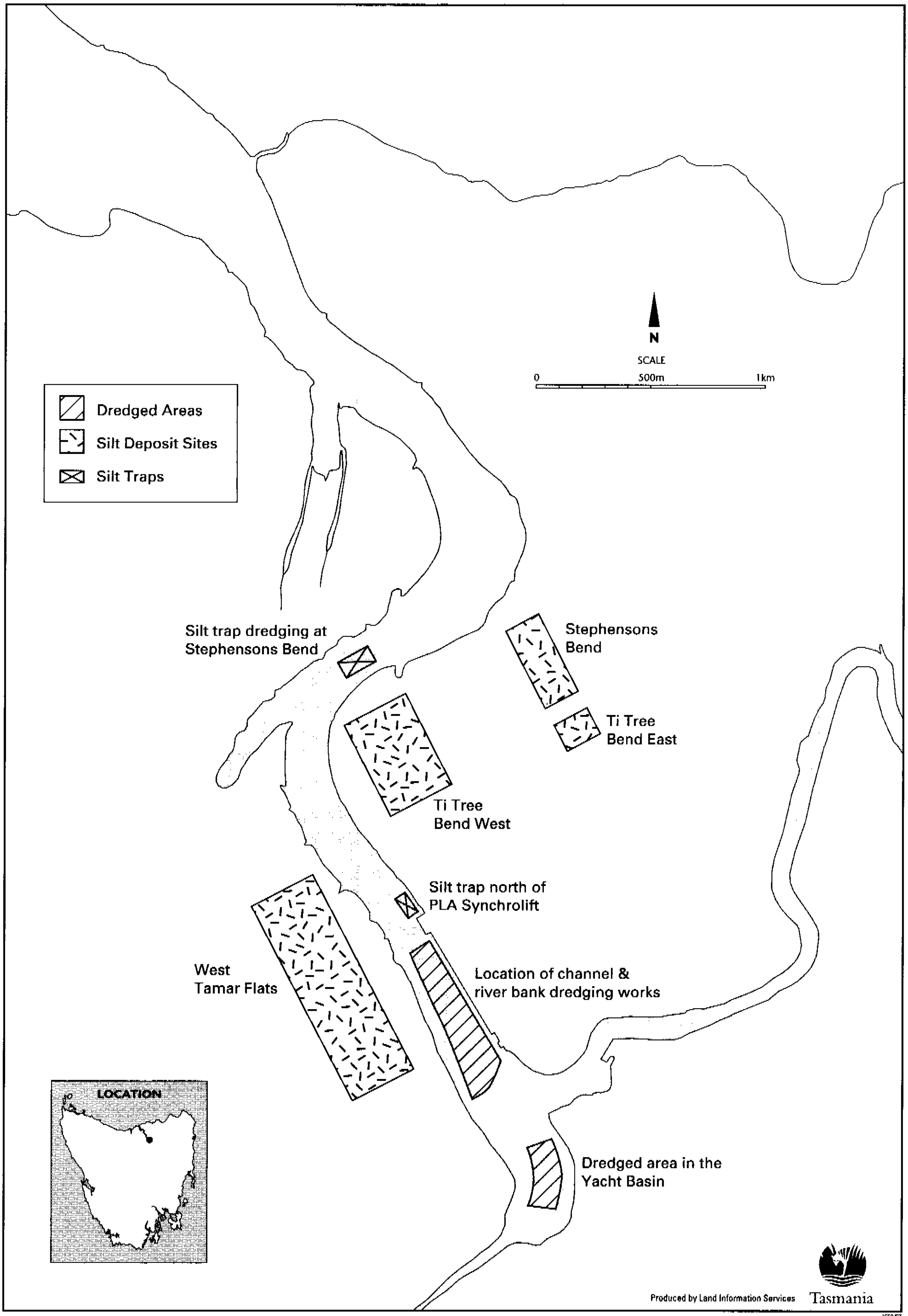


Figure 27 Dredged areas and silt deposit sites in Home Reach

Table 29 Dredging in the Tamar Estuary since 1987 - locations, volumes and costs

Contractor	Contract period	Dredge area	Dredge volume	Contract sum	Deposit area
Port of Launceston Authority	1987	East bank at the northern end of the yacht basin	10,000 m^3 (rock & silt)	$500,000	PLA land at Ti-Tree Bend East
Tasmanian Dredging Services	Jun 1988 to Dec 1990	West bank in Home Reach between the synchrolift and the North Esk River	122,000 m^3 (silt & debris)	$1,000,000	West Tamar Flats - 90,000 m^3 Ti-Tree Bend West - 32,000 m^3
Hazell Constructions	Jun 1991 to Jan 1992	Yacht Basin	50,000 m^3 (rock & silt)	$880,000	PLA land at Ti-Tree Bend East
Ron Read Dredging	Nov to Dec 1990	Stephensons Bend	12,000 m^3	$65,000	Ti-Tree Bend West
Tasmanian Dredging Services	Jul 1993 to Jan 1994	North of the Synchrolift in Home Reach Stephensons Bend	200,000 m^3 20,000 m^3	$200,000	Ti-Tree Bend West
L.D. Marine	Jan 1994 to Aug 1994	West bank in Home Reach between the synchrolift and the North Esk River	85,000 m^3	$340,000	West Tamar Flats - 65,000 m^3 Ti-Tree Bend West - 25,000 m^3
L.D. Marine	Mar 1995 to Sep 1995	East bank and channel between the synchrolift and the wheat berth	70,000 m^3	$290,000	Ti-Tree Bend West
*L.D. Marine	Sep 1996 to present	Home Reach	180,000 m^3	$756,000	Launceston Church Grammar School land at Stephensons Bend - 140,000 m^3 Ti-Tree Bend West - 40,000 m^3
TOTAL			***750,000 m^3***	***$4,031,000***	***> 392,000 m^3***

* Anticipated schedule for the current contract. As of July 1997, approximately 40,000 m^3 of material had been dredged from the yacht basin area.

Available sites for deposition of the dredge spoils in the vicinity of the Tamar Estuary are nearing capacity. At the completion of the current dredging contract, it is estimated that the remaining capacity of the prepared silt deposit areas at West Tamar Flats and Ti-Tree Bend West will be 30,000 m^3 each, for a total available capacity 60,000 m^3. This estimated available capacity will be confirmed following completion of the current dredging works. In an attempt to find an alternative for the deposition of dredge spoils, the recycling of silt mixed with sewage sludge for use as marketable fill has been proposed.

Environmental implications associated with dredging

Several environmental issues are associated with the implementation of dredging to control siltation. Dredging may cause the remobilisation of contaminants, which were previously relatively stable in the bottom sediments, resulting in higher bioavailability and potential impacts on the ecosystem. The disposal of dredge spoils adjacent to a water body also has significant environmental implications. Long term seepage of contaminated water may result, re-introducing pollutants to the waterway. Currently, the silt and debris dredged from Home Reach is placed in prepared silt deposit ponds adjacent to the estuary; inputs of contaminants from this source have not been quantified. Impacts on wetlands have also not been assessed.

Given the rapid filling of existing silt deposit areas adjacent to the Tamar, there is a need to identify viable alternative disposal sites. Land disposal of dredged materials requires careful consideration and is restricted according to guidelines developed by Environment Tasmania for the disposal of contaminated soils. In some cases, the disposal of dredged materials into deeper parts of the estuary could be considered, however, the flushing regime of the Tamar Estuary is such that dredged silt would need to be taken almost to the mouth of the estuary to prevent it from migrating back upstream.

Limited testing has been carried out on material dredged from the Tamar Estuary. In 1993, composite samples of dredged material and associated vegetation were collected from ten silt deposit ponds of varying ages (<1 to >18 years) near the Tamar. These samples were analysed for heavy metals (both total and DTPA-extractable), pH and nutrients (Department of Primary Industry and Fisheries, 1993). As indicated in Table 30, elevated concentrations of cadmium, chromium and zinc were found in a number of these samples, and cadmium was found to be readily leached. On the basis of guidelines established by Environment Tasmania for the off-site disposal of contaminated soils, it appears that 30 to 50% of the samples may be unsuitable for use as fill due to elevated concentrations of cadmium and zinc. Furthermore, chromium concentrations in all samples exceeded the guidelines.

Table 30 Metal concentrations in dredged silt from the Tamar Estuary

mg/kg	Total metal concentration range in Tamar dredge spoils	DTPA-extractable metal concentration range in Tamar dredge spoils	Environment Tasmania guidelines for disposal as fill
Cadmium	0.3-5.3	0.04-2.00	3
Nickel	24-39	0.34-1.94	60
Lead	4-63	ND-5.0	300
Chromium	53-79	ND	50
Iron		290-840	
Manganese		10-400	
Zinc	92-480	5-69	200
Copper	14-48	0.4-11.8	60

(Department of Primary Industry and Fisheries, 1993)

There was no clear difference in metal concentrations between older and more recently dredged material, suggesting that there is a continuing source of heavy metal contamination to the estuary. The main source of contaminants in the sediments of the upper Tamar Estuary is generally assumed to be historical mining activities in the South Esk catchment (Section 4.5) which ceased in 1982, however, mining wastes continue to leach into the river system. Other historic sources - particularly for chromium - may also be present in the Launceston urban/industrial areas. Further monitoring of metals in sediments and dredged materials is recommended.

In addition to implications of dredging associated with contaminants in the environment, silt deposition on mudflats near the estuary may also affect wetland habitat. Much of the upper region of the Tamar Estuary is protected as a nature reserve and is a refuge for a diversity of wildlife. Deposition of silt on the mud flats and the trapping of silt by vegetation is likely to accelerate the natural process of silt accretion and may significantly alter wetland habitats.

7.3 Remediation and prevention measures

An investigative program is currently underway to address the siltation problem and manage maintenance dredging on a wider basis. This has involved identifying areas of erosion and accretion in the river bed, which areas should be dredged and how much should be removed. Regular monitoring of the river bed in the upper reaches of the Tamar has been carried out to measure silt accretion, shifting channels and scour during floods. A physical hydraulic model of the river system has also been recommended by TRIPC (Tamar River Improvement Projects Committee, 1995).

Trials using various prevention and remediation measures have been carried out, including the following.

- The establishment of silt traps at strategic points in the river bed to reduce the cost of pumping dredged silt to deposition sites.
- Trial methods of mud bank stabilisation by silt accretion, including artificial seaweed, drift fences and natural vegetation (both plantings and brushwood fencing). As early as the 1940s, the rice grass *Spartina anglica* was introduced in an effort to trap sediment and reduce siltation in the main channel.
- Reducing siltation by the operation of the Trevallyn Power Station in phase with the tides was also trialled for a short period. This was not viable, however, due to increases in the cost of operation.
- Silt fluidising techniques to scour and mobilise bottom sediments have been trialed to utilise natural currents to carry the silt downstream.

The siltation of the upper reaches of the Tamar Estuary is clearly an important issue, but it is a result of the natural morphology and hydrology of the estuary and catchment rather than pollution. However several important environmental and water quality issues are associated with management of siltation by dredging, silt deposition and silt trapping.

8 Summary and recommendations

The environmental quality of the Tamar Estuary is a function of its physical setting, as well as historic and on-going inputs of pollutants. The estuary's physical features play an important and controlling role in the ultimate fate and distribution of contaminants. The Tamar is a narrow, highly tidal estuary with relatively large freshwater inputs at its head, and is presumed to be well-flushed, although residence time has not been determined. Broad tidal flats and wetlands border a relatively deep central channel, and become more extensive in the estuary's upper reaches. The Tamar's large tidal range (3 m) and strong tidal currents have resulted in an active sediment transport regime - marked by rapid sedimentation in the upper reaches - and a long history of dredging. The Tamar's catchment is very large (10,000 km^2) and land use is predominantly agriculture and forestry. River flows from the South Esk Basin are strongly influenced by hydropower developments at Poatina and Trevallyn.

Contaminants enter the estuary from a variety of point and non-point sources. These include sewage and industrial effluent, urban run-off (sometimes combined with sewer overflows in Launceston), atmospheric and ground-water pollution, as well as agricultural and mining run-off from the catchment. Until fairly recently (1980/90s), the majority of urban, industrial and mining wastewater was poorly treated. Contaminants associated with these sources include pathogens, nutrients, BOD and TSS (sewage and urban run-off), as well as metals, fluoride and cyanide (mining and metal processing industries). There have been significant decreases in most end-of-pipe emissions over the past 5 to 10 years - particularly due to sewage treatment plant upgrades and improved treatment of wastewater from TEMCO and Comalco. At this point, the remaining significant inputs are probably derived from diffuse sources, such as urban run-off (particularly CSOs) ground-and surface-water emissions from tips and contaminated sites, mining wastes and agricultural run-off from the South Esk catchment, and atmospheric contributions from urban and industrial activities. Some pollutants may also be derived from contaminated sediments within or adjacent to the estuary itself.

At present, the Tamar shows indications of environmental degradation in several areas, as outlined in Figure 28 and Table 31. These conclusions, however, are supported by *very limited information*. Most monitoring programs and studies relating to the Tamar's environmental quality are over 10 years old, were of short-duration, surveyed limited areas and focused on a limited range of contaminants. Furthermore, we have a poor understanding of the processes which control environmental quality in the Tamar - particularly with respect to estuarine circulation and sedimentation. It is strongly recommended that a comprehensive environmental survey of water, sediments and biota be carried out and that the on-going monitoring program be revised in light of these findings. It is possible that that the major issues and areas of concern highlighted in this report could shift significantly, once additional information is available.

On the basis of existing information, the following environmental issues appear to be of most concern in the Tamar Estuary. Water quality contamination by ***pathogens*** (faecal indicator bacteria) derived from sewage and abattoir wastes has historically been a problem in the upper estuary, with levels frequently exceeding guidelines for secondary contact recreation. Since 1994, however, when the Hoblers Bridge WWTP was upgraded and began treating industrial wastes, there has been a significant improvement. Still, several sites in North Esk River and upper Tamar (above Freshwater Point) exceed guidelines for primary contact recreation. Sources of faecal contamination have not been identified, but presumably reflect some combination of urban run-off, sewage, agricultural run-off and waterfowl/wildlife.

Heavy metals, particularly zinc and cadmium, appear to be elevated in several areas of the Tamar - notably the upper estuary around Launceston, Deceitful Cove and (possibly) Middle Arm. Heavy metal concentrations in water, sediments and shellfish collected from these areas have been in excess of recommended Australian and international guidelines, and as recently as 1993, it was recommended that oysters collected from the Tamar should not be consumed due to heavy metal contamination (Gawn and Richardson, 1993). There have been significant reductions in end-of-pipe emissions from industries in the lower estuary over the past 5 years, however, mining wastes from the Aberfoyle/Storeys Creek area still appear to be a significant source. Other diffuse sources of heavy metals may include ground-and surface-water emissions from tips and contaminated sites, urban run-off, and contaminated sediments/dredge spoils in or adjacent to the estuary.

The Tamar receives inputs of ***sediments*** from catchments of the South and North Esk Rivers, which, due to estuarine hydrodynamics, accumulate as fine-grained silt deposits in the upper reaches of system. These sediments probably serve as an effective trap for heavy metals and other contaminants from past mining in the South Esk catchment and other industrial activities in the Launceston area. The upper estuary has been extensively dredged over the past 50 to 100 years, as the accumulated sediments impede navigation, exacerbate flooding and are considered aesthetically undesirable. Environmental impacts of dredging activities and dredge spoil disposal have never been fully investigated.

Very little data is available on ***nutrients*** or chlorophyll *a* in the Tamar, beyond some indications of elevated phosphates in upper reaches. However, inputs from sewage treatment plants and agricultural activities in the South Esk catchment are relatively high. The Tamar is not known to experience recurrent nuisance algal blooms.

At the ecosystem level, ***introduced species*** have been identified as an issue of concern, particularly rice grass (*Spartina anglica*), which appears to accelerate siltation rates, and the Pacific oyster, which has colonised large areas of mudflats throughout the estuary. There is concern that other potentially destructive species (e.g. toxic dinoflagellates, Northern Pacific seastar) could also be introduced via ships ballast water. The degradation and potential loss of ***wetlands*** and seagrass beds is another important issue.

In summary, limited environmental monitoring data indicates that the Tamar is environmentally degraded in several areas, particularly in the vicinity of Launceston and near major industrial and mining areas. There have been a number of significant improvements in industrial and sewage emissions over the past 10 years. As major point sources around the estuary are progressively upgraded, it is anticipated that diffuse sources will contribute the majority of contaminants. These diffuse sources - urban, agricultural and mining run-off, atmospheric inputs, ground-water contamination - are typically difficult and expensive to remediate and will require careful planning and catchment-based solutions.

Recommendations

Improve environmental quality information

- A comprehensive survey should be carried for the entire estuary to document existing environmental quality of waters, sediments and biota. This should include the mapping of sediments, ecosystem types and important biological communities;
- The existing Tamar monitoring program conducted by Launceston City Council /DELM should be reworked in light of the findings of this survey and should include a broader range of parameters;
- A weekly bacterial monitoring program should be implemented at bathing and other areas used for primary contact recreation. The program should follow sampling procedures in line with the ANZECC guidelines;
- Hydrology and sediment transport in the estuary should be investigated;
- This 'State of the Tamar' document should be periodically updated/revised to review progress and raise awareness.

Review/refine input estimates

- Periodic review of licensed premises' monitoring data and requirements is recommended within a 'whole-of -estuary' context. Mass emissions should be routinely determined for point and diffuse inputs. Flow-proportional monitoring may be necessary, in some cases;
- Sewage mass loadings should also include inputs from storm-induced overflows and spills;
- Estimates of urban run-off/CSO inputs should be refined, using site-specific data where available;
- Inputs from industrial and municipal RDS and contaminated sites should be estimated;
- Mining inputs from the South Esk catchment may still be a significant source of metals - particularly during flood events. Mass loadings from this source should be estimated;
- Potential inputs from contaminated sediments/dredge spoil deposits should be assessed.

Possible actions to improve environmental quality in the Tamar

- Remediate CSOs in Launceston;
- Determine source and, if possible, remediate elevated bacteriological levels at upper Tamar/North Esk sites;
- Reduce/remediate mining inputs from Storys Creek/Rossarden;
- Evaluate effects of dredging/spoil disposal as regards metal contamination and ecosystem impacts;
- Address sediment contamination at Deceitful Cove;
- Assess viability of controlling existing introduced species, develop/implement strategy to avoid new problems (e.g. ballast water controls);
- Maintain/preserve important ecosystems (e.g. wetlands, seagrasses).

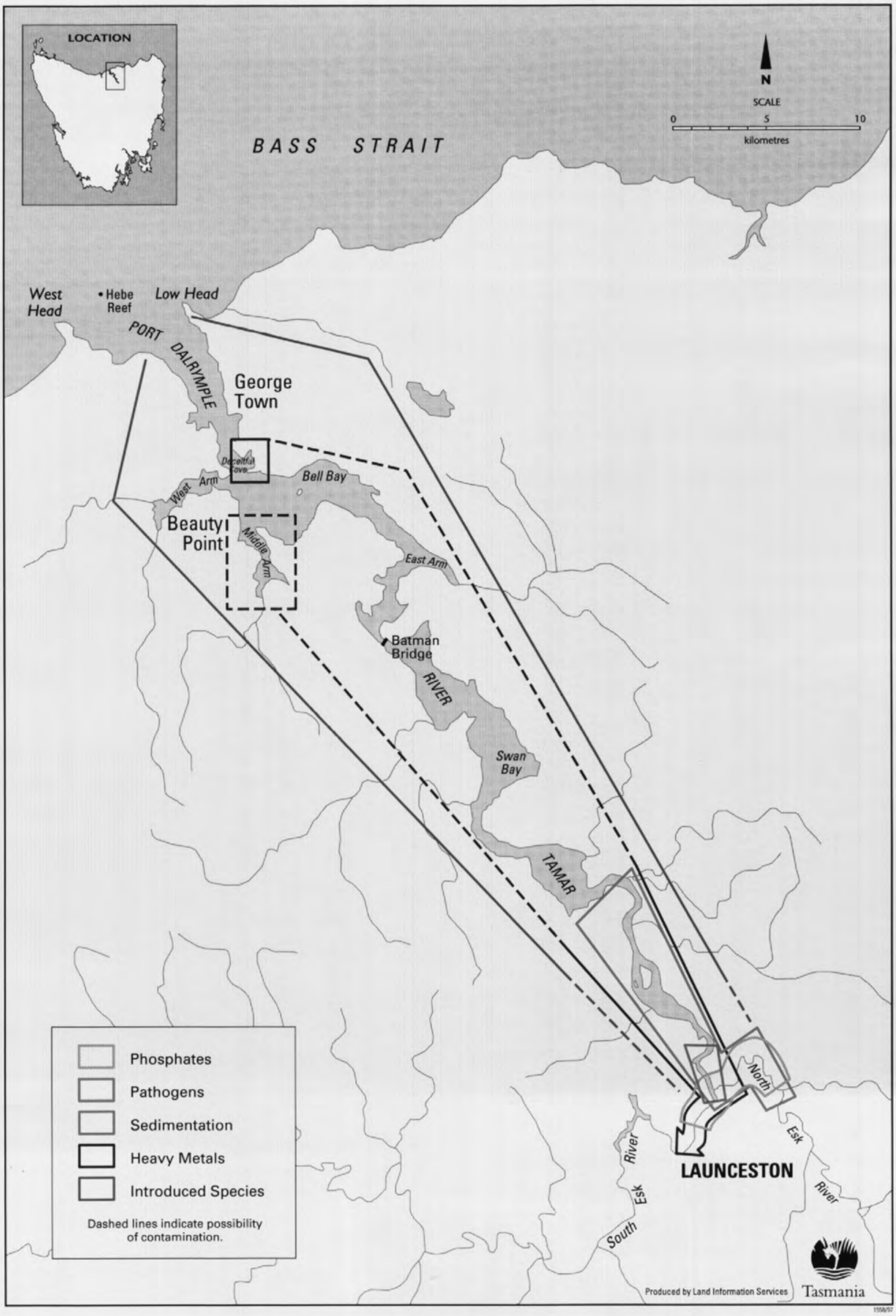


Figure 28 The Tamar Estuary: major environmental issues

Table 31 Summary of environmental issues in the Tamar Estuary

ISSUE	STATE	PRESSURE	POSSIBLE ACTIONS	INFORMATION
Pathogens				
Upper estuary (Hoblers Br. to Freshwater Pt.)	frequently exceeds primary contact recreation guidelines	sewage, agriculture, stormwater, wildlife, recreational boats	investigate; remediate	quarterly surveys @ 16 sites (1971 - present)
Bathing beaches	unknown some high levels recorded at Lagoon Beach, First Basin and Rotary Park in 1989	sewage, agriculture, stormwater, wildlife, recreational boats	investigate.	no recent data surveyed Jan-Mar, 1989
Dissolved oxygen				
Upper estuary	all sites > 6 mg/L (Hoblers and Henry St Bridges often lower until 1992)		no action	quarterly surveys @ 16 sites (1971 - present)
Suspended sediments				
	moderate to high (5-20 mg/L)	natural inputs from catchment, tidal mixing	no action	quarterly surveys @ 16 sites (1971 - present)
Nutrients				
orthophosphate	elevated in upper estuary, above Tamar Yacht Club (> 15 to > 300 µg/L)	sewage, agriculture, stormwater	investigate; remediate	quarterly surveys @ 16 sites (1971 - present)
Other nutrients	unknown		investigate	no clear data
Phytoplankton; chlorophyll a	unknown		investigate	no data
Heavy Metals				
Deceitful Cove	elevated Al, Mn, Zn, Cd, Pb,	industry	remediate	water, sediment and shellfish surveys 1992
Upper Estuary	elevated Zn, Cd, Pb, Cu	mining at Rossarden and Storys Creek, industry at Launceston, contaminated estuarine sediments and dredge spoil piles	investigate; remediate	water survey 1986 sediment/shellfish surveys 1973/74
Lower Estuary	elevated Al, Mn, Zn, Pb	industry at Bell Bay, sources in upper Tamar	investigate remediate	water, sediment and shellfish surveys 1992
Middle Arm	elevated Pb, Zn and Cu	Beaconsfield gold mine	investigate	sediment/shellfish surveys 1974
Fluoride				
	slightly elevated at Big Bay	industry	review guidelines	quarterly surveys @ 16 sites (1971 - present) localised surveys (1992)
Hydrocarbons				
lower estuary	low concentrations	Iron Baron oil spill (July 1995)	on-going monitoring no other action	oyster surveys 1995/96
middle/upper estuary	unknown	NA	investigate	no data

ISSUE	STATE	PRESSURE	POSSIBLE ACTIONS	INFORMATION
PAHS				
Deceitful Cove	low/high (contradictory findings)	industry, shipping	investigate	2 sediment/biota surveys 1992
lower estuary	low	industry, shipping	review reports	sediment/biota survey 1992
upper/mid-estuary	unknown		investigate	no data
Phenols				
Deceitful Cove	elevated	industry	remediate	water survey 1992
lower estuary	elevated	industry, shipping	remediate	water survey 1992
upper/mid-estuary	unknown		investigate	no data
Pesticides				
DDT/Dieldrin	not detected		monitor biota	quarterly surveys @ 16 sites (1971 - 1981)
other pesticides	unknown		investigate	no data
PCBs	unknown		investigate	no data
Sedimentation				
@ Home Reach				
Amenity/safety issues	impedes navigation. flooding concerns	sediments are derived/transported from natural sources	investigate reduce inputs alter hydrodynamics dredge levee augmentation no action	Foster et al., 1986
Dredging/disposal issues lack of disposal sites	approx. 2 years space remaining		identify new sites reduce dredging recycle spoils	
Dredging/disposal issues contaminated sediments contaminated spoil piles	areas being dredged probably contain heavy metals Spoil piles contain heavy metals (Cd, Zn, Cr); run-off/leaching to estuary	industry, mining, contaminated sediments	investigate contaminant levels and distribution identify/reduce inputs monitor/manage spoil sites	DPIF, 1993
Introduced species				
Rice grass	severe infestation	planted in 1950	control/contain	Hedge/DPIF, 1997
Pacific oysters	severe infestation	introduced to Port Sorell self-propagating	control/contain	
Wetlands	unknown		investigate	
Seagrass beds	unknown		investigate	

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APPENDIX A

Glossary of Terms and Units

Al	aluminium
ANZECC	Australia and New Zealand Environment and Conservation Council
Ba	barium
BOD	biochemical oxygen demand
Cd	cadmium
Cr	chromium
cfu/100ml	coliform unit per 100 millilitres of water
CN(WAD)	cyanide (weak acid dissoluble)
COD	chemical oxygen demand
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cu	copper
cumecs	cubic metres per second
DO	dissolved oxygen
DP&EMP	Development Proposal and Environmental Management Plan
DELM	Department of Environment and Land Management
DPIF	Department of Primary Industries and Fisheries
E&P	Division of Environment and Planning
EIP	Environmental Improvement Program
EMP	Environmental Management Plan
ERL	effects range low
ERM	effects range median
F	fluoride
Fe	iron
ha	hectare (10 000m^2)
HEC	Hydro Electric Commission (Tasmania)
Hg	mercury
kL	kilolitres (1 000 litres)
km	kilometre
km/day	kilometre per day
L	litre
m	metre
m/s	metre per second
m^2	square metre
m^3	cubic metre
m^3/day	cubic metre per day
mg/L	milligram per litre (one thousandth of one gram per litre)
μg/L	microgram per litre (one millionth of one gram per litre)
Mn	manganese
ML	megalitre (1,000,000 litres)
mm	millimetre
NFR	non-filterable residue
NH&MRC	National Health and Medical Research Council
NH_3-N	nitrogen as ammonia
NO_3-N	nitrogen as nitrate
NOx	nitrogen oxides
°C	degree Celsius
org/100 ml	organisms per 100 millilitres
PAH	polycyclic aromatic hydrocarbons
Pb	lead
PCBs	polychlorinated biphenols
pH	hydrogen potential (measure of acidity)
PO_4	orthophosphate
RDS	refuse disposal sites
ppt	parts per thousand
SO_2	sulphur dioxide
SOx	sulphur oxides

SPM	suspended particulate matter
STP	sewage treatment plant
TEMCO	Tasmanian Electro Metallurgical Company
TDS	total dissolved solids
TSS	total suspended solids
TN	total nitrogen
TP	total phosphorus
USEPA	United States (of America) Environment Protection Agency
WWTP	Wastewater Treatment Plant
Zn	zinc