TAMAR ESTUARY
ECOSYSTEM HEALTH ASSESSMENT PROGRAM
MONITORING REPORT 2012

NRM North
Tamar Estuary and Esk Rivers
Natural Resource Management in Northern Tasmania

MONITORING PERIOD OCTOBER 2010 – SEPTEMBER 2011

M. ATTARD, M. THOMPSON, R. KELLY AND A. LOCATELLI – NOVEMBER 2012

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EXECUTIVE SUMMARY

This report has been developed to describe data produced from October 2010 to September 2011 by the Tamar Estuary and Esk Rivers (TEER) Ecosystem Health Assessment Program (EHAP) which is used in the 2012 report card for the Tamar estuary. This is the second Tamar estuary report that has been produced using data specifically collected as part of TEER's EHAP. The EHAP describes ambient water quality along with seasonal factors such as temperature, salinity, rainfall and flooding that may influence water quality in the estuary.

Monthly ambient water quality samples were taken from October 2010 to September 2011 at 20 sites, in five functional zones of the estuary.

Data was compared to the relevant national guidelines and grades were calculated for each zone based on frequency of parameters meeting guideline criteria.

Water quality in the estuary improves with distance downstream towards the ocean. The lower estuary is well flushed, and the tidal marine influence gradually dilutes the concentrations of nutrients, metals, pathogens and sediments from the upper reaches. Major local sources of contaminants include industry, wastewater treatment plants and stormwater systems entering the estuary from the more urbanised upper estuary (Zone 1) area surrounding Launceston. Pollutants are also delivered to the upper estuary from a large catchment (10,000 km^2) area via the North Esk and South Esk rivers. Major findings from the annual review of water quality show:

- The 2012 report card grades are comparable to the 2010 and 2011 report cards.
- Wetter periods and associated freshwater inflows from the catchment, influence water quality as increased sediment, nutrient and bacterial loads are delivered to the estuary. This is expected given the higher flows and more erosive events during these times. Higher rainfall is also associated with more inputs from stormwater and wastewater treatment plants.
- Elevated nutrient and bacteria levels are key drivers of the poor grades in the upper estuary. Recreational water quality scores are poorest in the upper estuary (Zones 1 and 2) but are within guidelines in the mid to lower estuary (Zones 3, 4 and 5). It was expected that the upper estuary would have poorer water quality due to the proximity to high-density urban areas. During floods wastewater treatment plants can become overloaded and discharge untreated sewage into the river systems resulting in locally elevated bacteria and nutrient loads.
- Elevated copper and lead levels in Zones 1 and 4 are attributed to historic mining activities and other industry, as well as urban runoff. Metal data was not collected in Zones 2, 3 and 5 as previous studies had not found significant metals in these areas.

The TEER EHAP sampling operates on a four-year cycle of two years of monitoring followed by two years off, where a focus is placed on undertaking discrete scientific studies, and reviewing data from the routine monitoring. The EHAP sampling ceased in September 2011 after 24 months of data had been collected and it is envisaged that monitoring will recommence again in 2014 for a further two years. During the EHAP “off years”, from October 2011 to January 2014, several studies have been designed and are currently being implemented to improve current knowledge. These include:

- Water Quality Improvement Plan (WQIP)
- Launceston Sewage Treatment Plant ambient monitoring
- Mass loads
- Seafood safety study Freshwater Ecosystem Health Assessment Program (FEHAP)
- Development of Water quality objectives
- Identifying a biological indicator for the Tamar estuary TEER Storm Water Working Group

Data and information collected as part of the TEER EHAP and other discrete projects will be, and are currently being, utilised to help inform management, and develop targeted actions for the Tamar estuary. The TEER has actively been providing EHAP data to TEER partners and non-partner organisations that use the data in a variety of activities such as modelling, development applications, research projects and environmental assessments. The value of this data to internal and external users grows with each monitoring season. The TEER EHAP program has resulted in effective collaborative partnerships, and significant value adding for multi-stakeholder projects addressing key water quality and ecosystem health issues in the Tamar.

TEER products and publications also help educate, communicate and foster awareness about the Tamar estuary and surrounding catchments.

ACKNOWLEDGMENTS

This report has been prepared as part of the Tamar Estuary and Esk Rivers (TEER) program and has received valuable input from many people and organisations. TEER would like to acknowledge and thank the following people and organisations for their financial and technical contributions:

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Extracts are included from both the original 1997 State of the Tamar Estuary Report (Pirzl and Coughanowr, 1997) and the 2008 State of the Tamar Estuary Report (Aquenal and The Department of Environment, Heritage and the Arts, 2008). Major text segments from these two reports are attributed to Christine Coughanowr from the Derwent Estuary Program.

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ABBREVIATIONS

Al	Aluminium
AMC	Australian Maritime College
ANZECC	Australia and New Zealand Environment and Conservation Council
As	Arsenic
BLW	Ben Lomond Water
BOM	Bureau of Meteorology
Cd	Cadmium
Chl -a	Chlorophyll a
Cumecs	Cubic metres per second
Cu	Copper
DEP	Derwent Estuary Program
DEPHA	Department of Environment, Parks, Heritage and the Arts
DO	Dissolved Oxygen
DPIPWE	Department of Primary Industries, Parks, Water and the Environment
DRP	Dissolved Reactive Phosphorus
EHAP	Ecosystem Health Assessment Program
EHI	Ecosystem Health Index
EPBCA	Environment Protection and Biodiversity Conservation Act, 1999
EPA	Environment Protection Authority
EPN	Environmental Protection Notice
Fe	Iron
FEHAP	Freshwater Ecosystem Health Assessment Program
GTC	George Town Council
Hg	Mercury
LCC	Launceston City Council
Mg	Manganese
mg/L	Milligrams per litre
NATA	National Association of Testing Authorities
NH_4^+	Ammonium
NHMRC	National Health and Medical Research Council
NO_x	Nitrogen oxides (nitrate plus nitrite)
NRM North	Northern Tasmanian NRM Association
NRM	Natural Resource Management
NTU	Nephelometric Turbidity Units
Pb	Lead
PCDDs	Polychlorinated dibenzodioxins
PO_4^{3-}	Inorganic phosphorous
ppm	Parts per million
ppt	Parts per thousand
Se	Selenium
TAFI	Tasmanian Aquaculture and Fisheries Institute
Tamar NRM	Tamar Region Natural Resource Management Strategy Reference Group
TEMCO	Tasmanian Electro Metallurgical Company
TEER	Tamar Estuary and Esk Rivers program
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
TRCI	Tasmanian River Condition Index
ug/L	Micrograms per litre
UTAS	University of Tasmania
WHO	World Health Organisation
WWTP	Waste Water Treatment Plant
Zn	Zinc

1 INTRODUCTION

The Tamar estuary Ecosystem Health Assessment Program monitoring report is a summary of data collected as part of the Tamar Estuary and Esk Rivers (TEER) Ecosystem Health Assessment Program (EHAP). The ambient water quality monitoring program aims to better understand the ecosystem health of the Tamar estuary through collecting and analysing water quality and biological data. This data has been analysed and used to generate the Tamar estuary report cards which grade the ecosystem health in five defined functional zones along the estuary.

This report presents the Tamar estuary data collected for the second monitoring year of the program from October 2010 to September 2011 and provides background to grades given in the 2010, 2011 and 2012 Tamar estuary report cards. The grades published in 2010 Tamar estuary report card were based on historical data (baseline 10 years from 1999-2009) and a comparison with a single reference year, 2007. The 2011 and 2012 report card grades have been determined from data collected by the TEER EHAP ambient water quality program.

This report is divided in six main sections. The introductory section provides background information on the estuary, including a brief physical description; more information can be found in the State of the Tamar Estuary 2008 publication. The second section describes the monitoring program before an analysis of observed water quality in the estuary, which is provided in the third section. The fourth and fifth sections describe the report card and grades. Summary findings and future directions for the monitoring program based on the 2010-2011 data collection are given in the final section of this monitoring report. More detail on the methods used to derive report card grades is presented in Appendix 1.

1.1 ABOUT TEER

The TEER program was established in 2008 and represents a regional partnership between the agencies responsible for the management of the Tamar estuary and Esk rivers waterways. Major partners include the Tasmanian Government, Environmental Protection Authority, Department of Health and Human Services, Launceston City Council, West Tamar Council, George Town Council, Meander Valley Council, Northern Midlands Council, Ben Lomond Water and Hydro Tasmania. Other key industry and supporting partners are Bell Bay Aluminium (formerly Rio Tinto Alcan), Van Diemen Aquaculture, BHP Billiton TEMCO, BCD Resources (Beaconsfield Gold Mine), the University of Tasmania, the Australian Maritime College, Tamar NRM and Forestry Tasmania. The TEER program aims to provide a coordinated management approach and guide for solutions and strategic investment in activities that will protect, maintain and enhance the Tamar estuary and Esk river systems. A key goal of the program is to improve scientific understanding of the issues impacting upon the health of the TEER waterways to better identify and target priority areas requiring investment in on-ground works. The TEER program fosters collaborative partnerships and works closely with industry, community, government, research and business partners to monitor and report on ecosystem health as well as coordinating activities to reduce pollutants from entering waterways.

In 2008 the TEER Strategic Framework was developed through a process of community consultation. The framework describes the five key strategies that TEER works towards achieving in conjunction with our partners and the community.

1. Protect, maintain and enhance natural values.
2. Build sustainable futures.
3. Work together to provide integrated governance, planning and management.
4. Build community knowledge and awareness of the Tamar estuary and Esk river systems.
5. Improve the amenity of the Tamar estuary and Esk river systems.

To find out more about the TEER and associated projects visit the TEER website: www.nrmnorth.org.au/teer

1.2 TAMAR PHYSICAL SETTING

The Tamar River estuary is located in the north-east of Tasmania and is one of the largest estuaries in the state. It begins at the confluence of the North Esk and South Esk rivers, where the city of Launceston is established, and flows north-east for 70km before discharging into Bass Strait. It covers an area of approximately 100km^2 and is bordered by three local councils - Launceston City, West Tamar and George Town. The estuary is a drowned river valley with deep channels, in some areas reaching up to 45m in depth (Aquenal and DEPHA, 2008). Strong tidal currents with a height difference of 3m, and a one-hour lag time between the confluence and the mouth make natural and anthropogenic inputs extremely mobile in the system.

There are six catchments that drain into the Tamar estuary: the North Esk, South Esk, Macquarie, Brumby's-Lake, Meander and Tamar catchments (Figure 1), which covers an area of approximately 10,000km^2, or 15 percent of Tasmania's land mass. The principal land uses within these catchments are forestry and agriculture.

Flows into the South Esk also include diversions for hydro-electric power generation which divert flow away from the Derwent catchment via the Great Lake and subsequent power stations at Tods Corner, Poatina and Lake Trevallyn.

1.3 USES

Launceston is the largest city in Tasmania's north with a population of approximately 100,000. Smaller towns spot the length of the estuary with a concentration in George Town on the eastern foreshore. The Bell Bay area is an industrial hub with a major shipping port supporting companies such as, Bell Bay Aluminium, BHP Billiton TEMCO and Gunns.

Several aquaculture farms are established on the Tamar River estuary growing and harvesting species such as Atlantic salmon, seahorses and abalone. The estuary is netted by a small number of commercial fishers who provide fish for the seafood industry and aquarium trade.

The Tamar River estuary provides significant recreational use for local residents and tourists. Recreational fishing, boating and water sports are popular in most reaches and boardwalks have been constructed to encourage greater interaction with the estuary.

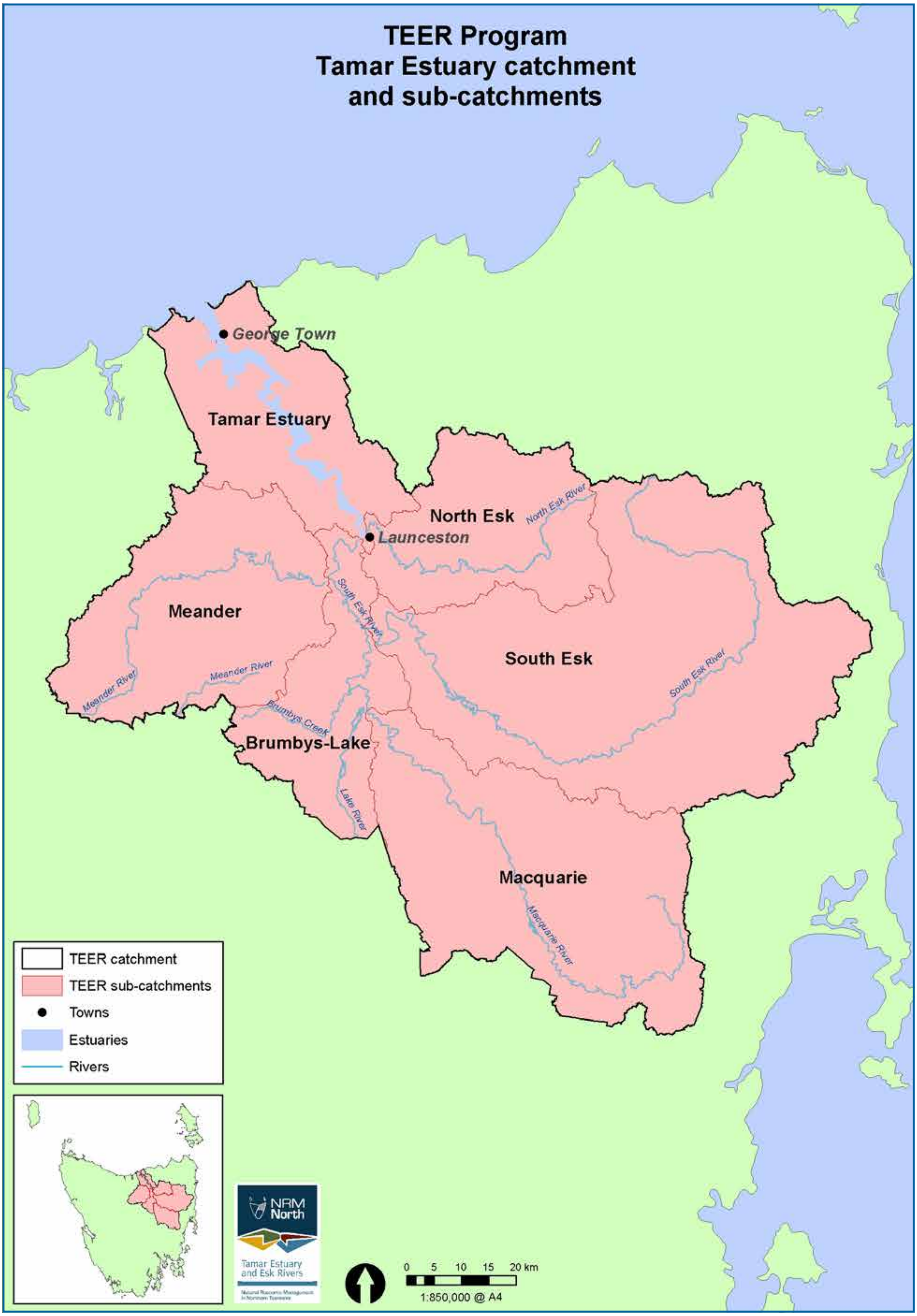


Figure 1. Tamar Estuary catchments

1.4 VALUES

Estuaries are generally considered to have high natural values due to the varied natural features occurring in a single area. A result of natural mixing of freshwaters and marine waters, estuaries support various habitats and are some of the most productive environments on Earth. The Tamar estuary supports a rich and diverse range of flora and fauna, and provides a stronghold and breeding ground for several threatened species listed under the Australian Government's Environment Protection and Biodiversity Conservation (EPBC) Act, *1999*, such as the Australian sea lion, Wedge-tailed eagle, White bellied sea eagle and native fish the Australian grayling. The estuary is recognised as a "hotspot" for coastal bird species and supports critical habitats including coral reefs, sponge gardens, seagrasses, mudflats and sand flats (Aquenal and DEPHA, 2008). The Tamar Island wetlands that fringe the south-western reaches provide valuable habitat and help to maintain water quality by acting as a natural buffer. The estuary's natural values are closely integrated with the social fabric of the region. People are attracted to the Tamar estuary for the many opportunities that the estuary offers, including aesthetics, recreational pursuits such as bird watching, water sports, yachting and fishing, and simply being able to connect with the natural environment (Aquenal and DEPHA, 2008).

The Tasmanian State Policy on Water Quality Management developed in 1997 aims to achieve the sustainable management of Tasmania's surface water and groundwater resources by protecting or enhancing their qualities while allowing for sustainable development in accordance with the objectives of Tasmania's Resource Management and Planning System. The Tasmanian State Policy on Water Quality Management, *1997*, outlines the minimum water quality management strategies for the Protected Environmental Values (PEVs) identified, i.e., the current uses and values, in the estuary.

The strategies seek to provide water of a physical and chemical nature to:

- Support modified but healthy aquatic ecosystems from which edible fish and crustacea may be harvested, but not shellfish, except where permitted by marine farming licences under the Living Marine Resources Management Act, 1995;
- Allow people to safely engage in recreation activities such as swimming (where permitted), paddling and fishing in aesthetically pleasing waters and which is suitable to support aquaculture in marine farming zones and existing marine farming licences issued pursuant to the Living Marine Resources Management Act, 1995; and
- Support the industrial use of the water for such uses as Gunns Ltd sawmills operations and cooling water for industrial activities.

The existing PEVs for estuarine waters in the Tamar catchment (excluding Deceitful Cove) are as follows (Department of Primary Industries, Water and Environment, 2005):

A: Protection of Aquatic Ecosystems

(i) Protection of modified (not pristine) ecosystems from which edible fish and crustacea are harvested but not shellfish except where permitted by Marine Farming Licences under the Living Marine Resources Management Act, 1995.

B: Recreational Water Quality and Aesthetics

(i) Primary contact water quality (where permitted).

(ii) Secondary contact water quality.

(iii) Aesthetic water quality.

C: Industrial Water Supply

(Aquaculture in marine farming zones and existing marine farming licences issued pursuant to the Living Marine Resources Management Act, 1995, Gunns Ltd and Bell Bay Power Station.)

For Deceitful Cove the PEVs are:

A: Protection of modified (not pristine) aquatic ecosystems from which edible fish, crustacea and shellfish are not harvested.

B: Recreational Water Quality and Aesthetics

(i) Secondary contact water quality.

(ii) Aesthetic water quality.

1.5 ENVIRONMENTAL ISSUES

Sedimentation in the Tamar's upper reaches has been an issue of long-standing concern, both for reasons of amenity and environmental quality. The upper sections of drowned river estuaries, like the Tamar, receive sediments delivered from the upper catchments and from the redistribution of existing sediments circulating within the estuary. Sedimentation in the Home Reach section of the Tamar is a natural occurrence causing difficulty with navigation and is aesthetically unattractive to many people in the community. The upper reaches have a long history of major dredging to improve navigation.

There are more than 20 Waste Water Treatment Plants (WWTPs) within the greater Tamar catchment of which 13 are located within the Tamar Estuary. These collect and treat sewage and other wastewater from surrounding townships (Figure 2). The level of treatment varies based on the type of wastewater, technologies available and environmental criteria. Many of these plants have water recycling schemes that reuse the effluent for pasture irrigation. However there are plants where recycling effluent is not possible and effluent is discharged into waterways under conditions set out in environmental protection notices (EPN) which are issued and regulated by the Environment Protection Authority, a division of the Tasmanian State Government Department of Primary Industry Parks Water and Environment (DPIPWE). Figure 2 outlines the proportion of WWTP and major industry discharges that enter the Tamar River estuary and the lower contributing tributaries of the North and South Esk Rivers.

The older parts of Launceston were designed to have a combined sewerage and stormwater drainage system. Storages have been built in recent years to capture the first flush of stormwater for treatment at the Ti Tree Bend WWTP. Whilst this system provides treatment of stormwater for low flows, during periods of high run-off, overflows of untreated sewage combined with stormwater occasionally enter the estuary. Other sources of sewage entering the estuary can be leaching from poorly maintained septic systems and discharged directly from recreational vessels (Aquenal and DEPHA, 2008).

Stormwater and urban runoff represent a significant diffuse source of pollution to urban waterways. Contaminants are washed off roofs, streets, parks and gardens, eventually entering the river system. Urban stormwater is generally characterised by high levels of suspended solids, nutrients, bacteria and a range of metals and hydrocarbons, all of which can be detrimental to estuarine ecosystems and water quality. The suburbs surrounding Launceston do not operate a combined stormwater-sewer system; stormwater is not collected or treated but flows directly into the Tamar estuary (Aquenal and DEPHA, 2008). The TEER Program operates a Stormwater Working Group in partnership with councils of the northern NRM region and Ben Lomond Water, established to coordinate and progress stormwater management in the region through employment of the NRM North Stormwater Officer.

Heavy industry in the Tamar Valley catchment has existed for many years, and types of industrial discharges into the Tamar estuary have varied over time with upgrades of Environmental Protection Notices (EPNs) regulated by the Environmental Protection Authority (EPA). Industrial pollutants may enter the Tamar via a number of possible environmental pathways such as direct discharges of liquid processing wastes, stormwater run-off, groundwater seepage and spills. In some cases, mass emission from indirect and/or infrequent inputs may be greater than average end-of-pipe discharges (Aquenal and DEPHA, 2008). Advancing technologies in waste processes and treatment are driven by the control measures imposed by the EPA, industry and the community to reduce the impact on the Tamar estuary as the receiving body.

Introduced pest species within the Tamar estuary are also an environmental concern with several target pests identified; Pacific oyster (*Crassostrea gigas*), rice grass (*Spartina anglica*), mosquito fish (*Gambisia holbrooki*), Asian bag mussel (*Musculista senhousia*) and the European green crab (*Carcinus maenas*) (Aquenal and DEPHA, 2008). Pest identification and surveys are beyond the scope of this TEER EHAP, for more information on these introduced pest species please see the State of the Tamar Estuary 2008 (Aquenal & DEPHA, 2008) available on the TEER website.

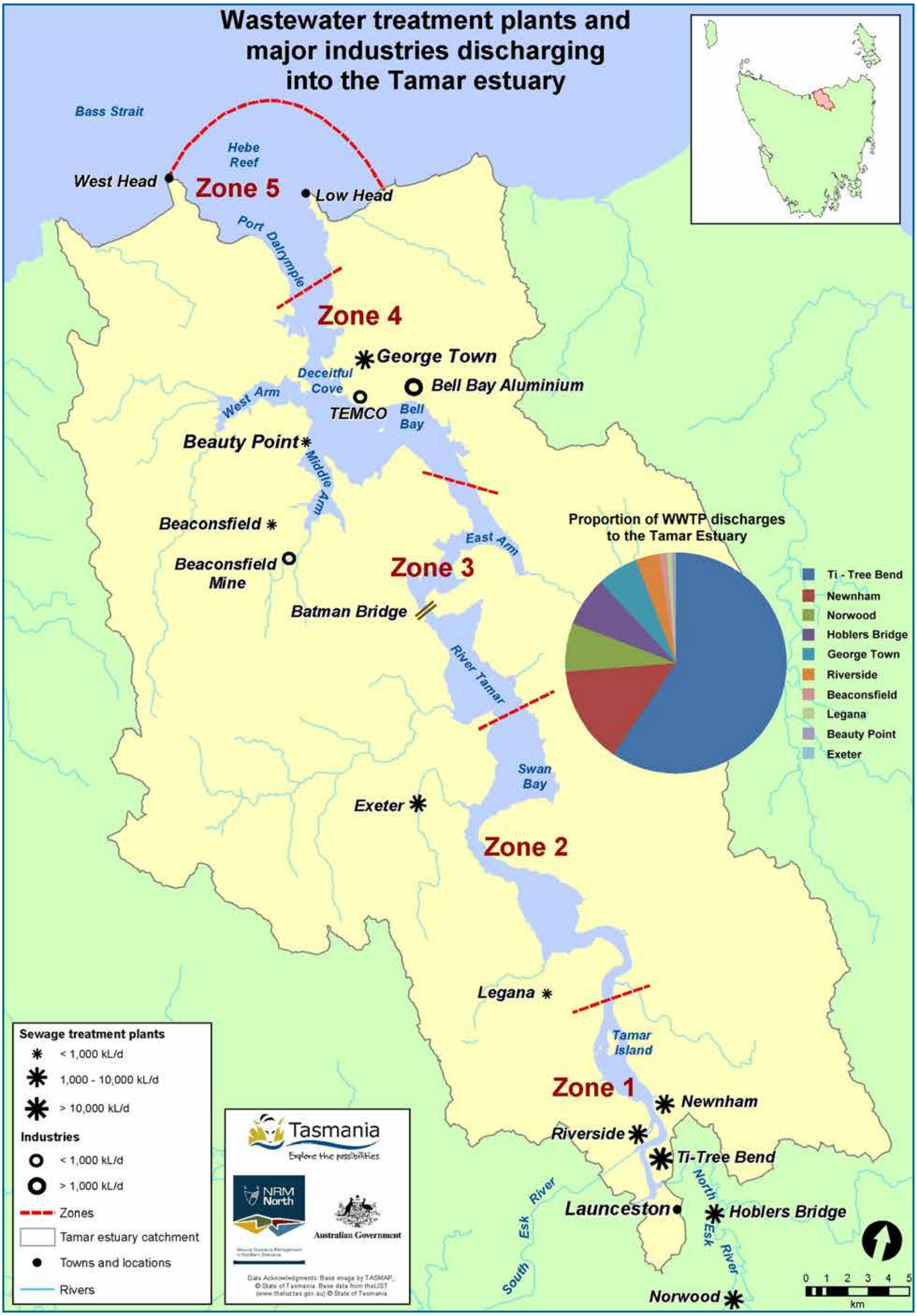


Figure 2. Waste water and major industry discharges into the Tamar Estuary.

2 AMBIENT WATER QUALITY MONITORING PROGRAM

The Ecosystem Health Assessment Program (EHAP) aims to monitor and report on the ecological health of the estuary by collecting and analysing water quality indicators to gain an understanding and classify the status of the ecosystem. The 2012 EHAP report incorporates Tamar estuary data that has been collected in the second year of the monitoring program from October 2010 to September 2011.

Ecosystem health can be determined by the response of the ecosystem to natural and human inputs (EPA 2007).

Monitoring the ecological health serves four main purposes (Downes *et al*., 2002):

1. To assess the ecological state of ecosystems
2. To assess whether performance criteria have been exceeded
3. To detect and assess the impact(s) of human generated disturbances, and
4. To assess the responses of the ecosystem to restoration efforts

To allow the ecological assessment of the estuary, the Tamar has been divided into five functional zones (Figure 3); (see section 2.3 for more detail). The zones reflect the differences in critical habitats, key processes and anthropogenic impacts on the estuary and also provide a focus for management actions and future research (Pantus and Dennison, 2005). The EHAP aims to improve the scientific knowledge around the processes impacting on the health of the waterways. Reliable scientific data is collected to gain a greater understanding of the Tamar estuary with findings communicated to the community and estuary managers through reports, publications, targeted research projects and local media launches.

MONITORING METHODS

Water quality monitoring occurred monthly at 20 sites along the Tamar estuary from Kings Bridge in Launceston in the upper reaches and extending out past Hebe Reef where the lower estuary discharges into Bass Strait. Each of the five functional zones has four sampling sites (Figure 3). Each month, sampling was conducted on a single day.

At all sites, in situ water quality parameters (Table 1) are measured at discrete depths throughout the water column by a calibrated multi-probe water quality meter which is lowered from the surface to the bottom of the water column. Water clarity and light penetration are measured by lowering a Secchi disk from the surface of the water and recording the distance where the disk is no longer visible.

Surface and bottom water samples from each site are analysed at Analytical Services Tasmania (AST), a Hobart–based NATA-accredited laboratory for nutrients, metals, chlorophyll a and total suspended solids (TSS) Nutrient samples were filtered (0.45μm) in the field to allow for total and dissolved nutrient samples to be analysed. TSS samples are .45 micron filtered in the lab to trap solids on the filter and measure the amount of sediments per volume of water. Surface water samples are taken by grab sampling approximately 10cm under the surface of the water and bottom samples are taken by using a Niskin bottle to collect water at a depth at approximately one metre from the bottom of estuary.

Bacteriological samples are taken for surface waters at each site and analysed for *Enterococci* at Tasmanian Laboratory Services (Launceston).

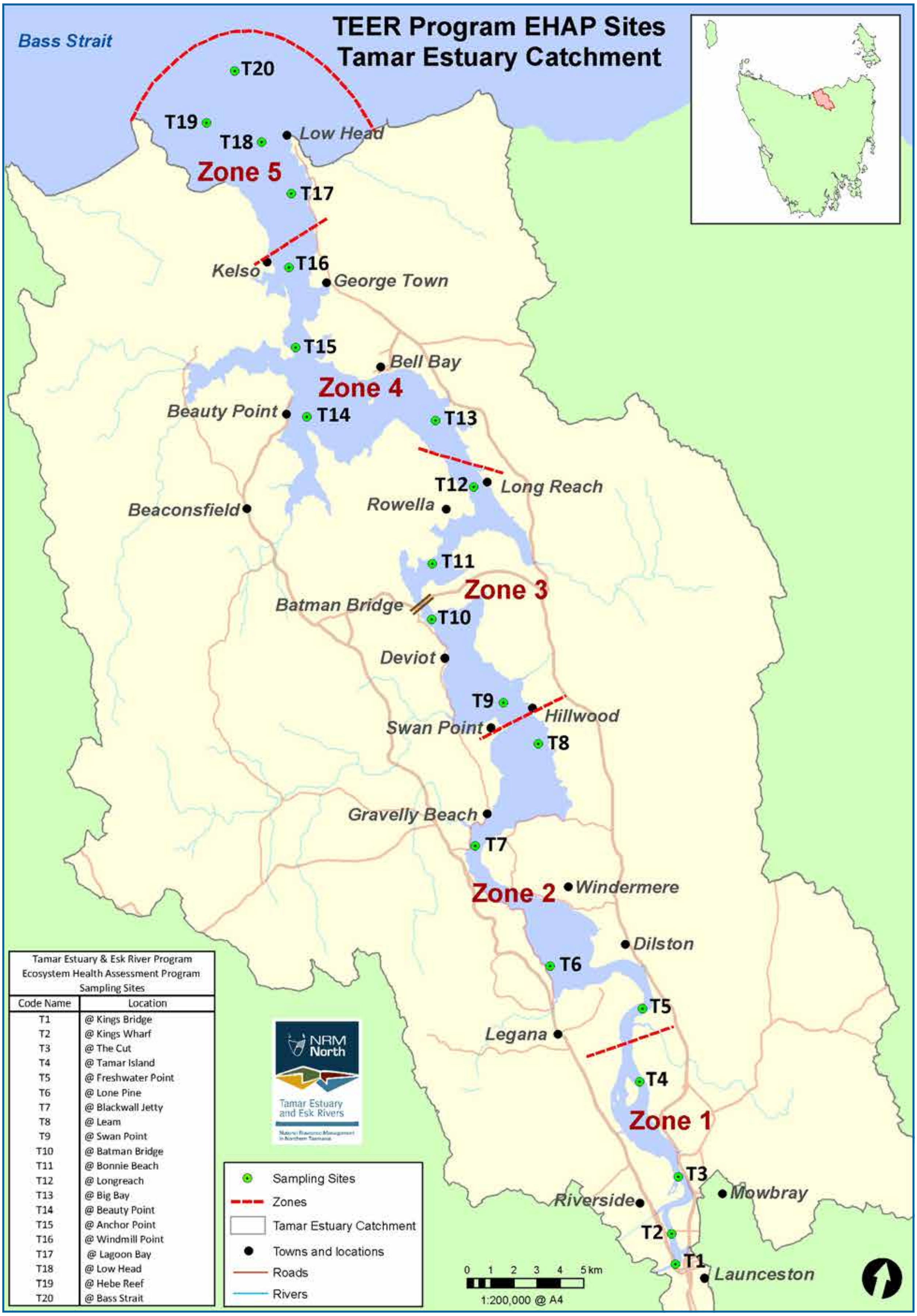


Figure 3. TEER EHAP zones and sampling sites.

Table 1. TEER EHAP sampled parameters

Physical Chemistry	Nutrients	Dissolved Metals (µg/L)
Temperature (°C)	Total Phosphorus (µg P/L)	Copper (Cu)
Salinity (ppt)	Dissolved Reactive Phosphorus (µg P/L)	Mercury (Hg)
Dissolved Oxygen (% Sat + mg/L)	Total Nitrogen (µg N/L)	Lead (Pb)
pH (Units)	Nitrite + Nitrate (µg N/L)	Zinc (Zn)
Turbidity (NTU)	Ammonia (µg N/L)	Cadmium (Cd)
Chlorophyll a (µg/L)		Aluminium (Al)
Specific conductivity (mS/cm)		Iron (Fe)
Total Suspended Solids (0.45 micron filtered) (mg/L)		Manganese (Mn)
Secchi Disk (m)	**Pathogens**	Arsenic (As)
	Enterococci (counts/100ml)	Selenium (Se)

2.1 QUALITY ASSURANCE AND QUALITY CONTROL (QAQC)

Quality assurance and quality control measures are a set of operating and sampling procedures carried out by the TEER EHAP monitoring team that help to ensure that calibration, sampling techniques, storage, transport and analysis of samples are as consistent as possible, reducing the variation in results due to incorrect procedures or contamination. The laboratory analysing the samples provides specific instructions to follow when sampling in the field. Duplicate, field and trip blank samples are taken at a nominated sampling site allowing results to be compared and any inconsistencies to be brought to the attention of the program. The QAQC results are uploaded and stored in the database and compared to the results from the reference site for each monitoring date.

During the 2010/2011 monitoring period duplicates, field and trip blank samples for nutrients, metals and TSS were within acceptable levels at site T15 (Anchor Point).

- Duplicates - Replicate sampling to estimate variability.
- Field blanks - pre-prepared laboratory samples which are treated the same way as ambient samples, to measure potential for contamination.
- Trip blanks: Laboratory prepared samples which remain unopened and are analysed when they arrive back at the laboratory to assess potential for transport and storage conditions to alter results.

2.2 WATER QUALITY GUIDELINES

Where appropriate, data used in this EHAP report is considered alongside national water quality guidelines, in particular the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).

The ANZECC guidelines provide a framework to enable the assessment and management of environmental values including ambient water quality in relation to fresh, estuarine and marine ecosystems.

The guidelines provide guidance on assessing water quality and to identify if systems are functioning outside of normal or expected ranges. Guidelines are used as default triggers where site specific information is lacking, and may help identify management priorities.

For the protection of aquatic ecosystems ANZECC 2000 recommend using a range of guidelines which include biological, physical and chemical and sediment guidelines. Aquatic ecosystem types and the relative indicator categories are displayed in figure 4. This report incorporates the ANZECC default guidelines for physical and chemical stressors (Table 2), and also toxicant guidelines (Table 3) which are used to compare metals data (ANZECC rational for toxicant guidelines are described in the metals section of this report. Section 3.8)

No biological or sediment guidelines are applied in this report.

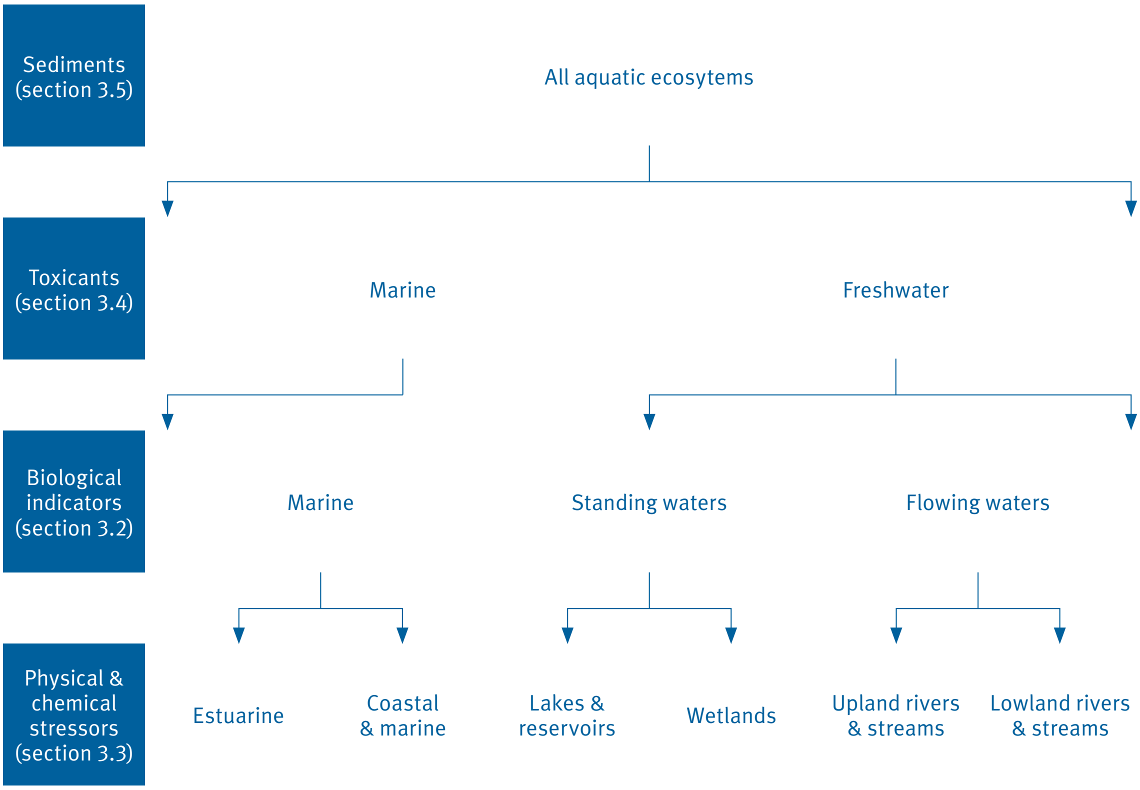


Figure 4. Classification of ecosystem type for each of the broad categories of indicators (Flow diagram sourced from ANZECC 2000)

Due to the salinity range in the Tamar estuary, both estuarine and marine ANZECC default trigger values are applied to the physical and chemical guidelines; whereas only the marine category applies for the toxicant (metal) guidelines. The trigger values used for the Tamar estuary rely on the classification of the estuary as a "slightly to moderately disturbed" ecosystem, reflecting a range of historical and current land use that puts pressure on the aquatic environment.

The ANZECC guidelines can be found at:

www.environment.gov.au/water/policy-programs/nwqms/index.html

It is important to note that the ANZECC default trigger values for south-eastern Australia have been adopted here (detailed in Table 2) even though they **do not** include data from Tasmanian estuaries. The water quality "trigger values" produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) for some Tasmanian estuaries (Murphy *et al.*, 2003) have not been used as they did not include data from the Tamar estuary in their assessment.

For the purposes of comparing EHAP bacterial results this report adopts the guidelines for *Enterococci* from the Public Health Act 1997, *Recreational Water Quality Guidelines* (RWQG), 2007. Tasmanian Government. This report uses the trigger value of 140 *Enterococci* /100mL as the guideline to measure bacterial impacts and assess ecosystem health in the Tamar estuary. The rationale and application of the bacterial guideline is detailed in the bacterial pathogens Section 3.7.

The EPA and TEER are developing site specific Water Quality Objectives (WQO) or trigger values for the Tamar estuary which is based on 24 months EHAP monitoring data. Also, for the maintenance and progressive improvement of water quality in the estuary, water quality targets should be set for those water quality indicators affected by anthropogenic influence.

Table 2. ANZECC Physical and Chemical Estuarine Default trigger values for south-east Australia in slightly disturbed ecosystems

Parameter	**Chl-a µg/L**	**TP µg P/L**	**DRP µg P/L**	**TN µg N/L**	**NH_4^+ µg N/L**	**NO_x µg N/L**	**DO % Sat**	**pH units**	**Turbidity NTU**
ANZECC **Estuarine** Trigger level	4	30	5	300	15	15	Lower- 80 Upper-110	Lower- 7 Upper- 8.5	10
ANZECC **Marine** Trigger level	1	25	10	120	15	5	Lower- 90 Upper-110	Lower - 8 Upper - 8.4	10

Chl-a = chlorophyll a, TP = Total Phosphorus, FRP = Filterable Reactive Phosphorus, TN = Total Nitrogen, NH_4^+ = ammonium, NO_x = nitrate plus nitrite, DO=Dissolved Oxygen, NTU= Nephelometric Turbidity Units

Table 3. ANZECC default guideline trigger values for metals (µg/L) for south-east Australia in slightly disturbed ecosystems

Metal (total) µg/L	Copper	Lead	Mercury (inorganic)	Zinc	Cadmium
ANZECC **Marine** Trigger level 95% level of protection	1.3	4.4	0.4	15	5.5

2.3 IDENTIFICATION OF TAMAR ESTUARY FUNCTIONAL ZONES

For the development of the TEER EHAP, the Tamar estuary has been divided into five functional zones that reflect differences in critical habitats, key processes and anthropogenic impacts of the estuary (Figure 2). A functional zone is defined as a geographic entity with common structural and functional characteristics which can be defined in a conceptual model and quantified by measurement (Dennison *et al*., 1999). The zones provide a focus for management actions and future research (Pantus and Dennison, 2005). The five functional zones define clear boundaries through which change can be measured over time along the length of the estuary.

Zones 1 - 3 are considered estuarine due to the salinity range and Zones 4 and 5 fall into the marine category (Table 3). Physical and chemical Estuarine ANZECC guidelines apply to Zones 1-3 and Marine guidelines apply to Zones 4 and 5, while for ANZECC toxicant guidelines all 5 zones are considered marine.

Table 4. Zone 1-5 Salinity, water temperature, pH, and depth range for the 2010-2011 monitoring period.

Zones	Sites	Salinity (ppt)	Water Temp (°C)	pH	Water sample depth (m)
Zone 1 upper estuary	T1-T4	0.5 – 6.0	5.5 – 21.5	6.8 – 8.4	5 – 8
Zone 2	T5-T8	0.5 – 25.0	6.5 – 22.0	7.2 – 8.2	11 – 20
Zone 3 mid estuary	T9-T12	3.0 – 29.0	9.0 – 21.0	7.8 – 8.2	17 – 33
Zone 4	T13-T16	3.0 – 35.0	10.0 – 21.0	8.1 – 8.2	4 – 42
Zone 5 lower estuary	T17-T20	28.0 – 35.0	11.0 – 18.7	7.9 – 8.3	14 – 40

PROXY SITES FOR ZONES 1-5

For the purposes of describing and comparing the differences between the zones in regard to water quality and physical characteristics, one sampling site was chosen to represent each of the five zones (Figure 5). The zone proxy sites were chosen according to salinity and the sites spatial characteristics within each zone so that proxy sites are representing the middle area of each zone.

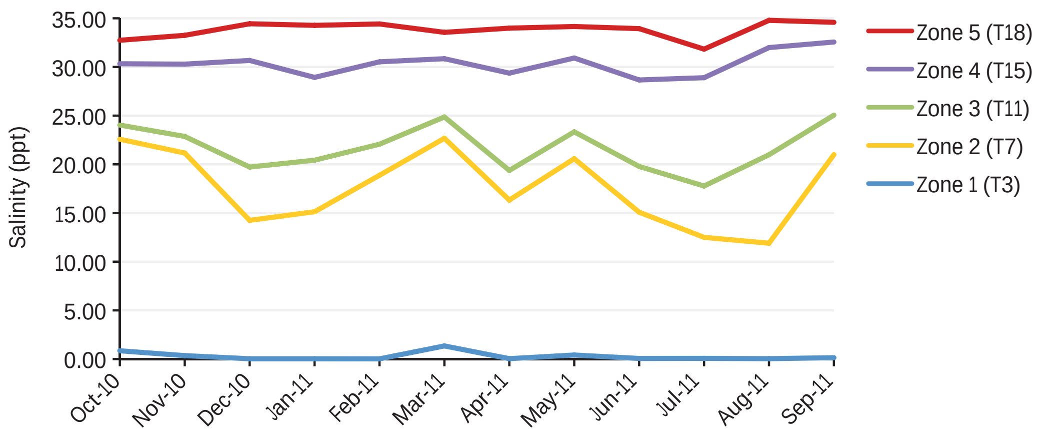


Figure 5. Zone 1-5 Proxy Sites Salinity for the 2010/2011 monitoring period.

ZONE 1. UPPER ESTUARY (SITES T1-T4)

Zone 1 extends from the town of Launceston to north of Tamar Island in the upper estuary (Figure 3). The foreshore of this zone is the most heavily urbanised of the estuary, supporting an urban population of around 100,000. In the upper reaches of this zone there are direct freshwater inputs from the North Esk and South Esk rivers which drain the whole Tamar catchment (Figure 2). Another major freshwater input is delivered from the Lake Trevallyn Tail Race hydro-electric power scheme (Figure 6). As a result, this zone has limited marine influence, with bottom waters only slightly more saline than surface waters.

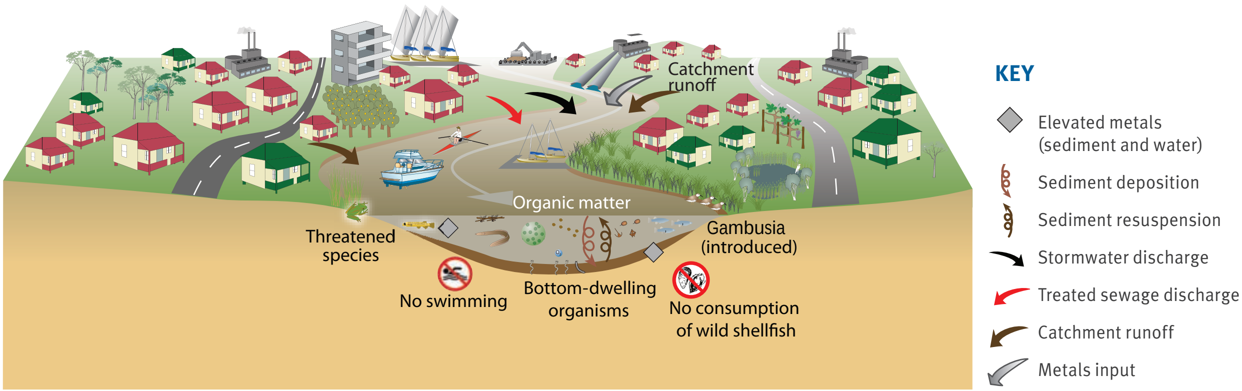


Figure 6. Zone 1 Conceptual diagram describing land use and major water quality influences around upper Tamar Estuary.

Zone 1 is the shallowest section in the estuary where depth ranges from 5–8 metres with broad shallow tidal flats. The bottom habitat, like much of the Tamar estuary, is silt (Lucieer *et al.*, 2009). The introduced *Gambusia holbrooki* (mosquito fish) inhabits areas in and around the Tamar Island wetlands. Due to the urbanised nature of the Launceston city area, there are many diffuse and point source pollution inputs to this zone including stormwater runoff and effluent from wastewater treatment plants. These inputs are represented in Zone 1 conceptual diagram (Figure 6). The Tamar catchment has a historic legacy of metal contamination from mining and smelting activities which continue to accumulate in the estuary's sediments. The upper reaches of the estuary around sites T1 and T2 have a history of extensive dredging for navigational purposes and are an area of sediment accumulation. Sediments are delivered from the upper catchments and existing sediments are redistributed within the estuary. Zone 1 also has ship lift operating close to the Launceston CBD where ship repairs, maintenance, hull cleaning and painting occur. The Seaport Hotel, residential and restaurant precinct located on the southern bank of the lower North Esk supports a marina with permanent and visiting vessels using the mooring facilities.

Tourism Company Tamar Cruises operates two boat tours on the Tamar Estuary, one does a short run from the Seaport up into Cataract Gorge and back to the North Esk and the second a larger vessel operates a return cruise down river from Launceston to the Batman area in Zone 3. Rowing is a major recreational activity in Zone 1 with several school rowing clubs operating close to the city of Launceston. Another feature of Zone 1 is the Tamar Island wetlands located on the Western shore just north of Launceston. It provides habitat for a variety of birds, mammals, reptiles, frogs, fish and invertebrates, as well as being an important historic landmark in the early settlement of Launceston. It is part of the Tamar Conservation Area, which protects the Tamar River's remnant wetlands.

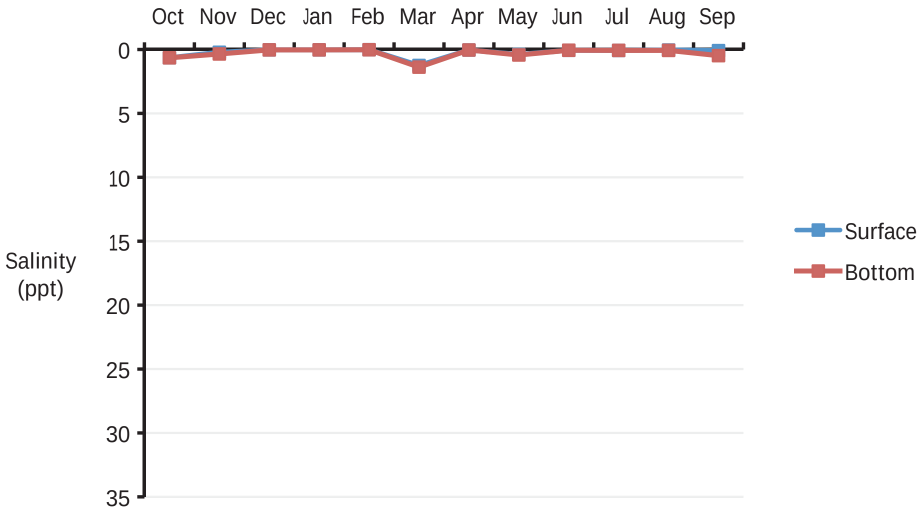


Figure 7. Salinity in Zone 1 at proxy site T3 Oct 2010-Sep 2011

During the 2010/2011 sampling period the water column in Zone 1 was well mixed and dominated by freshwater with little differences in salinity between surface and bottom waters (Figure 7). The freshwater inputs in this zone were much greater than during the previous 12 months (which saw bottom waters brackish in summer and autumn) reflecting the high rainfall and incidence of flooding during the 2010-2011 monitoring period.

ZONE 2. MID UPPER ESTUARY (SITES T5-T8)

Zone 2 extends northwards from Tamar Island to Swan Point in the mid to upper estuary (Figure 3).The waterway in this section begins to broaden with the widest point reaching over 3km in distance. The benthic habitat is predominately silt bottom (Lucieer *et al.*, 2009) with the introduced plant species *Spartina anglica* (rice grass) and the introduced fish species *Gambusia holbrooki* (mosquito fish) both present within this area. The salinity and depth increases along the length of the estuary travelling north. Zone 2 had a salinity range of 0.5-24.5 ppt (Figure 9) and a sampling depth range of 11-20 metres during the sampling period from October 2010 to September 2011. There are small communities spread out along the eastern and western shores of this zone with the largest being Legana and Exeter. Historically the dredge spoils from Launceston were deposited in zone 2 south of Windermere near the vast mudflats of Nelsons Shoal. There are also large sections of agricultural land along the eastern shore of this zone primarily used for grazing, cropping, orchards and vineyards (Figure 8).

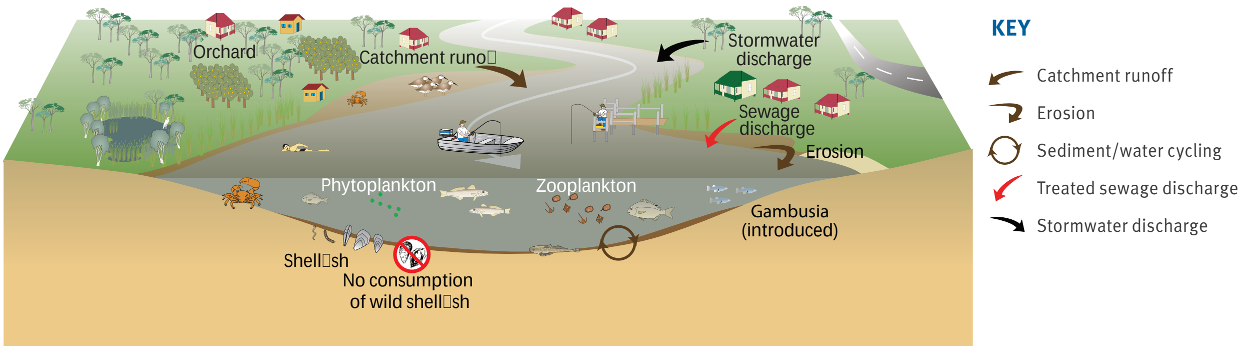


Figure 8. Zone 2 Conceptual Diagram describing land use and major water quality influences in mid-upper Tamar Estuary

Zone 2 experiences large and dynamic changes in salinity. The influence of freshwater inflows is reduced compared to Zone 1, however the surface water is always lower in salinity than the bottom (Figure 9), and winter rains result in lower salinities than drier summer months. As with Zone 1, there is interannual variability, and years with higher rainfall and more frequent flooding can result in significant differences in surface and bottom water masses (see December, Figure 9). Zone 2 is the most dynamic zone in the estuary with respect to tidal marine influence and freshwater inflows.

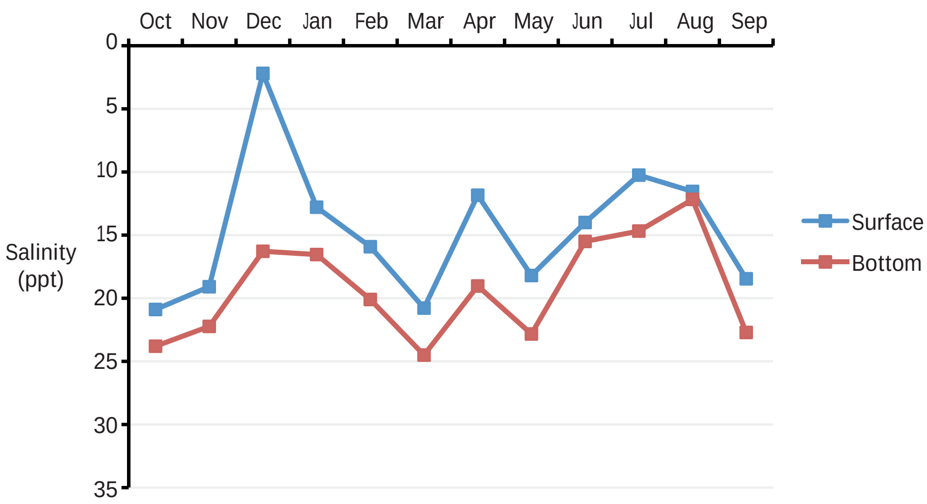


Figure 9. Salinity in Zone 2 at proxy site T7 Oct 2010-Sep 2011.

ZONE 3. MID ESTUARY (SITES T9-T12)

Zone 3 is located mid estuary between Swan Point and Rowella halfway along the Longreach section of the Tamar estuary (Figure 3). This area features large silt bays with smaller rocky channels, especially around the Batman Bridge where the substrate is mainly cobble and reef (Lucieer *et al.*, 2009). The salinity range for the 2010/2011 monitoring period was 3.0-29.0 ppt with the sampling depth ranging from 17-33 m. This zone within the estuary has less variation in salinity between surface and bottom samples (Figure 11), and thus could be considered to have a well mixed water column. This may be due to the zones location in the middle of the estuary and the geomorphology of deep rocky pools and narrow bends combing with powerful tidal influences. Although the water in this zone is well mixed a seasonal signal is still evident. A prominent man-made feature in this section of the estuary is the Batman Bridge (Est. 1968) which spans 200m and connects the eastern and western shores of the estuary at Whirlpool Reach. Zone 3 has smaller rural communities along the shores of the Tamar with grazing, cropping, vineyards, orchards, wood processors and salmon farming all operating close to the estuary's shore (Figure 10) Zone 3 is also used for recreational activities such as swimming, boating, camping and fishing.

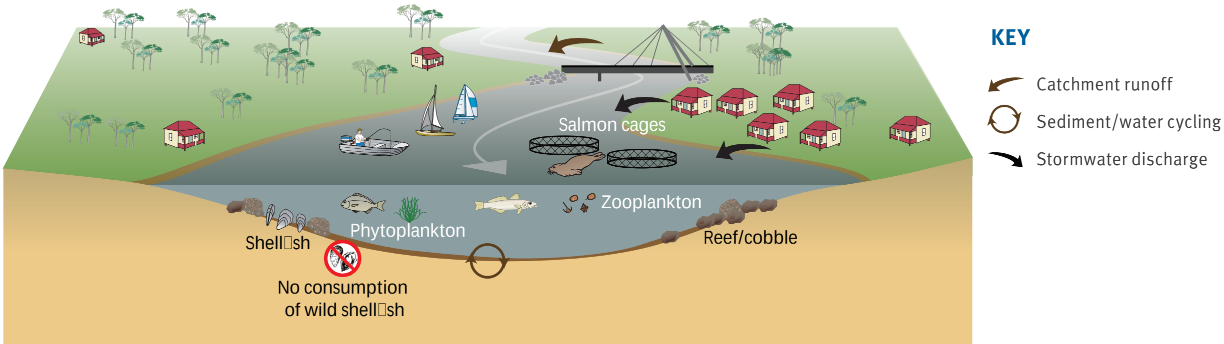


Figure 10. Zone 3 conceptual diagram describing land use and major water quality influences in mid Tamar estuary.

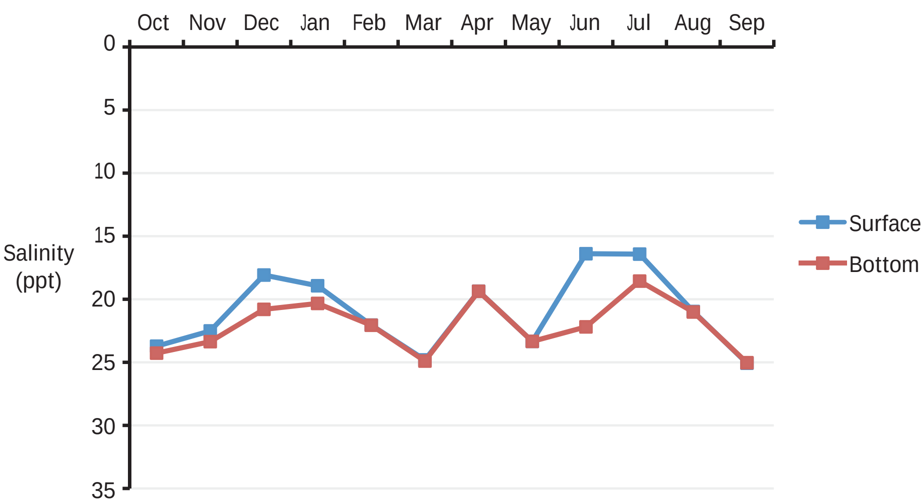


Figure 11. Salinity in Zone 3 at proxy site T11 Oct 2010-Sep 2011.

ZONE 4. MID-LOWER ESTUARY (SITES T13-T16)

Zone 4 is situated in the lower estuary between Rowella and George Town. The estuary here is wide and deep with Middle Arm and West Arm joining the estuary on the western shore (Figure 3).

The benthic habitat is mainly silt in the southern half of the zone with cobble and reef predominating in the northern section from Deceitful Cove to George Town (Lucieer *et al.*, 2009). The sample salinity ranges from estuarine to full marine at 3.0-35.0 ppt (Figure 13) with a sample depth range of 4-42 metres). There is a strong marine influence, and less stratification of the water column compared to Zones 1-3. Surface water quality may still influenced by freshwater flows.

There are a number of introduced pest species found in this area and the greater Tamar estuary including the Pacific oyster, Asian bag mussel, European green crab and rice grass (Aquenal & DEPHA, 2008).

The main population centres are Beauty Point on the western shore and George Town on the eastern shore. Bell Bay is the most industrialised section along the estuary supporting mining, metal processing, timber and shipping industries (Figure 12).The area has a history of elevated metal concentrations in sediments from historic practices of both mining and metal processing. Zone 4 is also widely used for recreational activities such as skiing, swimming, fishing and boating.

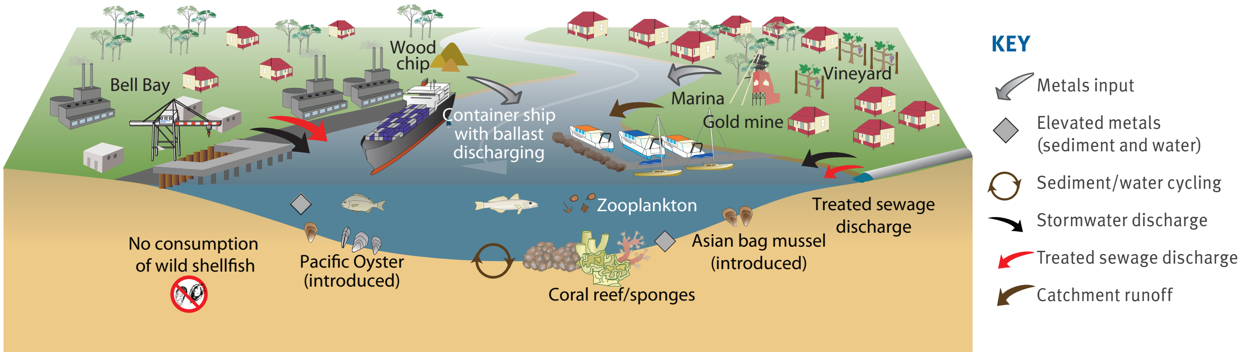


Figure 12. Zone 4 conceptual diagram describing land use and major water quality influences in mid- lower Tamar estuary.

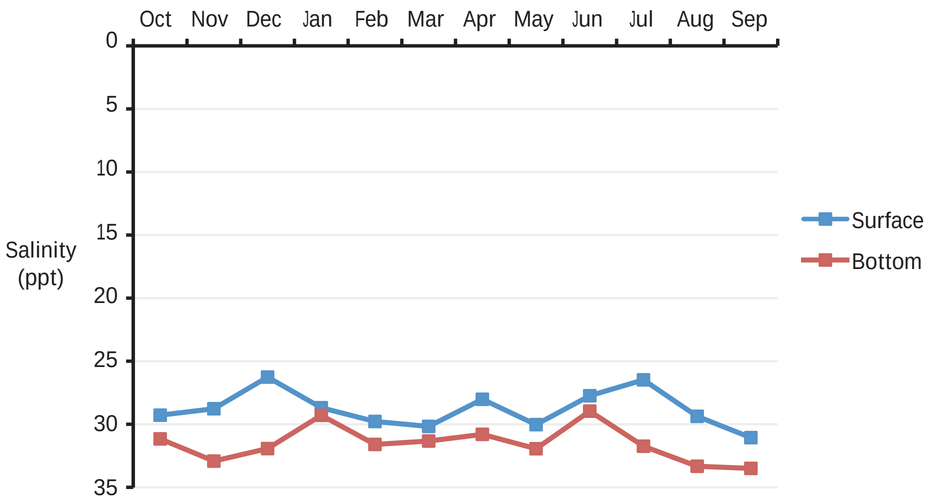


Figure 13. Salinity in Zone 4 at proxy site T15 Oct 2010-Sept 2011.

ZONE 5. LOWER ESTUARY (SITES T17-T20)

Zone 5 is located in the lower Tamar estuary and extends from George Town to Bass Strait, 3.5km past the mouth of the estuary (Figure 3). This zone is where the estuary meets the sea and as a result the salinity here is predominately marine except in times of large floods moving down the estuary (Figure 15). The salinity in Zone 5 ranges from 29.5-35.4 ppt with a sample depth range of 14-40 m. This area within the estuary has the largest variety of benthic habitats, comprising a mixture of sand, seagrass, sponge garden, cobble and reef with sandy rocky shores and sandy beaches closer to the ocean (Lucieer *et al*., 2009). This zone is the entry to the Tamar estuary and is a shipping route to the industry ports of Bell Bay and Longreach (Figure 14). As the area is the main shipping route from Bass Strait to the ports in the estuary, Zone 5 also has a number of invasive species that have been introduced via shipping activities such as: the Pacific oyster, Asian bag mussel and the European green crab. Zone 5 is also used for recreational activities such as swimming, boating, fishing and scuba diving.

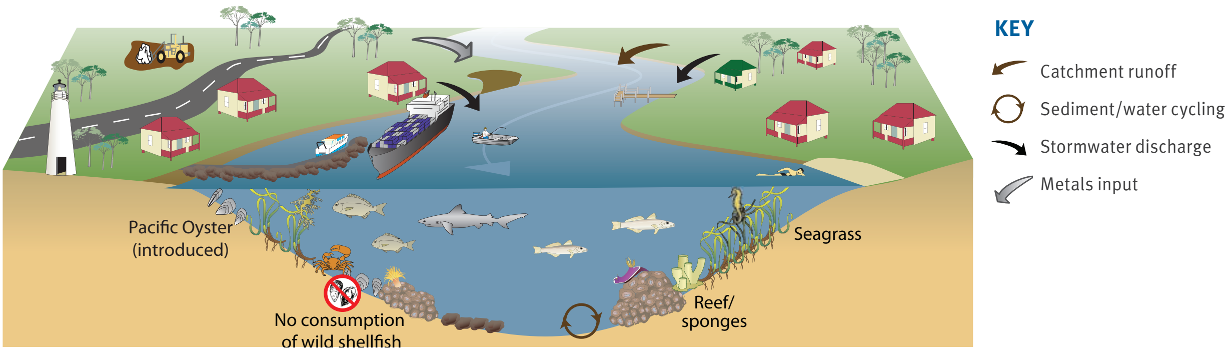


Figure 14. Zone 5 conceptual diagram describing land use and major water quality influences in lower Tamar Estuary.

Due to the distance from the upper estuary and freshwater inflows, surface and bottom waters have similar salinity values, although a slight "freshening" of the surface waters is occasionally observed.

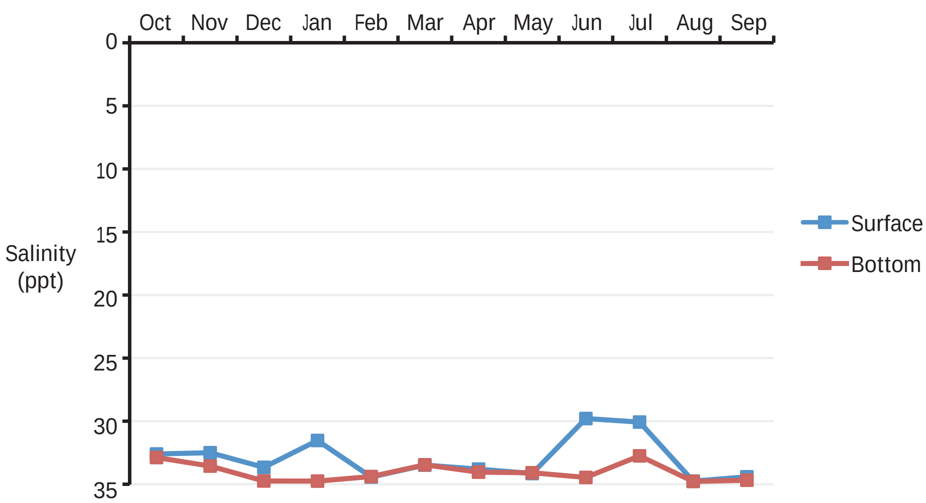


Figure 15. Salinity in Zone 5 at proxy site T18 Oct 2010-Sep 2011.

2.4 NORTHERN TASMANIA CLIMATE AND FLOW DESCRIPTION

Waterways are heavily influenced by climatic conditions. In wet years, catchments with saturated soils deliver high surface runoff and river flows, mobilising pollutants which ultimately end up in the estuary. Dry years are characterised by higher summer temperatures and decreased flows in the catchment. These conditions may lead to lower dissolved oxygen concentrations, which can be problematic for river and estuary health. This section describes the climate during the sampling period of October 2010 to September 2011 as background to the results shown in this report.

Launceston has a temperate climate with average air temperatures ranging from 13.1°C in the winter to 23.6°C in the summer (Table 5).

The long-term average yearly rainfall for Launceston is 696.6mm (Bureau of Meteorology, 2011).

Table 5. Launceston long term climate averages. Source Australian Bureau of Meteorology. Launceston Climate (2011).

Climate Averages for Launceston				
	Spring	**Summer**	**Autumn**	**Winter**
Maximum Temperature (deg C)	17.9	23.6	19.0	13.1
Minimum Temperature (deg C)	7.0	11.5	7.5	2.8
Rainfall (mm)	172	122	153	230

The EHAP sampling period from October 2010 to September 2011 was wetter than usual across northeast Tasmania (Figure 16). Months with above average rainfall were common throughout 2011 particularly between June and September (Bureau of Meteorology, 2012). In 2011 the northeast of the state experienced flooding events in January, March and April and August which saw major flooding occur in the South Esk River with the Trevallyn Dam spilling frequently over the sampling months (Bureau of Meteorology, 2012).

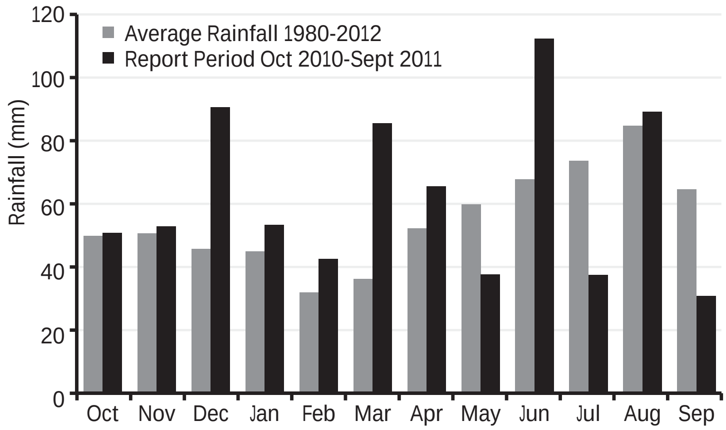


Figure 16. Launceston Rainfall. Ti Tree Bend Gauge (Data from Australian Bureau of Meteorology)

There are six catchments draining into the Tamar estuary; the North Esk, South Esk, Macquarie, Brumbys-Lake, Meander and Tamar catchments, however only the North and South Esk Rivers directly release freshwater to the Tamar estuary where they connect around the city of Launceston. The Macquarie, Meander and Brumbys-Lake catchments all converge into the larger South Esk River catchment, while North Esk Catchment is a smaller catchment (Figure 1). The majority of freshwater draining into the estuary is delivered by the South Esk River catchment and to a lesser extent the North Esk River catchment (figure 18). The South Esk River is regulated for hydro power generation at Lake Trevallyn close to Launceston at the bottom of the catchment and also at the Poatina hydroelectric power station that uses redirected flows from Great Lake which flow through the Brumbys-Lake Catchment. The smaller North Esk is not regulated for power generation. Estimated flow data from the North Esk and South Esk rivers (Figure 17 and 18) are used in this report to describe the flows entering the Tamar estuary. The Flow data was obtained from Hydro Tasmania the and Bureau of Meteorology (BoM) at flow stations situated at the Trevallyn Dam on the South Esk and at Cora Lynn on the North Esk River.

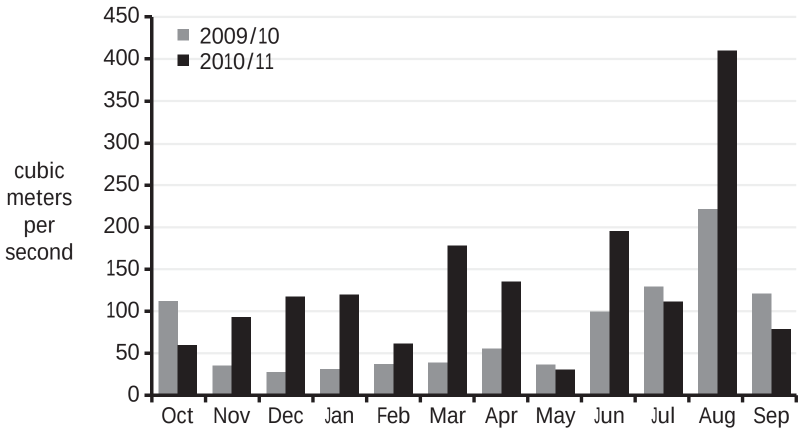


Figure 17. Estimated combined monthly flow averages into Tamar Estuary from the North Esk and South Esk rivers for 2009/2010 and the 2010/2011 monitoring periods.

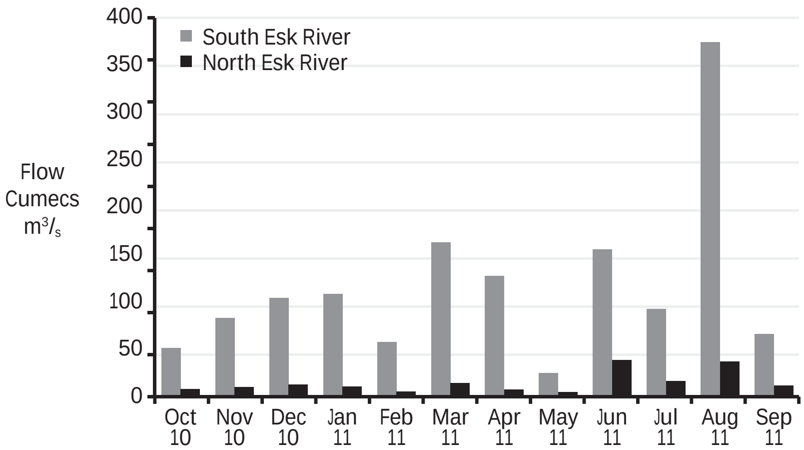


Figure 18. Comparison of monthly average flow contributions into the Tamar river estuary from the North and South Esk rivers.

Flow data from the North and South Esk Rivers, sourced from the Bureau of Meteorology (BOM) and Hydro Tasmania respectively, show average monthly flows for the 2010/11 period were higher than the recorded flows of the previous monitoring year (Figure 17).

The majority of rainfall occurring in 2009/10 was in the winter and spring months. However, the following year (2010/11) experienced unseasonal increased flows in the summer and autumn months as well as peaks in June and August. The relative flow contributions from the South and North Esk to the Tamar River Estuary are given in (Figure 18), showing that the greater flow contributions are from the larger South Esk River catchment.

BOX 1. CATCHMENT FLOWS-FLOOD IMPACTS ON ESTUARIES.

The 2010/2011 TEER EHAP monitoring period was characterised by high rainfall and surface water flows within the Tamar catchment. 2011 in particular had record breaking rainfall in the Northern catchments of Tasmania (Figure 17). Flooding was frequent within the Tamar catchment and as a result the TEER ambient monitoring program captured a number of flood events impacting on the Tamar estuary. Major floods cause considerable addition of organic and inorganic matter to the water (Nilsson 2008).

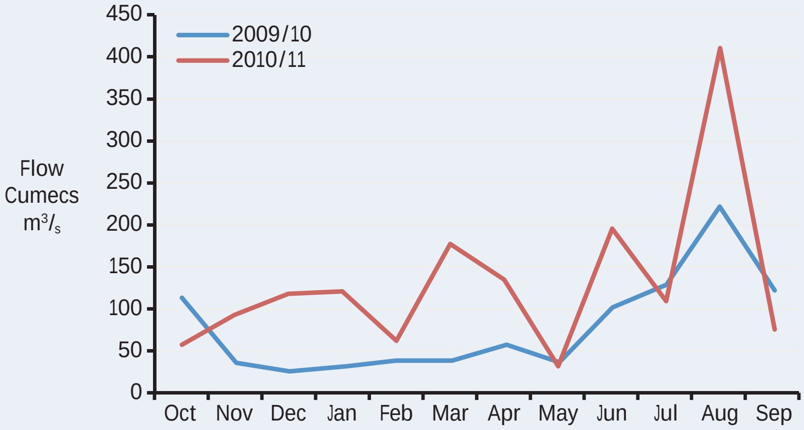


Figure 19. Combined monthly flow averages from the North and South Esk Rivers 2009/2010 and 2010/2011

The 2010/2011 TEER EHAP results show that high nutrient, sediment and bacterial loads were delivered to the estuary from the rivers contributing to the catchment. Major effects of flooding on estuaries include large plumes of suspended sediments, nutrients, phytoplankton and possible pollutants and a resulting increase in turbidity. There may also be changes in phytoplankton composition in response to nutrient pulses from the flood event (Grice et al 2000).

The effects of flooding in an estuary depend on the attributes of the receiving ecosystem, past disturbance history, the volume and duration of the flood event. During a rising flood a first flush occurs where water contaminant levels are intensified as they are transported and concentrated into receiving waters, as the flood continues a dilution effect occurs where the contaminant levels are diluted from the large volumes of water that follow after the first flush. In most cases, because of dilution, effects on water quality are not permanent (Nilsson 2008). Storm runoff consistently lowers quality standards in rivers and estuaries (Leaman 2007). The 2010/2011 water quality parameter results in this report show high levels of Total Suspended Solids, Chlorophyll-a, Turbidity, Total Phosphorus, Total Nitrogen, and *Enterococci* correlate with high flows entering the estuary.

Sediments are eroded and scoured from land and in stream sources in the upper catchment; the sediment load is then delivered to the estuary in large volumes during floods contributing to elevated TSS and turbidity levels.

Sediment levels of flood plumes will be greatly increased in catchments with substantial land clearance and erosion, particularly gully and stream bank erosion (Caitcheon et al 2001).

Nutrients are derived from a variety of natural and anthropogenic sources in the catchment and may be transported to the estuary via rainfall, rivers and streams, ground-water, surface runoff and direct discharges (Aquenal and DEPHA 2008). These sources of nutrient such as agricultural and urban runoff, fertilizers, livestock wastes and waste water treatment plants are all influenced by floods.

Flow has a marked impact on bacterial levels in the estuary as increased rainfall and flows deliver increased bacterial loads from tributaries, stormwater runoff and waste water treatment plants within the catchment (Aquenal and DEPHA 2008).

Due to high flows experienced in 2010/2011 the EHAP water quality parameters show higher maximum values compared to the previous dryer monitoring period, however median values are only slightly elevated and show similar patterns and distributions to the previous monitoring year.

3 RESULTS OF AMBIENT WATER QUALITY MONITORING

This section describes results from the water quality sampling program for October 2010 to September 2011. ANZECC guidelines are shown, where available, for comparison. Appendix 2 provides a description of the sampling conditions such as prior 7 day rainfall, monthly flow and tidal stage at time of monthly ambient sampling.

3.1 EHAP DATA REPRESENTATION

For the purposes of general discussion, much of the data in the following sections are presented as ''box-and-whisker'' diagrams (Figure 20). Box-and-whisker diagrams are a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower 20th percentile, median, upper 80th percentile and largest observation (sample maximum). A box plot may also indicate which observations, if any, might be considered outliers. These diagrams display the full spectrum of data collected, together with key statistical information. The 80th and 20th percentiles are used when representing physical parameters (such as salinity) and 95th and 5th percentiles are applied to toxicants (such as metals). The spacing between the different parts of the box helps to indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. The letter 'n' and a number will be located above each box-and-whisker plots, i.e. (n=12), this indicates how many samples have been included in the box-and-whisker analysis.

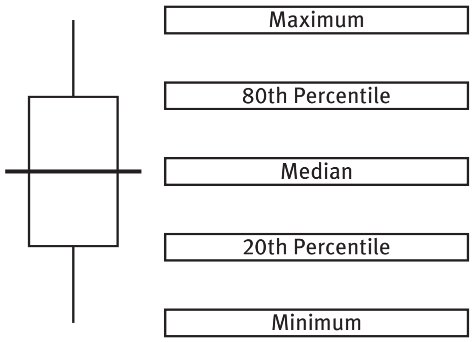


Figure 20. Key to data representation-'Box-and-Whisker' plots

3.2 TEMPERATURE, SALINITY AND PH

Temperature, salinity and pH provide important contextual information about estuarine circulation. Both temperature and salinity provide important detail about water column structure and estuarine mixing, and are essential information for the development and calibration of hydrodynamic models (Aquenal and DEPHA, 2008). Temperature, salinity and pH influence the types and rates of biogeochemical processes and affect the distribution, diversity and abundance of aquatic species. Temperature is important in determining the rates of microbial, plant and animal growth. The timing of fish, and other animal, migration and reproduction is also influenced by temperature (Aquenal and DEPHA, 2008).

Most plant and animal species have very specific salinity tolerances, and the distribution and variability of salinity dictate to a large degree the types and distribution of estuarine biota within a system. Salinity also plays an important role in the flocculation and settling of particles. Where fresh, turbid river waters enter an estuary, dispersed particles tend to agglomerate at the interface between fresh and brackish water. Salinity levels within an estuary generally range from near fresh <0.5 ppt to near seawater 34 ppt (Aquenal and DEPHA, 2008). pH, a measure of the acid balance of water, influences many biological and chemical processes, and is an important control on the solubility of some metals, particularly iron and copper. If pH levels are lowered, metals bound in estuarine sediments can be released to the water column. Estuary pH levels generally average from 7 to 7.5 in fresher sections and between 8 and 8.6 in more saline areas (USEPA, 2002).

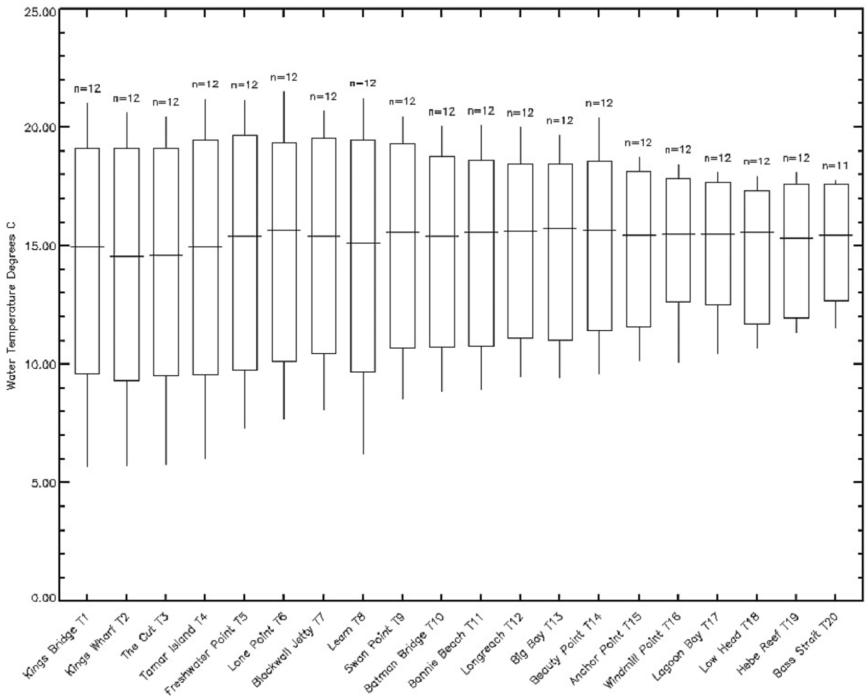


Figure 21. Water temperature (°C) for TEER sites 1-20 at surface waters for the 2010-2011 study period.

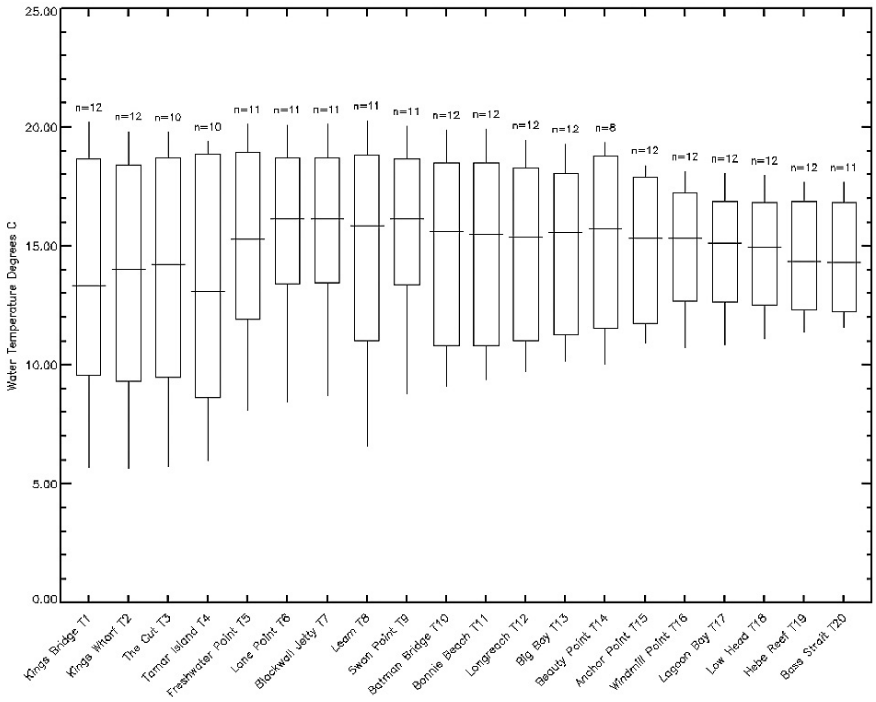


Figure 22. Water temperature (°C) for TEER sites 1-20 at bottom waters for the 2010-2011 study period.

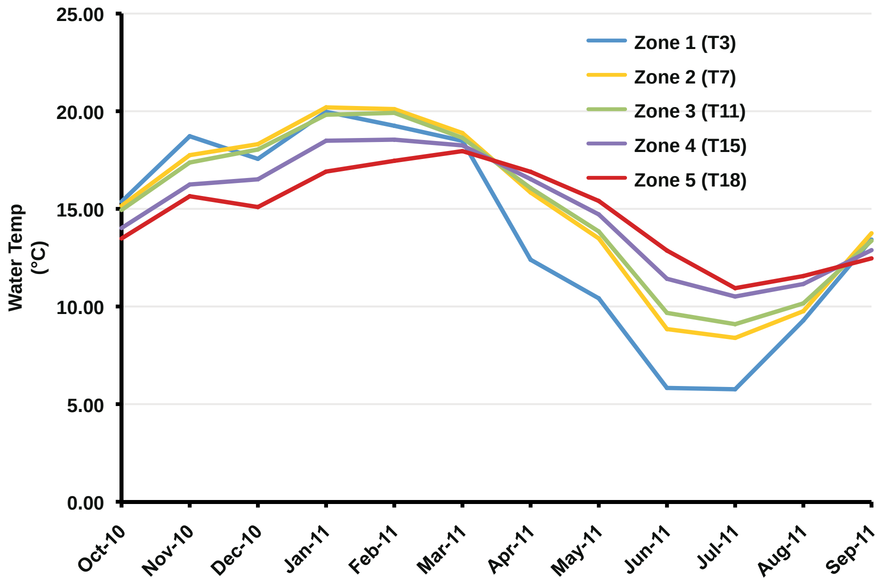


Figure 23. Water Temperature (°C) Zone 1-5 Proxy sites monthly profile averages.

Figures 21 and 22 display the water temperature (°C) for the 20 TEER EHAP sites between October 2010 and September 2011 at the surface and at the bottom respectively. Water temperature in the estuary varies according to season, ranging from approximately 5°C to 10°C in winter and 18°C to 20°C in summer (Figure 23). Temperature can also vary according to location in the estuary as well as depth of the water column. Summer leads to warm (›17oC) waters throughout the water column in Zones 1 to 3, with water temperature decreasing with depth and with proximity to the dominant marine influence in Zones 4 and 5 (Figure 24). In winter, water column profiles show cold (6oC) water in the upper estuary (Zone 1) with waters becoming increasingly warmer with depth and distance downriver (Figure 25).

Thermal stratification can occur along the estuary under different scenarios such as thermal heated surface layers from the sun, colder water at greater depths and haloclines where the denser saltwater lies beneath the less dense freshwater layer. Stratification is more pronounced in the upper part of the estuary.

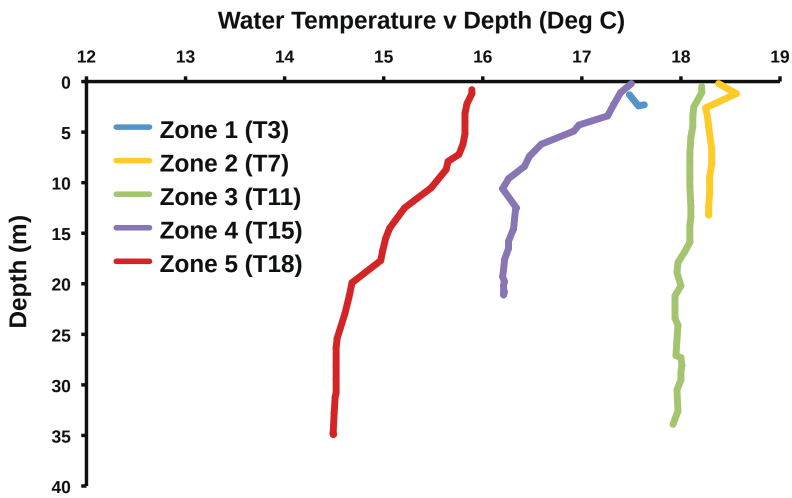


Figure 24. Summer (December 2010) water column profiles for proxy sites in each functional zone.

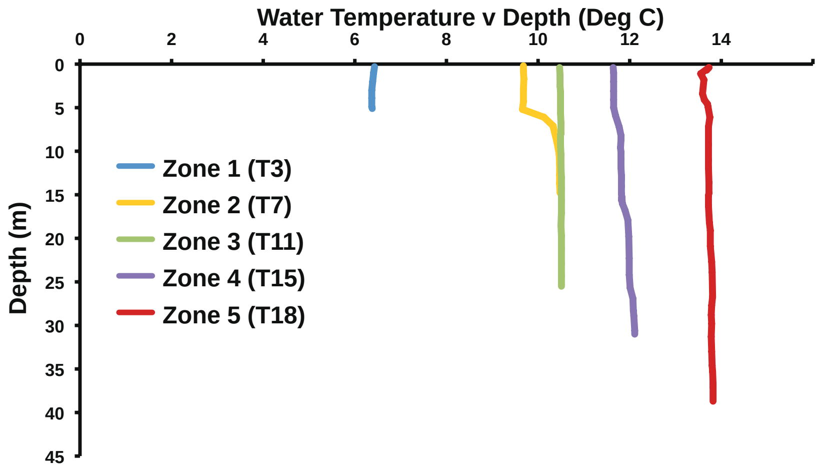


Figure 25. Winter (June 2010) water column profiles for proxy sites in each functional zone.

The same seasonal patterns are evident across all zones; there are generally lower temperatures in Zone 1 and higher temperatures in Zone 5 from March to September. Conversely between October and February Zone 1 experiences higher water temperature than Zone 5 (Figure 23). The range in water temperature during the 2010/2011 EHAP monitoring period was greater in the upper estuary (5.6-22.0°C) when compared to the water temperature range in the lower estuary (11.0-18.7°C) (Table 4).

Key findings: Water temperature for the estuary follows seasonal influences and is highest in summer with the largest temperature range found in Zone 1 in the upper estuary ranging from 5.6°C to 22.0°C compared to Zone 5 in the lower estuary which showed a range of 11.0°C to 18.7°C. Bottom waters reflect marine influences which are cooler than surface waters in summer, and show less variability. Average water column temperatures are uniform across all zones in the estuary in March.

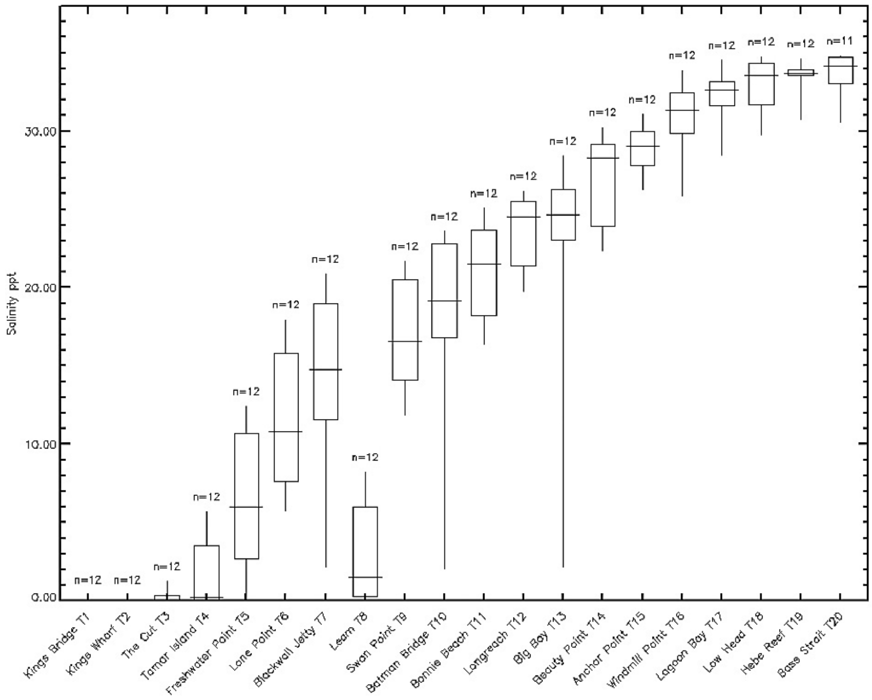


Figure 26. Salinity (ppt) for TEER sites 1-20 in surface waters for the 2010-2011 study period.

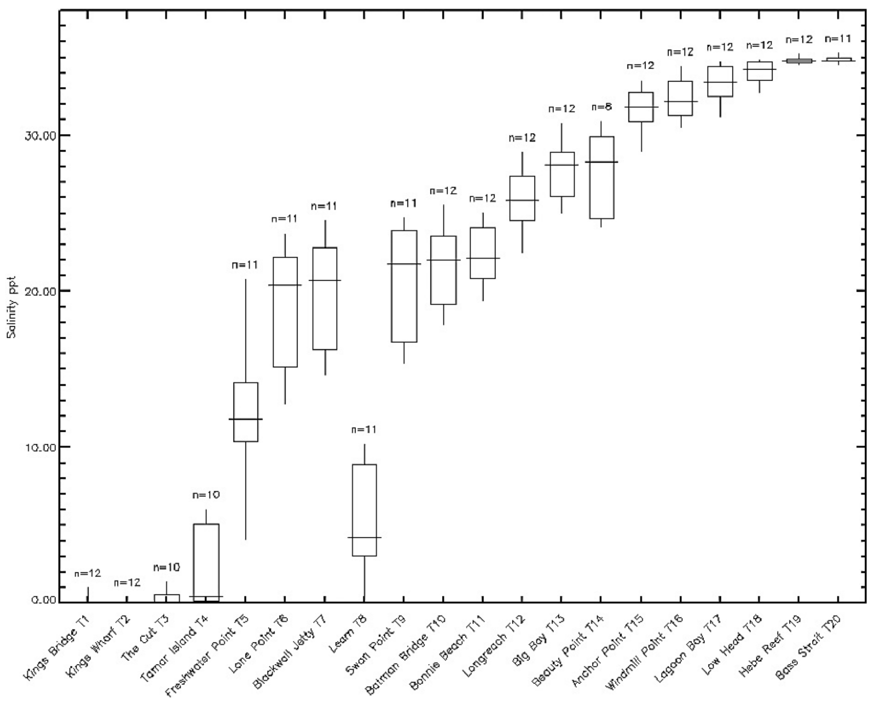


Figure 27.Salinity (ppt) for TEER sites 1-20 in bottom waters for the 2010-2011 study period.

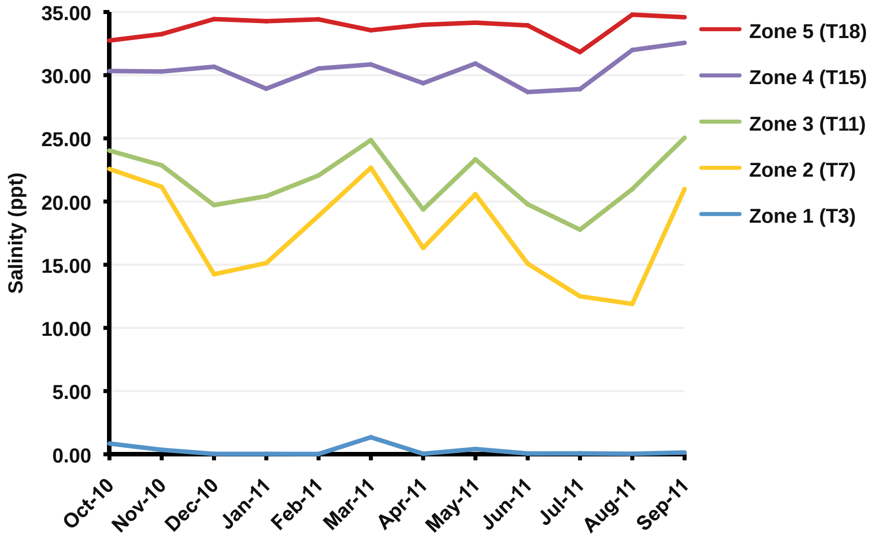


Figure 28. Salinity Zone 1-5 Proxy sites monthly profile averages.

Salinity levels in the Tamar range from seawater at the mouth (35 ppt) and gradually become less saline (brackish) with distance upstream and at times may be entirely fresh in the upper reaches (Figures 26 and 27). Salinity varies seasonally in the estuary, with summer salinities generally higher than winter salinities due to lower freshwater catchment inflows during the summer months (Figure 28). Salinity also varies with depth in the estuary and this is most marked in the middle estuary where incoming denser saline water is overlayed by a less dense fresher water layer, creating a salt wedge (Figure 29). The salt wedge will move and vary within an estuary depending on the interaction between freshwater seasonal flows and tidal influences. Water stratification occurs when water masses with different properties, in this case salinity form layers that act as barriers to water mixing.

The stratification in the middle estuary may be most pronounced during winter months when higher inflows of freshwater occur from the upper estuary, however summer floods such as those experienced in December 2010 (Figure 17) may also cause significant stratification in the middle and lower estuary.

Both surface and bottom samples for salinity at site T8 (Leam) had distinctly lower salinity than either of the EHAP ambient sites on each side of it (Figure 26 & 27). This observation is repeated in other comparisons between water quality parameters and is believed to be due to the unique mixing processes occurring at this site. Similar trends were observed in the 2009-2010 monitoring period

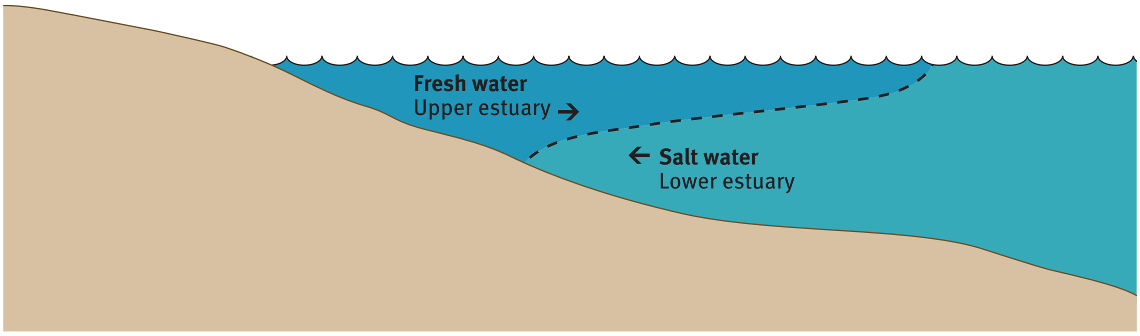


Figure 29. Estuary Salt wedge diagram showing high density saltwater moving under lower density freshwater inflows from the upper estuary and catchment.

Water stratification occurs when water masses with different properties - salinity (halocline), oxygenation (chemocline), density (pycnocline), temperature (thermocline) - form layers that act as barriers to water mixing.

Summer water column profiles for proxy sites in each functional zone in the estuary are shown in figure 30. Zone 1 is completely fresh, while Zone 5 has a strong marine signal. Zones 2 to 4 show significant freshening in the surface waters, with more saline water at depth. Figure 31 shows the same proxy sites in winter (June) with fresher surface waters in Zone 3 and 5.

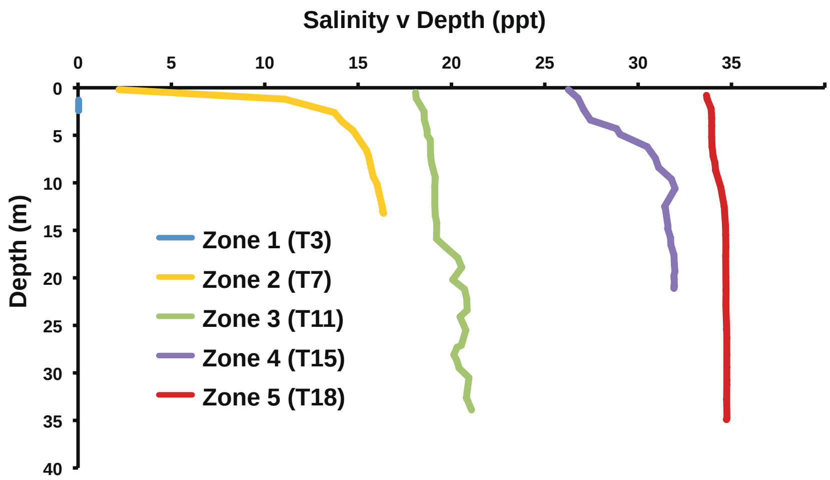


Figure 30. Summer (December) water column salinity profiles for proxy sites in each functional zone.

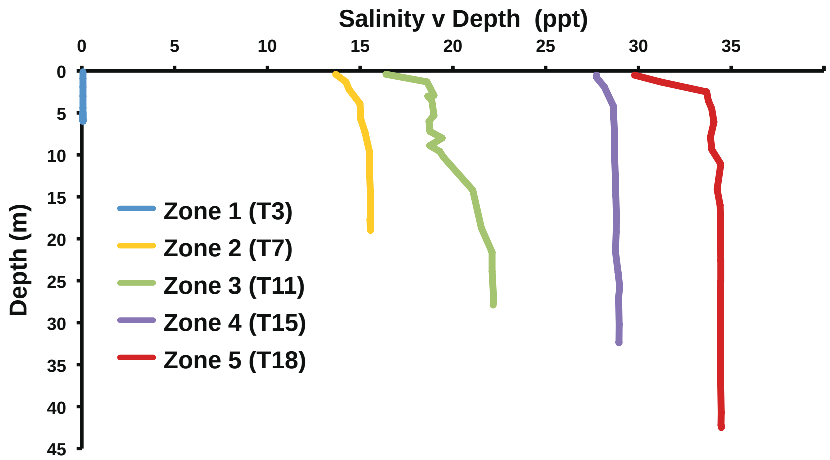


Figure 31. Winter (June) water column salinity profiles for proxy sites in each functional zone.

The general trend of increasing salinity as the zones extend towards the ocean and the distinct differences in salinity between the zones is shown in Figure 28. Zones 2 and 3 tend to be brackish, with widely variable salinity.

Key findings: Tamar estuary salinity ranges from 0.01 ppt in Zone 1 and increases to 35.4 ppt in the lower estuary in Zone 5 closer to the estuary mouth. Salinity changes with depth, with less dense freshwater layering on top of denser saltier water. Floods dilute salinity along the estuary, and push the salt wedge downstream. Stratification in summer is most evident in Zones 2 and 3 while higher freshwater inputs during winter can extend stratification as far as Zone 5 near the estuary mouth.

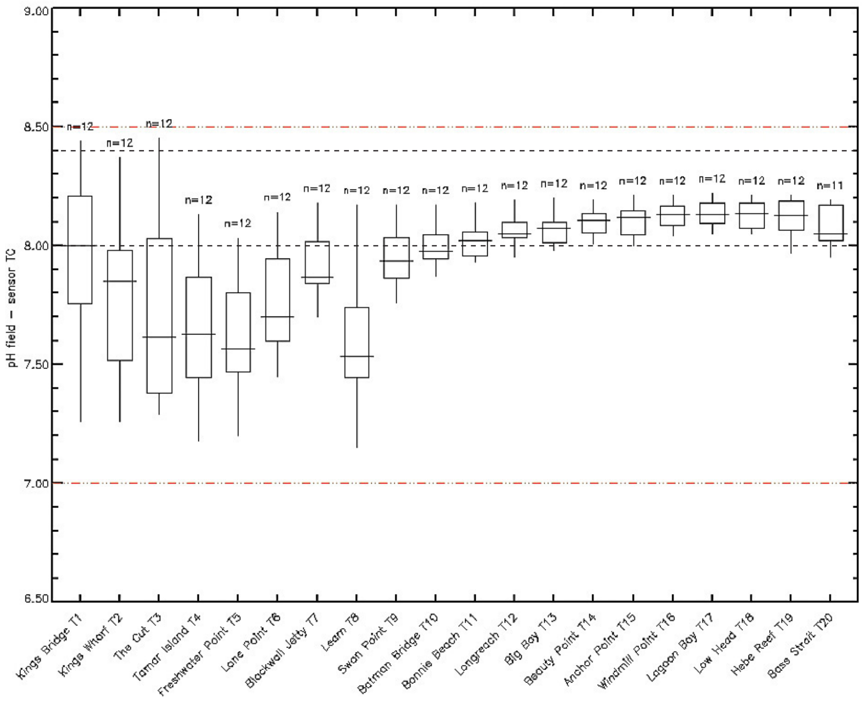


Figure 32. pH for TEER Sites 1-20 at surface waters for the 2010-2011 study period. Dashed lines indicate the upper and lower ANZECC marine and estuarine default guideline trigger values.

Marine guideline range (black dashed line) is 8.0-8.4 and Estuarine range (red dashed line) is 7.0 - 8.5.

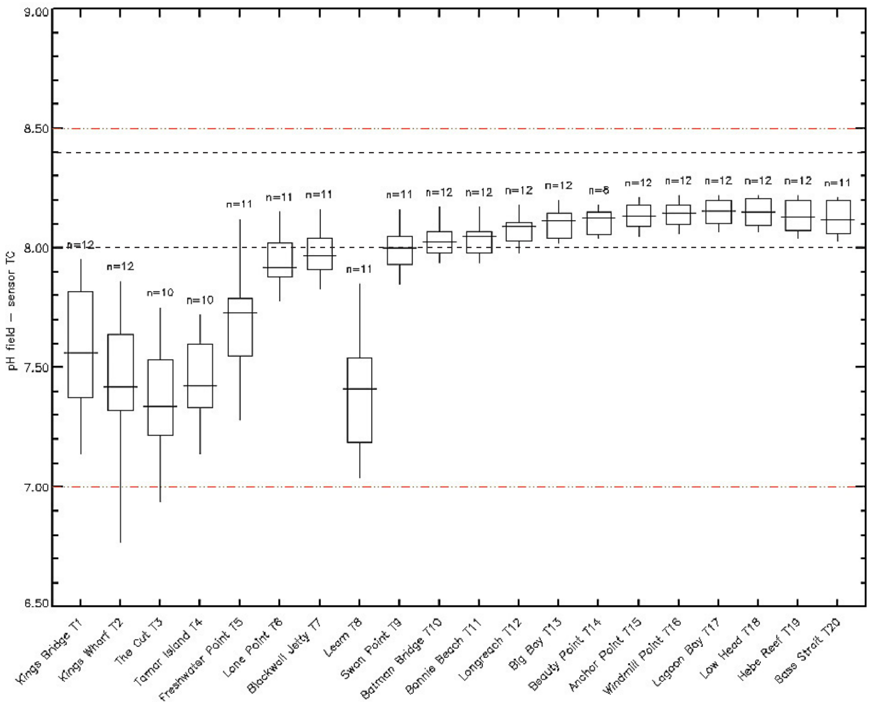


Figure 33. pH field for TEER Sites 1-20 at bottom waters for the 2010-2011 study period. Dashed lines indicate the upper and lower ANZECC marine and estuarine default guideline trigger values.
Marine guideline range (between black dashed line) is 8.0-8.4 and Estuarine range (between red dashed line) is 7.0- 8.5

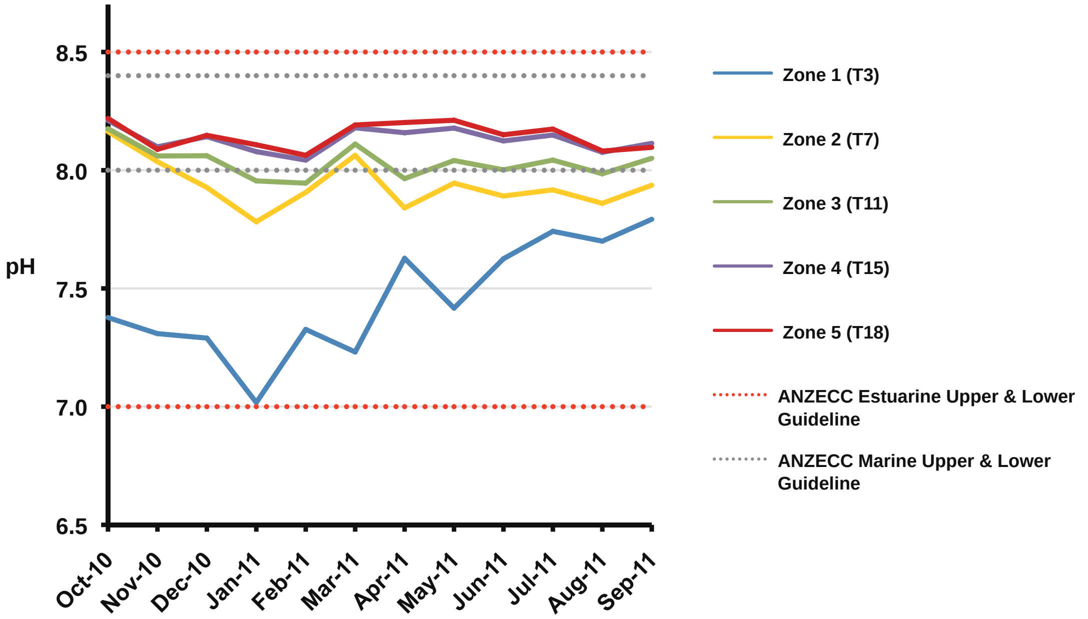


Figure 34. pH Zone 1-5 Proxy sites monthly profile averages for the 2010-2011 study period. Dashed lines indicate the upper and lower ANZECC marine and estuarine default guideline trigger values. Marine guideline range (in between grey dashed line) is 8-8.4 and Estuarine range(in between red dashed line) is 7.0- 8.5

The median pH values in Zone 1 are the lowest in the estuary due to the high freshwater inputs but are still within estuarine pH guidelines. The pH then increases downstream from pH 7.5 in the upper estuary to pH 8.2 in the lower estuary (Figures 32 & 33). The pH in the Tamar estuary sampled from October 2010 to September 2011 was within ANZECC default guidelines. The pH default trigger values have lower and upper limits of 8.0 and 8.4 respectively for marine waters and lower and upper limits of 7.0 and 8.5 respectively for estuaries (Table 2).

Site T8 at Leam has lower pH values than adjoining sites (Figures 32 and 33), showing median values of pH 7.7 for surface and bottom samples whereas sites T7 and T9 show median pH values above 8.0.

Zone 1 has a lower and more variable pH compared to all other zones, which have a similar pH over time (Figure 34). The lower reaches experience a greater marine influence and the pH is buffered to a higher degree than in sites dominated by freshwater inputs. This has implications for biological processes, toxicant bioavailability and water chemistry. While Zone 1 is within the ANZECC guidelines, results for January 2011 show the pH approaching the lower limit (pH 7.0) on occasion. Zone 1 also shows high variation between sampling months when compared to Zones 2-5 which show more uniform pH values (Figure 34).

Key findings: pH is within ANZECC guideline levels for all sites in the Tamar. As expected, pH increases towards the mouth of the estuary, with lower variability the result of the buffering capacity of seawater. Surface water pH was generally higher than bottom waters, particularly in the upper reaches of the estuary.

3.3 DISSOLVED OXYGEN

Oxygen is essential to nearly all forms of life and influences most chemical and biological processes in water bodies. Reduced dissolved oxygen (DO) levels can be stressful to fish and other aquatic organisms, particularly those living at the sediment-water interface, where low DO events tend to be most pronounced (ANZECC, 2000). Chronic or intermittently low DO levels can eliminate more sensitive organisms and significantly alter benthic community structure. Where oxygen levels are undetectable, types and rates of bacterial processes in sediments are altered, potentially resulting in the release of sediment-bound nutrients and toxic metals, and the production of methane and hydrogen sulphide gases (Aquenal and DEPHA, 2008). High levels of organic enrichment can trigger these anoxic benthic conditions.

Levels of DO in a healthy estuarine environment generally lie between 6.5 and 9.0 mg/L, or 80-90% saturation as measured over at least one daily cycle (ANZECC, 2000). Most organisms can grow and reproduce unimpaired when DO levels exceed 5mg/L (Aquenal and DEPHA 2008). However, when levels drop to 3 - 5 mg/L they become stressed, and below 3 mg/L (hypoxia) many species will move elsewhere and immobile species may die. Where anoxia occurs (‹0.5 mg/L), organisms that require oxygen for survival will die (USEPA, 2002a).

DO levels in estuarine waters are dependent on a number of factors, including temperature, salinity, biological activity, turbulence and mixing, and may fluctuate widely over a period of hours, weeks or months (Head , 1985).

Aquatic plants are net producers of oxygen during daylight hours (photosynthesis), but are net consumers at night (respiration); therefore, DO levels also vary over a 24-hour period, with the lowest concentrations occurring around sunrise (Aquenal and DEPHA, 2008).

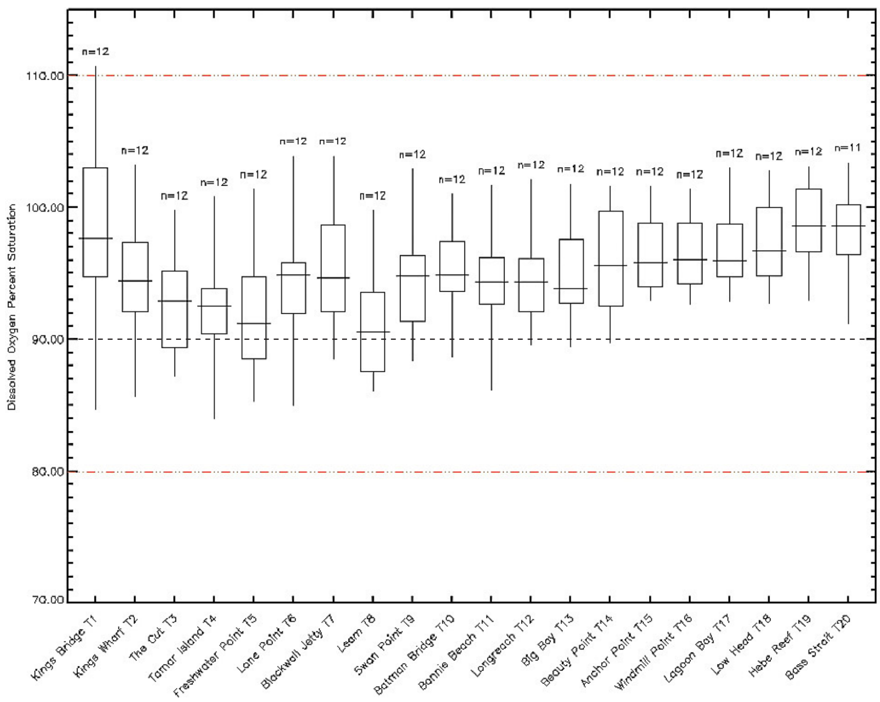


Figure 35. Dissolved Oxygen % Saturation for TEER sites 1-20 at surface waters for the 2010-2011 study period. Dashed lines indicate the upper and lower ANZECC marine and estuarine default guideline trigger values. Marine guideline range 90-110 (between mid black dashed line and top red dashed line). Estuarine guideline range 80-110 (between red dashed line).

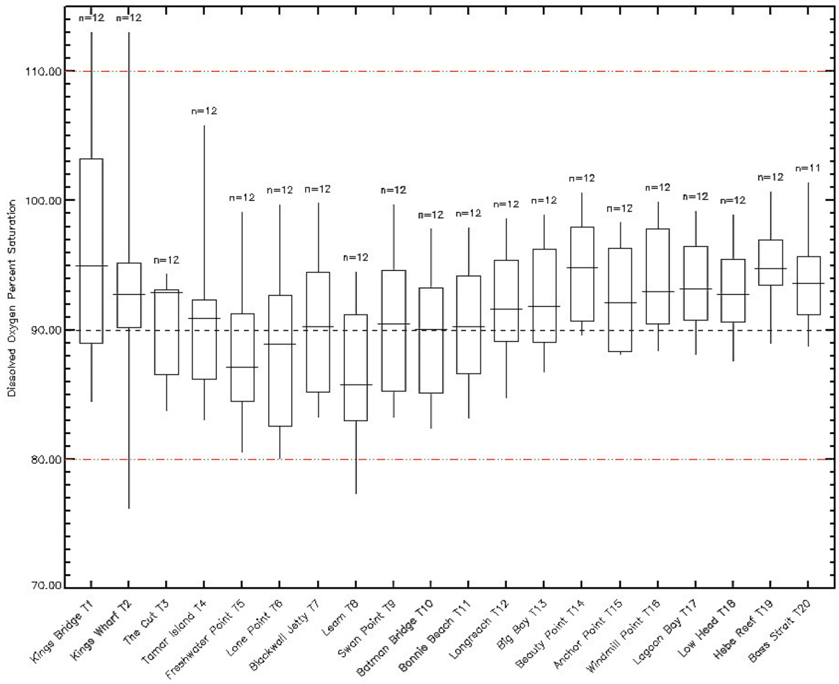


Figure 36. Dissolved Oxygen % Saturation for TEER sites 1-20 at bottom waters for the 2010-2011 study period. Dashed lines indicate the upper and lower ANZECC marine and estuarine default guideline trigger values. Marine guideline range 90-110 (between mid black dashed line and top red dashed line). Estuarine guideline range 80-110 (between red dashed line)

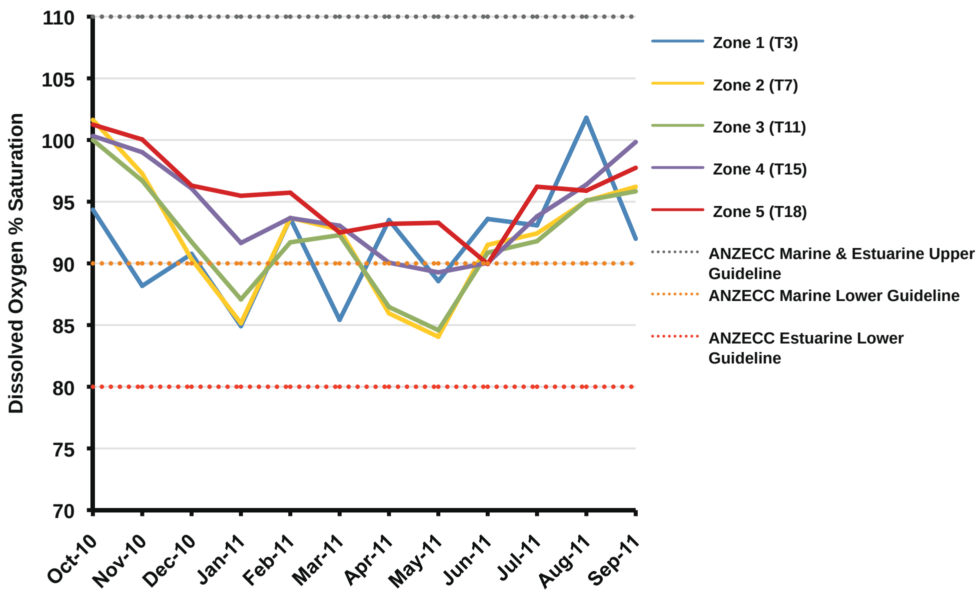


Figure 37. Dissolved Oxygen Zone 1-5 Proxy sites monthly profile average.

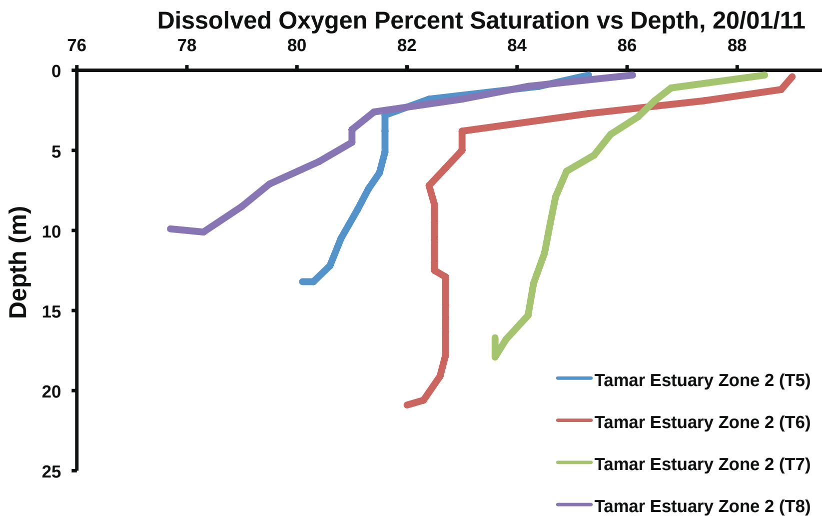


Figure 38. Water column profiles for DO from all sites in Zone 2 (T5-T8).

Median dissolved oxygen concentrations were generally higher in the lower estuary, showing a declining trend moving up the estuary, while DO levels also tended to be higher in surface waters than bottom waters, particularly in the middle and upper estuary (Figures 35 and 36). Dissolved oxygen concentrations are most variable in the upper estuary in Zone 1, with the highest concentrations attributed to cold freshwater associated with a high flow event in August 2011. Median values did not exceed the lower and upper ANZECC estuarine guidelines of 80 and 110 for estuaries categorised as slightly disturbed ecosystems. Minimum recorded DO values fell below recommended ANZECC guidelines in bottom waters at Kings Warf (T2) and Leam (T8) in the upper and mid estuary (Figure 36).

Oxygen dissolves more readily at low temperatures and low salinity, thus DO levels tend to be higher in cold freshwater than in warm seawater (Aquenal and DEPHA, 2008).

In general, elevated water temperatures and stratified conditions (i.e. limited vertical mixing) may contribute to reduce DO, often during summer months when river flows are generally lower and water temperatures higher resulting in strong thermal and salinity stratification. In the Tamar, there is evidence of lower dissolved oxygen in the upper most part of the water column, with greatest variability in the brackish Zone 2. Water column profiles for DO from all sites in Zone 2 (T5-T8) in January 2011 are presented in Figure 38. Oxygen at depth increases with distance down river; however as with salinity and pH, T8 behaves more like a Zone 1 site. All sites showed a small drawdown in oxygen at the bottom of the water column, most likely influenced by re suspension of organic rich sediments.

Key findings: Dissolved oxygen is generally within ANZECC guideline levels for all sites in the estuary. Fresh, cold waters entering the estuary from the catchment carry the highest concentrations of dissolved oxygen in winter, there may be localised surface depletion of oxygen in summer, and deeper waters subject to re suspension of sediment may similarly experience localised depletion.

3.4 NUTRIENTS

Nutrients, in particular nitrogen (N) and phosphorus (P), are essential for the metabolism of aquatic biota. The exchange of nutrients between the water column and bottom sediments is a critical pathway for nutrient cycling (Kennish, 1996). Nitrogen is present in animal and plant tissues chiefly as proteins while phosphorus is contained in cell walls and energy transporting molecules (EHMP, 2008). Nitrogen and phosphorus levels in aquatic ecosystems can fluctuate due to natural processes such as current upwelling, weathering and the breakdown of naturally occurring organic matter (Aquenal and DEPHA, 2008). However large inputs of N and P in urbanised estuaries are more likely to be derived from anthropogenic sources such as wastewater treatment plants (WWTP), industry outfalls, stormwater and agricultural runoff.

TEER partner Ben Lomond Water (BLW) manages drinking water, stormwater and waste water in the Tamar catchment. BLW, the local water authority, is actively undertaking monitoring, analysis and modelling to assess impacts from Sewege Treatment Plants (STP's) on the Tamar River estuary. This information will be used to inform decisions on management and future upgrades of STP's in the Tamar Estuary.

Stormwater and agricultural inputs are largely unquantified at this point, but have been identified as key issues in the WQIP to be developed by the TEER.

Excess nutrients in waterways can stimulate growth of aquatic vegetation and algae to reach nuisance, and in some cases bloom, proportions. Algal blooms, in particular cyanobacteria (blue green algae), have the potential to be toxic and poisonous to humans and animals and have adverse affects on the surrounding aquatic environment. Algal blooms can also cause dissolved oxygen and pH levels to fluctuate and limit light penetration in the water column by dispersing locally resident organisms.

ANZECC guidelines recommend that site-specific nutrient guidelines be developed for estuaries using either local data, or data from appropriate reference systems, and that these guidelines also be based on studies of ecological and biological effects. Where this information is not available, low-risk default values have been identified based on reference data collected from unmodified or slightly-modified estuaries within five geographical regions across Australia.

The ANZECC estuary guidelines for nutrients (Table 2 Section 2.2) used here do not incorporate any data from Tasmanian estuaries; a precautionary approach should be adopted when applying these default trigger values to Tasmanian systems (Aquenal and DEPHA, 2008). Developing Tamar specific nutrient water quality triggers is a priority for TEER to better understand the impact of nutrients in the estuary.

As trends for some surface and bottom box-and-whisker plots are similar, plots for most TEER EHAP bottom nutrients are presented in Appendix 3.

3.4.1 TOTAL PHOSPHORUS (TP)

The data collected for total phosphorus (TP) as part of the TEER EHAP show elevated levels of TP in the majority of the estuary (sites T1-T13) for both surface and bottom samples (Figure 39). The ANZECC default trigger of 30 µg/L of phosphorus was exceeded the majority of the time. Again site T8 at Leam does not follow the trend and is higher in phosphorus than either of the adjoining sampling sites. Zone 1 shows the highest concentrations of TP (Figure 39). The catchment adjacent to Zone 1 is the most urbanised and has inputs from stormwater and wastewater treatment plants; this is also the zone that receives the greatest amount of freshwater and in turn receives Phosphorus loads from the North Esk and South Esk rivers draining the greater Tamar catchment especially during times of high flow. TP levels are elevated particularly in Zone 1 and peaks correspond with high flow events during the 2010/11 sampling period (Figure 40).

A trial monitoring program to quantify mass loads of nutrients entering the upper the estuary from the North and South Esk is currently underway. Samples are collected on the same day as the estuary monitoring.

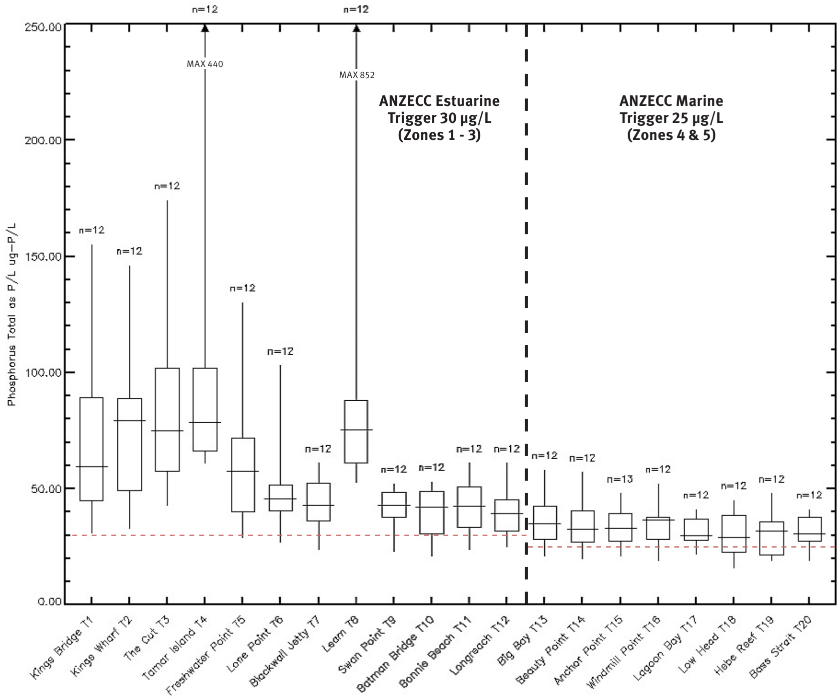


Figure 39. Total Phosphorus (µg/L) for TEER sites 1-20 at Surface waters for the 2010-2011 study period.

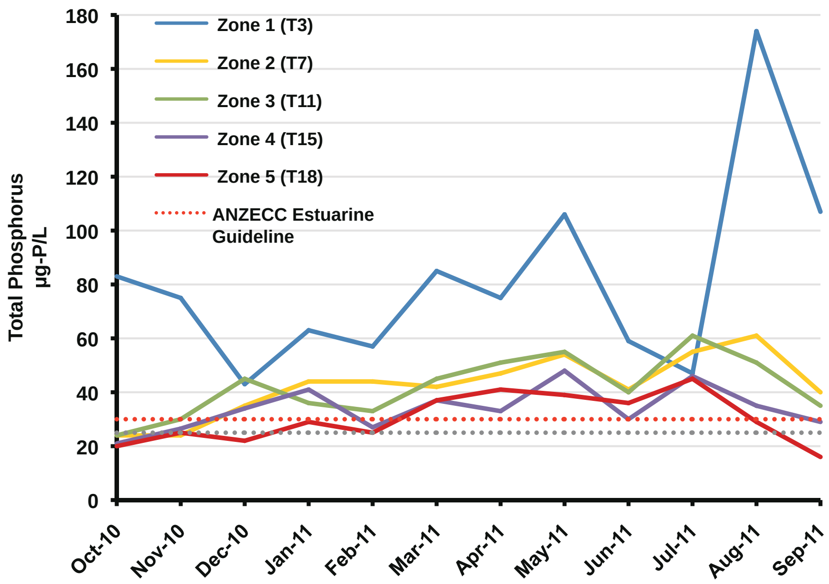


Figure 40. Total Phosphorus Zone 1-5 Proxy Sites monthly surface samples

Key findings: In the 2010/11 sampling period Total Phosphorus levels were higher in the upper estuary around Zones 1 and 2 with median values exceeding the ANZECC 2000, default trigger guidelines for the majority of the Tamar estuary. Phosphorus levels in Zone 1 peaked during August 2011 and coincided with a large flood event. The source of high TP to the estuary is being investigated as part of the mass loads study.

3.4.2 DISSOLVED REACTIVE PHOSPHORUS

Dissolved Reactive Phosphorous (DRP) consists of inorganic phosphate (PO_4^{3-}) (Whitehead *et al.*, 2010). Median DRP concentrations in the Tamar estuary ranged from 7.0 - 22 µg/L at sites monitored along the length of the estuary (Figure 41). All median values for surface and bottom samples exceeded the ANZECC estuarine default trigger of 5µg/L. The DRP results show similar patterns to TP with the higher values concentrated in the upper reaches of the estuary and values decreasing further down the estuary. As with TP, sources of DRP are likely to be STP inputs, industry outfalls, stormwater and agricultural runoff. Zones 1-3 T1-T12 exceeds ANZECC estuarine default triggers for most of the year with a seasonal pattern of highest levels in winter and spring (Figure 42). In Zone 4 and 5 median levels of DRP fall under the marine ANZECC default guidelines except for T13 (Figure 42).

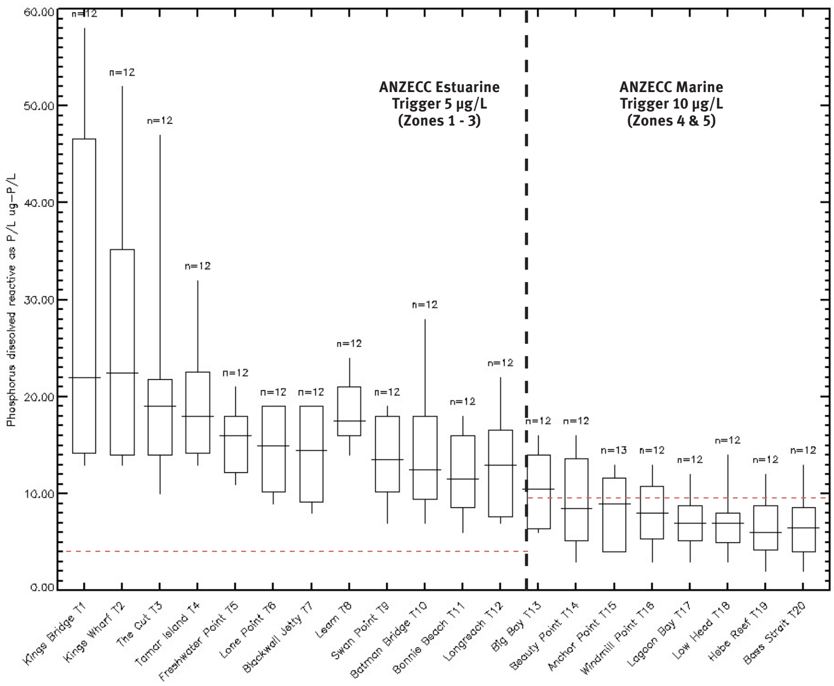


Figure 41. Dissolved reactive phosphorus (µg/L) for TEER Sites 1-20 at surface waters for the 2010-2011 study period.

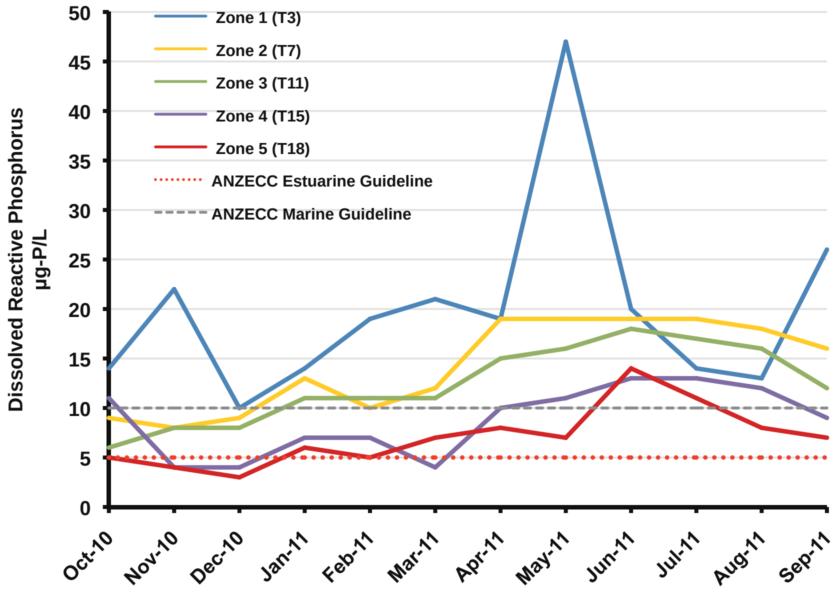


Figure 42. Dissolved Reactive Phosphorus Zone 1-5 Proxy sites, monthly surface samples.

Key findings: Median Dissolved reactive phosphorus values exceed the estuarine ANZECC 2000 guidelines along the entire length of the estuary with higher levels occurring in the upper estuary in Zone 1. The median values in the marine zones of 4 and 5 are all under the marine ANZECC guidelines with the eexception of T13 which is on between the marine and estuarine zone section. Concentrations of DRP generally decrease with distance downstream, reflecting the greater marine influence. In the lower marine zones, there is a weak seasonal trend with concentrations lowest in summer, and highest in winter.

3.4.3 TOTAL NITROGEN (N)

Median values for total nitrogen between sampling sites T1-T12 along the Tamar estuary exceed the ANZECC estuarine default trigger guidelines for both surface and bottom data during the 2010/11 sampling period (Figure 43). Higher levels of total nitrogen were detected in the upper estuary with levels tending to decrease down the estuary. Zone 1 concentrations of nitrogen were elevated compared to all other zones in the estuary (Figure 44). Zones 2-5 follow the same broad trend as Zone 1, however, the concentrations are lower, with peaks "smoothed" (Figure 44).

Across all proxy sites there is an increase in Total Nitrogen during winter. Leam (T8) has elevated values for nitrogen compared with adjoining sites, and as with most parameters is more similar to Zone 1 sites. As with other nutrient loads, Nitrogen sources were more concentrated in the upper estuary which may be due to the whole upper catchment discharging via freshwater tributaries the North Esk and South Esk rivers and the urbanised area around the city of Launceston.

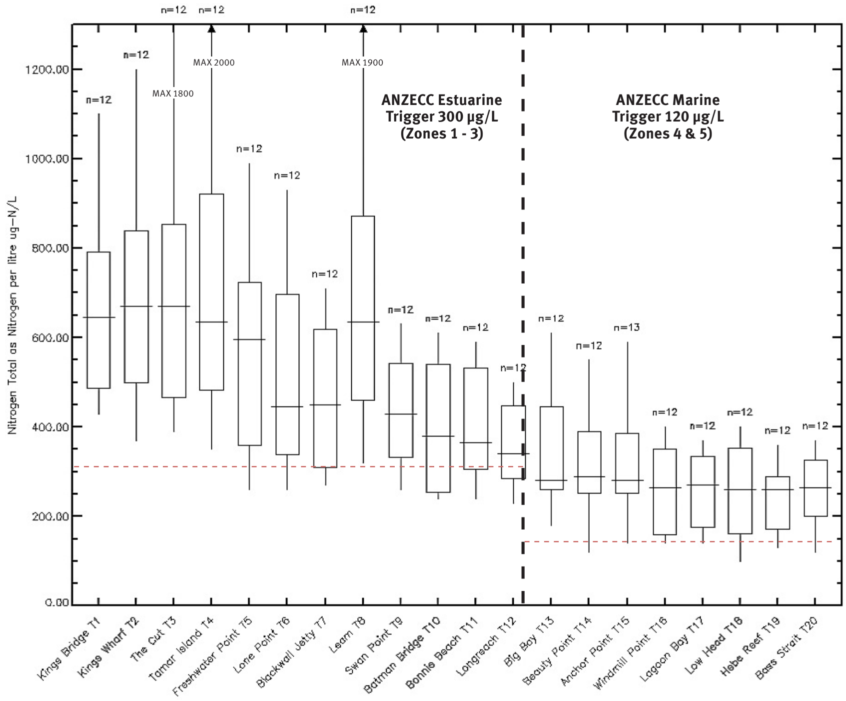


Figure 43. Total Nitrogen (µg/L) for TEER sites 1-20 at Surface waters for the 2010-2011 study period.

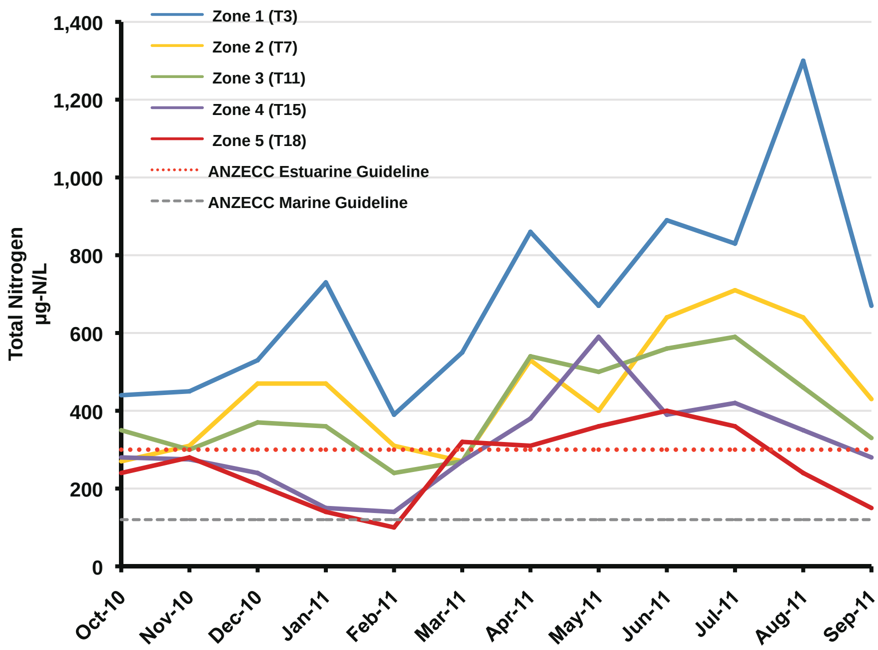


Figure 44. Total Nitrogen. Zones 1-5 Proxy sites monthly surface samples

Key findings: Median total nitrogen values exceed guidelines for the entire estuary (T1 - T12) with higher levels occurring in the upper estuary in Zone 1 and 2. Not sure why you just pick on sites 1-12, when examination of the data reveals that median values for 13-20 all in fact exceed the marine trigger levels. Maybe you had not finalised the key findings of this section as yet?

3.4.4 AMMONIA AND AMMONIUM (NH_{4+})

Ammonia (NH_3) is a soluble gas in water, whilst ammonium (NH_4) occurs as dissolved inorganic ions in the water (Whitehead *et al.*, 2010). The majority of the sampling sites in the estuary; Zones 1-4 have median values that are above the ANZECC estuarine default trigger for ammonia and ammonium (15µg/L) (Figure 45).

In the upper estuary from Kings Bridge (T1) to Beauty Point (T14) the median values for each site exceed the default trigger. From Anchor Point (T15) out to Bass Strait (T20) the median values fall below the default trigger for ammonia + ammonium. On a temporal scale proxy sites for Zones 1-3 were elevated for ammonia against the ANZECC default guideline trigger values for the majority of sampling days. Seasonal influences were observed in all zones with increased ammonium concentrations during the autumn and winter months from April through to August (Figure 46). Conversely during midsummer, February 2011 through to March all zones showed decreasing levels of ammonium with Zones 2-5 falling below the ANZECC default guideline trigger for ammonium. Leam (T8) has elevated ammonium concentrations compared to adjoining sites.

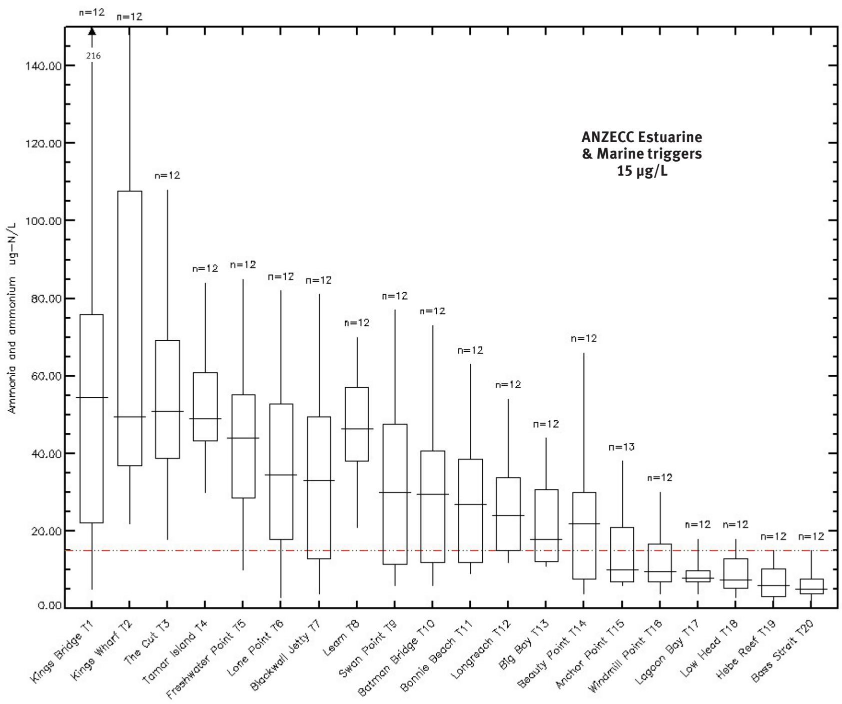


Figure 45. Ammonia and ammonium (µg/L) for TEER sites 1-20 at surface waters for the 2010-2011 study period.

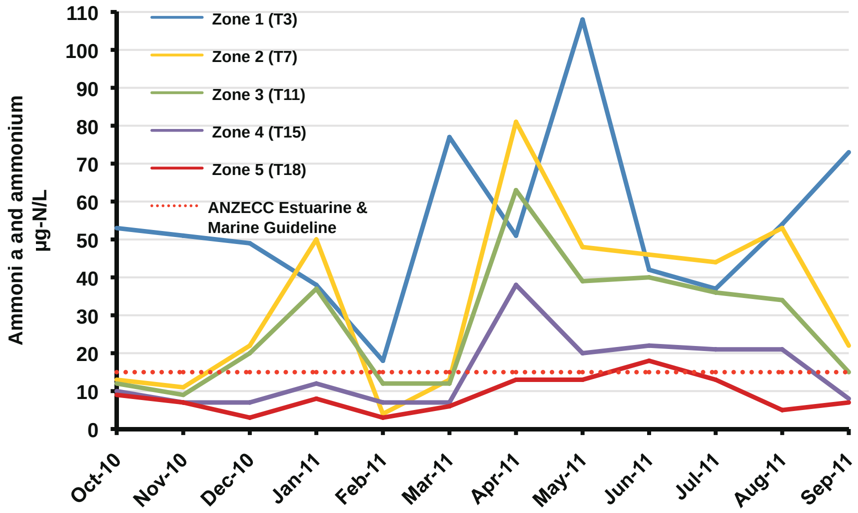


Figure 46. Ammonia and ammonium Zone 1-5 Proxy sites monthly surface samples.

Key findings: Median ammonia values exceed the ANZECC 2000 guidelines for the majority of sites in the estuary with greater concentrations of ammonia occurring in the upper estuary. Values are higher during the winter months

3.4.5 NITRATE + NITRITE

In marine and estuarine waters, the majority of nitrate + nitrite (NOx) is present as nitrate, as nitrite (NO_2) is quickly converted to nitrate (NO_3) by bacteria during the nitrification process (Whitehead *et al.*, 2010). Nitrate + nitrite levels (NO_3^- and NO_2^-) for all 20 TEER sites exceed the ANZECC default triggers for the majority of the estuary for surface and bottom samples taken for the TEER EHAP (Figure 47). Only at site T20, in the more marine environment, did median values fall below the guideline level. In the upper estuary, all measured values were above the estuary and marine guidelines, while at T20 only higher percentile values lie above the guideline. A seasonal influence is once again observed with increased concentrations of nitrate + nitrite (NO_3^- and NO_2^-) during the winter months and decreasing concentrations during summer months in the upper estuary (Figure 48).

There is also a seasonal signal in the most marine site at T20 (Figure 50), with winter increases in nitrate + nitrite attributed to oceanographic processes and reduced influence of the East Australian Current in winter months. The implications of seasonal changes in nitrate + nitrite inputs in both freshwater (Figure 49) and marine ends of the estuary suggest that it is important that seasonality should be considered when developing the Tamar Estuary WQOs.

The results of the mass loads study and coordination of estuary monitoring with the WWTP ambient water quality monitoring will be fundamental to understanding the source and fate of high concentrations of nitrate and nitrite throughout most of the estuary.

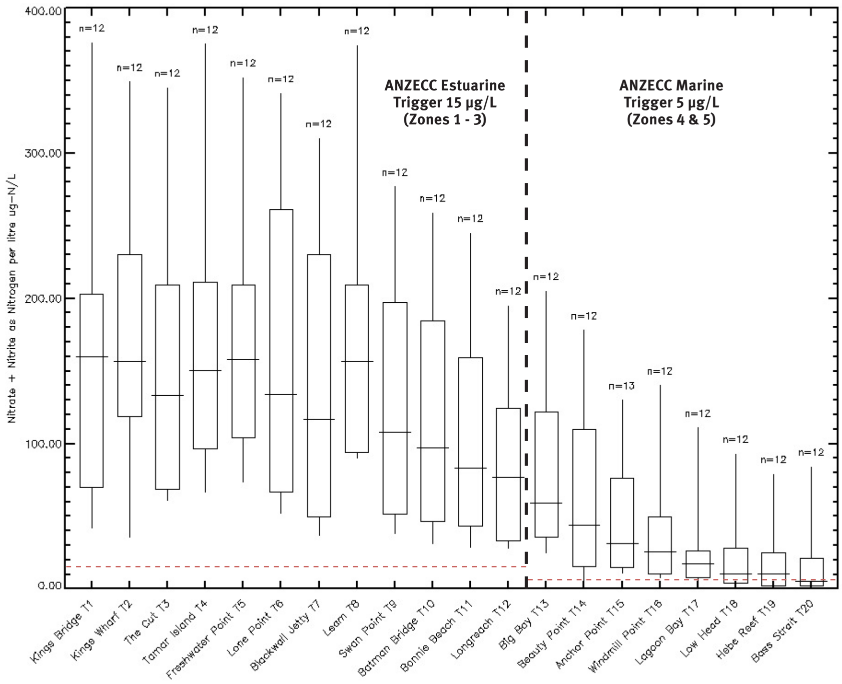


Figure 47. Nitrate + Nitrite (µg/L) for TEER sites 1-20 at surface waters for the 2010-2011 study period.

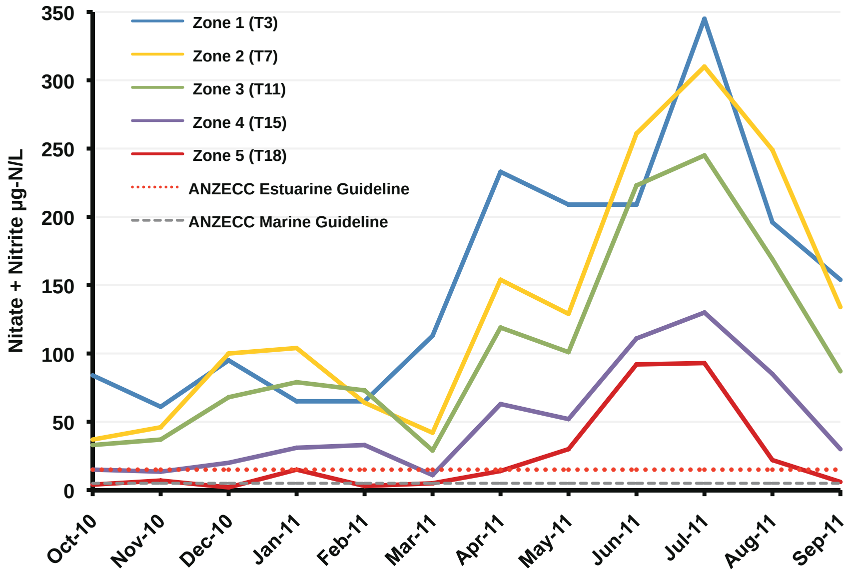


Figure 48.Nitrate + Nitrite Zones 1-5 Proxy sites monthly surface samples.

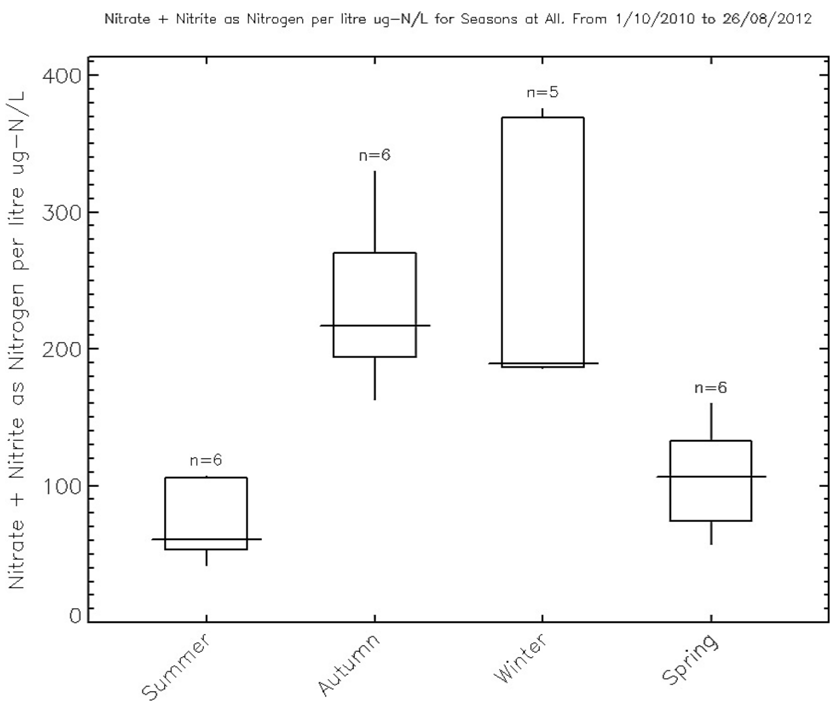


Figure 49. Box and whisker plots for seasonal nitrate + nitrite concentrations at T1, upper estuary. Note data includes both surface and bottom water samples.

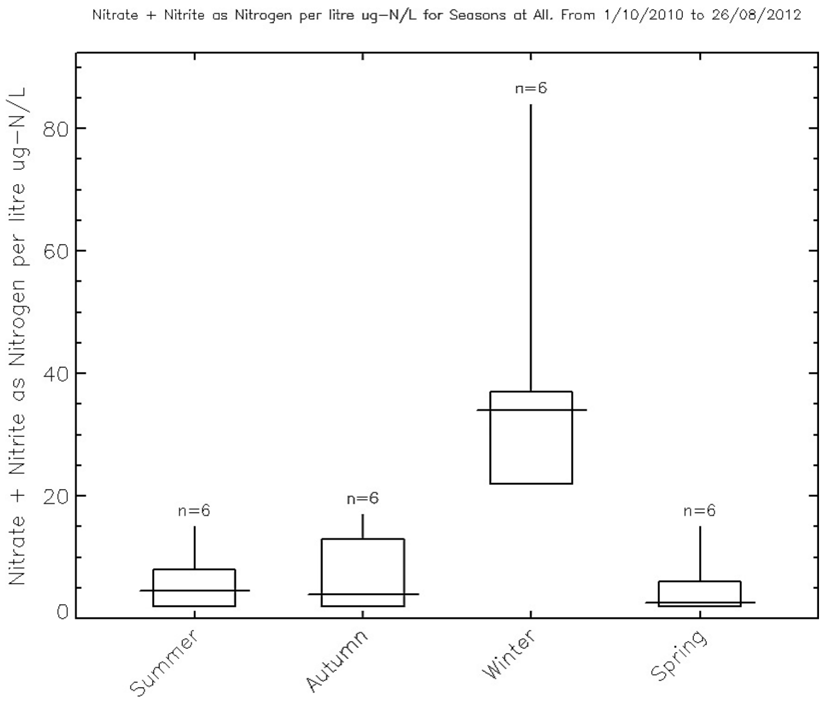


Figure 50. Box and whisker plots for seasonal nitrate + nitrite concentrations at T20, lower estuary. Note data includes both surface and bottom water samples.

Key findings: Median nitrate + nitrite estuarine and marine guidelines were exceeded for the entire estuary with the exception of the furthest marine monitoring site T20. Nitrate + nitrite concentrations are highest in the upper estuary and gradually decrease down the estuary towards the more marine environments. A seasonal influence is observed with the highest recorded concentrations in winter.

Generally nutrients exceed guideline levels in all zones of the estuary. Nutrients are generally highest in the upper estuary and decline closer to guideline levels in the lower estuary, with some measurements in the lower estuary within ANZECC default trigger values. Nutrient levels for both ends of the estuary are generally highest in winter months and lowest during summer. Setting Tamar estuary Water Quality Objectives (WQO) for nutrients is a priority, and will need to address seasonal variability in sources.

3.5 CHLOROPHYLL-A

The green pigment chlorophyll-a is present in most photosynthetic organisms and provides an indirect measure of algal biomass in a water body (Chapman, 1992).

The concentration of chlorophyll-a in water bodies is primarily dependent on the light input and the supply of biologically available nitrogen or phosphorus (EHMP, 2008). High levels of chlorophyll-a can be indicative of eutrophication. Algal blooms and high chlorophyll-a in estuaries usually occur in middle and lower estuarine areas (Aquenal and DEPHA, 2008).

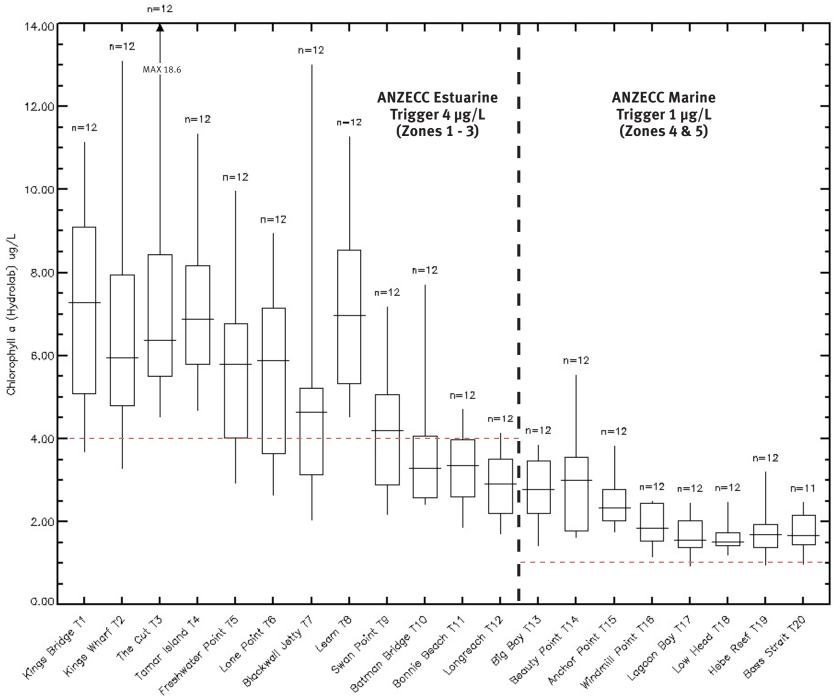


Figure 51.Chlorophyll-a (Hydrolab) (µg/L) for sites 1-20 at surface waters for the 2010-2011 study period.

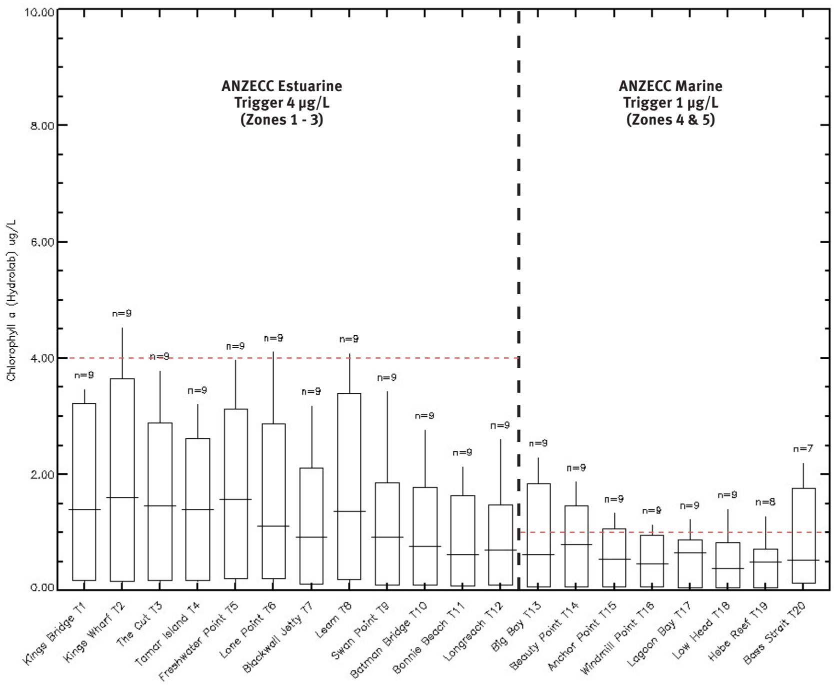


Figure 52. Chlorophyll-a (Hydrolab) (µg/L) for sites 1-20 at surface waters for the 2009-2010 study period.

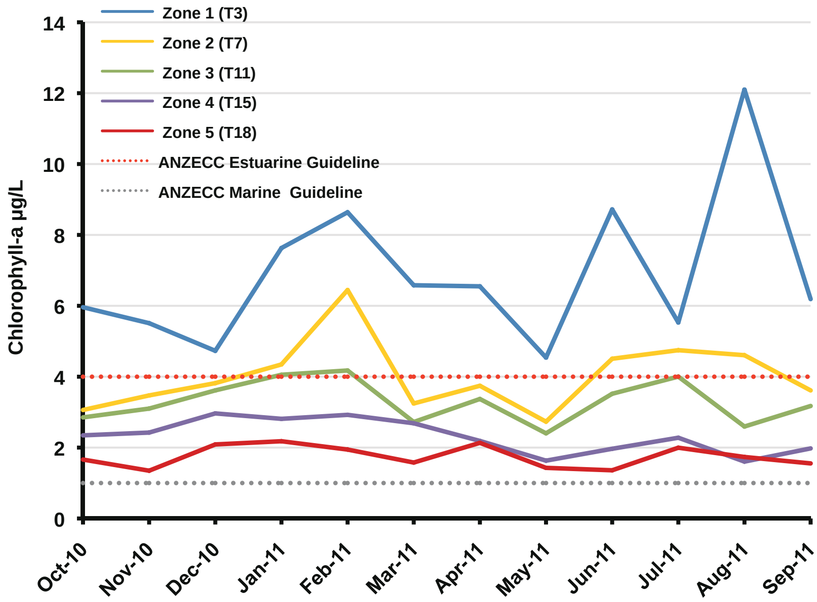


Figure 53. Chlorophyll-a Zones 1-5 Proxy Sites. Monthly profile average.

The chlorophyll-a results for the 2010/2011 monitoring period are elevated compared to the results from the previous monitoring year (2009/2010) (Figures 51 & 52). As with TN, TP and ammonium, chlorophyll-a plots are broadly similar across the zones, however Zone 1 is constantly higher, and fluctuates more. Zone 5 is always lower.

The 2010/2011 results show that median chlorophyll-a levels exceed the ANZECC 2000 estuarine and marine trigger guidelines at the majority of Tamar estuary sites (Figure 51), these results are in direct contrast to the previous year's results (Figure 52) that showed median chlorophyll-a values were all below the ANZECC 2000 trigger guidelines. Zone 1 chlorophyll-a levels are higher than the subsequent four zones (Figure 53).

The 2010/2011 peaks in Chlorophyll-a correspond with sampling periods that had high flows and flooding within the Tamar catchment. The variation recorded in Chlorophyll-a may be due to a number of factors where the impacts and processes of flooding influence the level of chlorophyll-a. During floods re-suspension of benthic algae from mudflats may be elevating chlorophyll-a levels as algae can be redistributed from the estuary bottom into the water column. Flooding may deliver nutrients to the estuary from the upper catchment and also release sediment bound nutrients which may be then utilised by phytoplankton for growth. Paulo *et al* 2009 suggest that phytoplankton biomass variation seems to be most influenced by hydrology, which is primarily driven by meteorological factors like wind, rainfall and evaporation.

Water column profiles of chlorophyll-a collected during summer and winter are presented in Figures 54 and 55. Summer depth profiles show chlorophyll-a is highest in the surface waters, and may vary quite considerably with depth in the more brackish Zone 2. During the major winter flood in August, profiles are fairly uniform with depth for Zones 2-5, and the concentrations of chlorophyll-a recorded are lower than for the same sites in summer. Zone 1 experienced high surface chlorophyll-a concentrations, which may potentially have been swept into the estuary from the catchment.

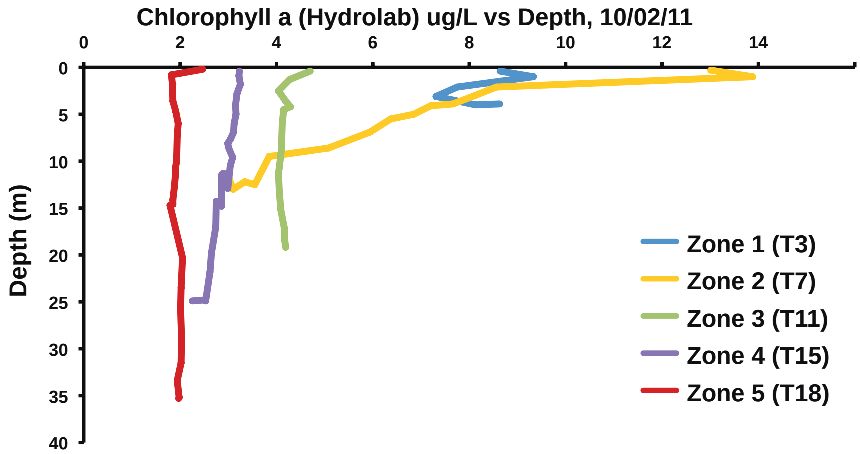


Figure 54. Chlorophyll-a water column profile in proxy sites for Zones 1-5, for summer (February 2011).

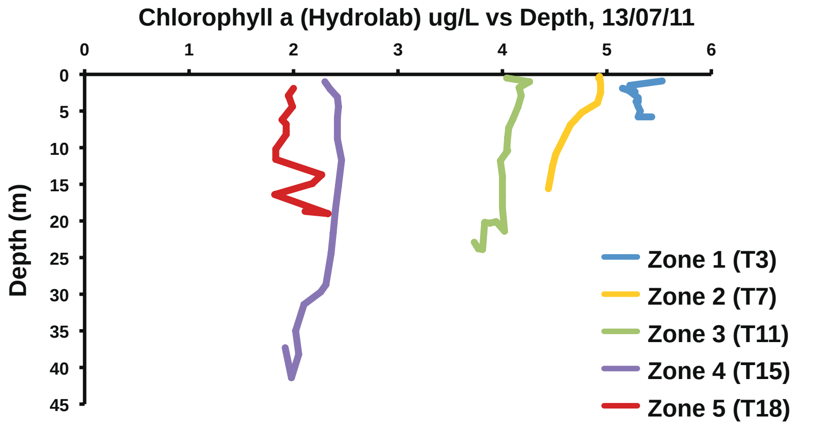


Figure 55. Chlorophyll-a water column profile in proxy sites for Zones 1-5, for winter (August 2011).

Chlorophyll levels generally decrease travelling down the estuary towards the mouth with levels decreasing around mid estuary at TEER EHAP site T10 near the Batman Bridge. The first State of the Tamar Report published in 1997 highlights that algal blooms have not historically been a problem in the Tamar (Pirzl and Coughanowr, 1997).

Key findings: Chlorophyll-a level were elevated compared to the previous monitoring year, both ANZECC 2000 estuarine (4µg/L) and marine (1µg/L) chlorophyll-a guidelines were exceeded at most sites along the estuary while in the previous monitoring year chlorophyll-a levels were all below guidelines. The elevated chlorophyll-a levels are probably influenced by a number of complex interactions, including flooding processes. A review of the monitoring program to include more laboratory analysis of chlorophyll-a samples is proposed.

3.6 TOTAL SUSPENDED SOLIDS, TURBIDITY AND SECCHI DISK

3.6.1 TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS) (mg/L) are the measure of particulate matter in water. Total suspended solids consist of silt and clay, phytoplankton, decaying organic matter and other particles derived from both natural and anthropogenic sources (Aquenal and DEPHA, 2008). Excess TSS can contribute to environmental damage by, reducing light penetration through the water column, smothering benthic organisms, irritating fish gills and transporting contaminants (SEQ Ecosystem Health Monitoring Program, 2008) (Sutherland, 2006).

Sediment levels in estuaries vary in response to river flow, effluent discharges, wind and tidal mixing and phytoplankton blooms. TSS tends to accumulate at the interface between salt and freshwater, which in the Tamar is generally found at the toe of the salt wedge in the stratified section of the estuary around Freshwater Point (Aquenal and DEPHA, 2008). This flocculation process is not captured by the monitoring data.

The most significant external sources of TSS to the Tamar estuary are the North Esk and South Esk rivers, particularly during heavy rainfall. Anthropogenic loads originate from urban runoff, stormwater, WWTPs and industry (Aquenal and DEPHA, 2008).

TEER partner Ben Lomond Water manages drinking water, stormwater and waste water in the Tamar catchment. BLW is actively undertaking monitoring, analysis and modelling to assess impacts from STPs on the Tamar River estuary. This information will be used to inform decisions on management and future upgrades of STPS in the Tamar Estuary.

Note: There are no specific ANZECC, 2000, guidelines for TSS; however TEER site specific TSS water quality objectives are a priority for future work.

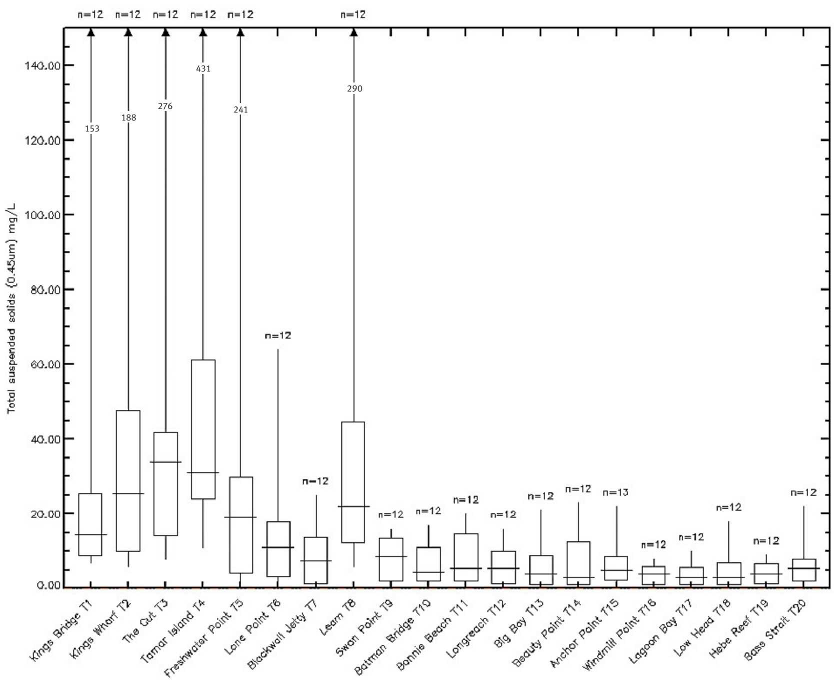


Figure 56. Total suspended solids (0.45μm) (mg/L) for T 1-20 at surface waters for the 2010-2011 study period.

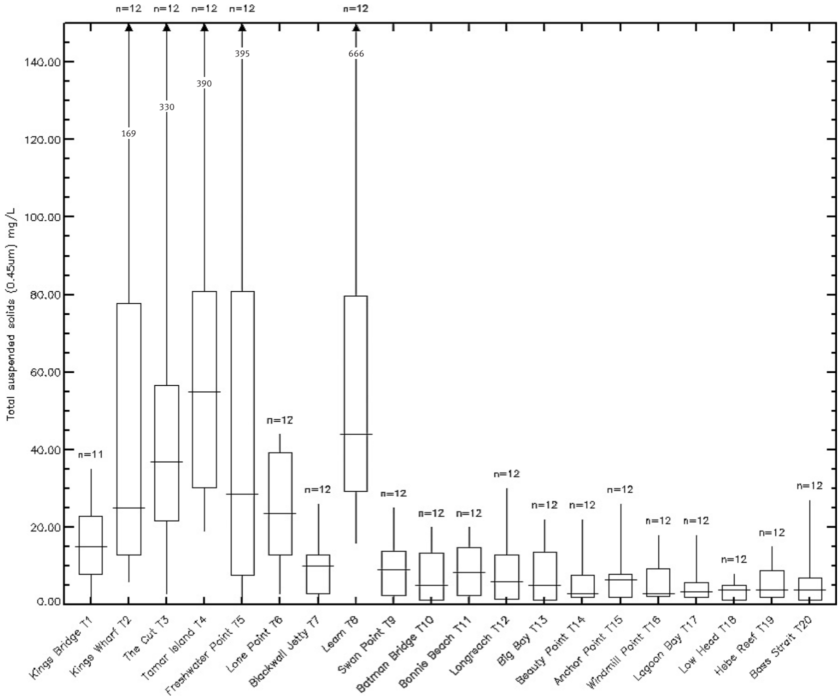


Figure 57. Total suspended solids (0.45µm) (mg/L) for T 1-20 at bottom waters for the 2010-2011 study period.

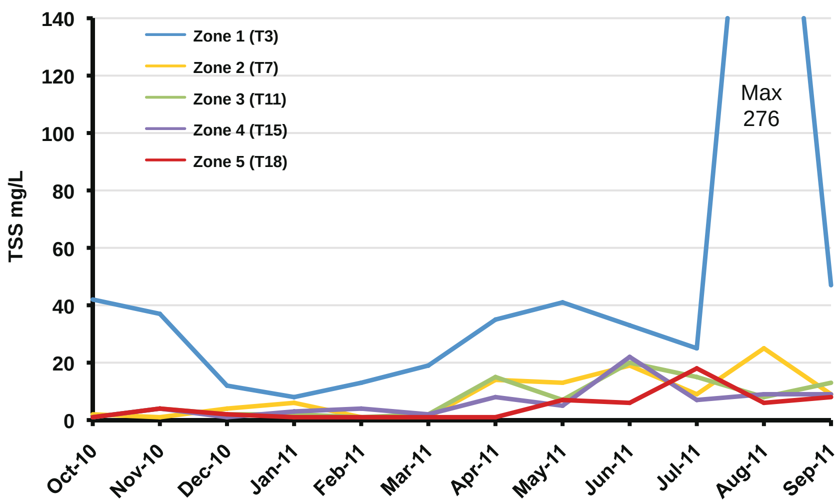


Figure 58. Total Suspended Solids (0.45 um filtered) Zone 1-5 Proxy Sites. Monthly samples.

Total suspended solids results for surface and bottom samples show increased levels in the upper estuary with elevated values from Kings Bridge (T1) to Leam (T8) (Figures 56 and 57). The highest median values for both surface and bottom TSS were recorded at the Cut (T3) and Tamar Island (T4) respectively. Bottom sample values for TSS are higher compared to the surface samples, probably due to tidal scouring of the bottom substrate. A relationship exists between TSS and turbidity (Figure 59). Turbidity has previously been used as a rapid field measurement proxy for suspended solids in the Tamar Estuary and Esk Rivers Catchment model (Stewart etal., 2010)

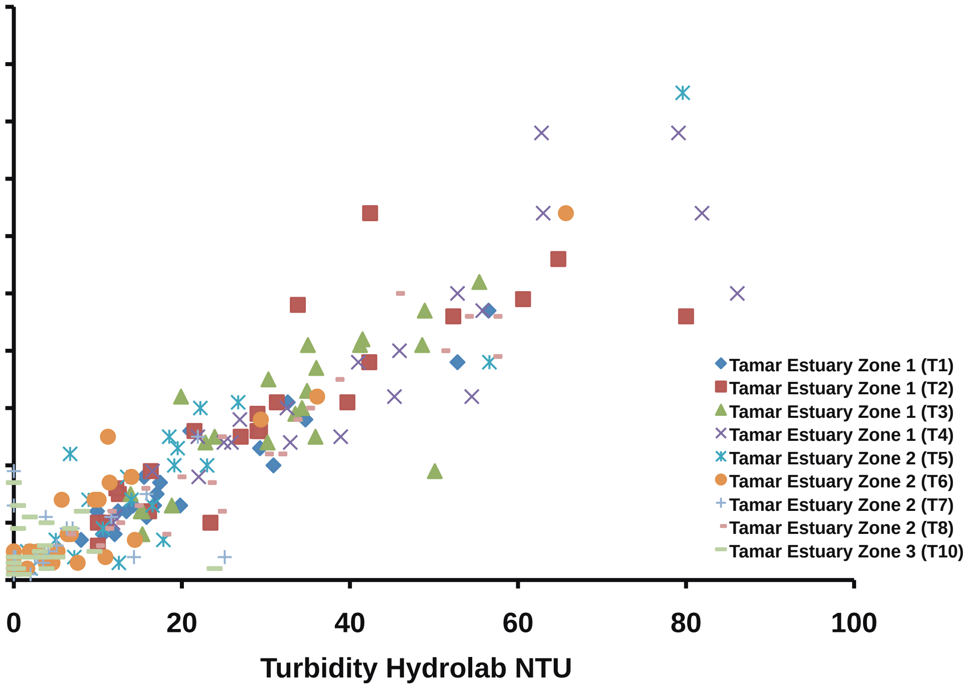


Figure 59. Relationship between Turbidity (Hydrolab, NTU) and TSS (0.45 um, mg/L) in the upper and mid estuary (T1-T10) for the 2010-2011 monitoring period.

Overall TSS values decrease dramatically north of Leam (T8) heading down stream; which may be due to tidal influence and clearer saline waters entering the system. Site T8 at Leam shows dramatic differences in TSS values to adjoining sampling sites, once more suggesting that perhaps there is a unique mixing process occurring that warrants further investigation in relation to this site's interaction with the estuary (Figure 57). High flow events are characterised by having increased TSS as flooding delivers eroded and scoured soils from the surrounding catchment, in August 2011 a large flow event was captured during sampling which showed elevated TSS results compared to the yearly average (Figure 58). The 2010/11 TSS mean values and the zone pattern was similar to the previous year's sampling (2009/10) even though more flood events were sampled in 2010/11.

Zone 1 has higher TSS values than other zones in the estuary (Figure 58), due to past and present processes occurring in the upper estuary. Suspended sediments are delivered directly to the estuary from the North Esk and South Esk Rivers, which carry sediment loads generated from the 10,000km^2 Tamar catchment. In addition to this there are existing estuary sediments that are resuspended by tidal process and move dynamically around Zone 1 (McAlister *et al.*, 2009). There was extensive dredging of the areas around Launceston prior to the 1960's when it was an operating port, these dredge spoils were deposited downstream around Rosevears and Windermere. Newly generated and existing sediments in the Tamar tend to resuspend and circulate around Zone 1 before being deposited according to tide and flood energy. For more information on sediment quality, sedimentation and dredging refer to the State of the Tamar Estuary Report 2008 (Aquenal and DEPHA, 2008).

3.6.2 TURBIDITY

Turbidity is a measure of the scattering of light by suspended particulate and dissolved solids in water. It is measured by passing a beam of light through a water sample contained in a transparent cell. The measurement is made by detecting the amount of light scattered by a sample (infrared or visible) compared to a pure water solution. Changes in light penetration in the water column affect the ability of aquatic plants to utilise light for photosynthesis.

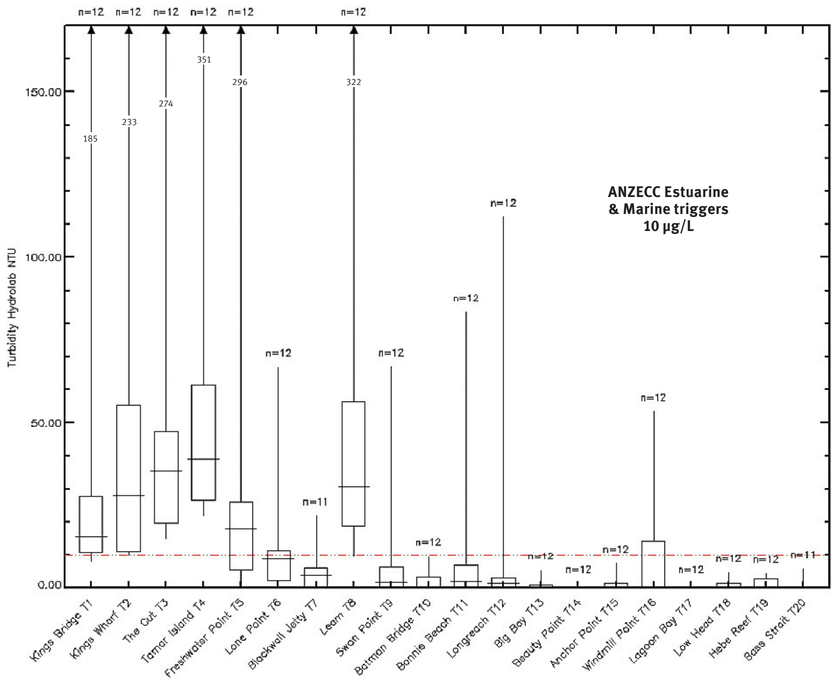


Figure 60. Turbidity Hydrolab (NTU) for sites T 1-20 at Surface waters for the 2010-2011 study period.

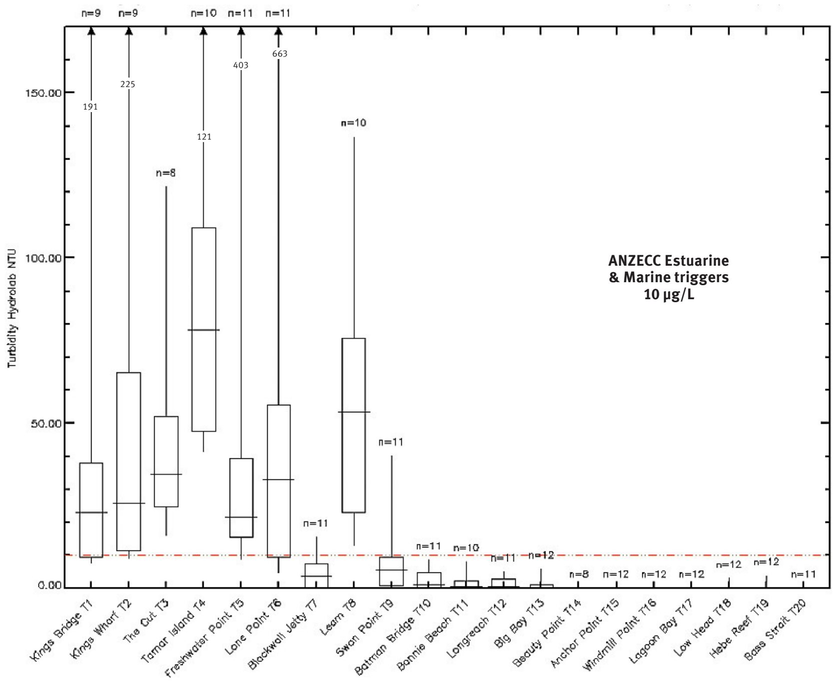


Figure 61. Turbidity Hydrolab (NTU) for TEER sites T 1-20 at bottom waters for the 2010-2011 study period.

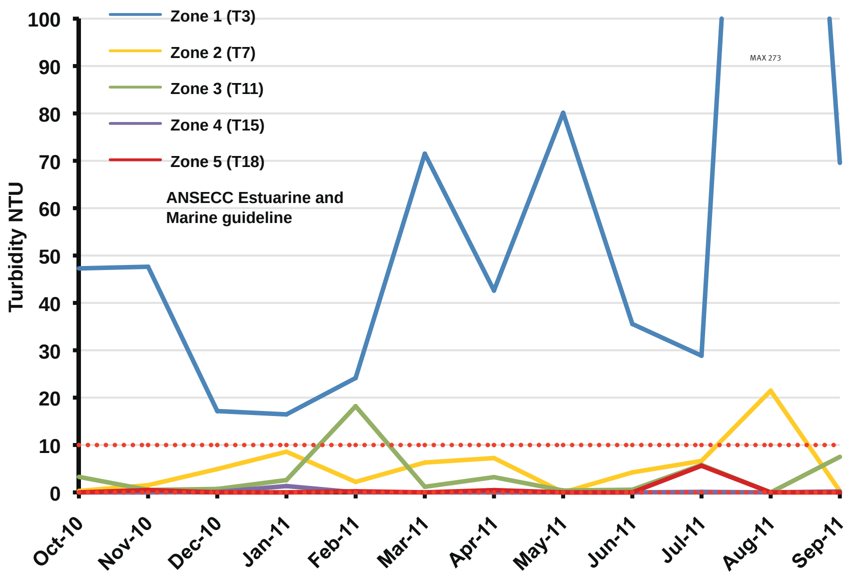


Figure 62. Turbidity Zone 1-5 Proxy Sites. Monthly profile average.

Turbidity results in the Tamar estuary display a similar pattern to that of the TSS results with elevated levels of turbidity occurring in the upper estuary, particularly in Zone 1 (Figures 60, 61 and 62). Median bottom turbidity values are greater than the median surface samples (Figure 61). This may be due to the tidal scouring of the bottom substrate transporting sediments. The highest median values for turbidity (similar to TSS results) were found in bottom samples at Tamar Island, site T4 (Figure 61), and, as shown with bottom TSS results, turbidity values tend to decrease travelling north to the lower estuary. The 2010/11 results for turbidity show the turbidity ANZECC estuarine guideline (10 NTU) being exceeded at all sampling times in Zone 1 and also in the first two sites of Zone 2 (T5 and T6) (Figure 62). The 2010/2011 monitoring period captured more flow events than the first sampling period (2009/2010) and as a result much larger maximums were recorded. Median values were slightly higher however the trends between the two different sampling periods remain similar.

3.6.3 SECCHI DISK

Water transparency, or light absorption, is affected both by dissolved and particulate material. An estimate of the transparency of the surface layer can be made using a Secchi disk (Head *et al*., 1985).

Secchi depth is measured using a circular plate coloured in quarters of black and white, known as a Secchi disk, which is lowered into the water until it is no longer visible. High Secchi depths indicate clear water; whereas low Secchi depths indicate cloudy or turbid water. This method gives an indication of the amount of light penetrating a water body, the euphotic depth (Aquenal and DEPHA, 2008). The euphotic depth dictates at what depth aquatic plants can manage to survive and photosynthesise. The Secchi depth can be greatly influenced by weather, particulate and algal matter occurring in a water body. Generally, in estuaries, the closer the oceanic input, the greater the Secchi depth, although this can vary seasonally.

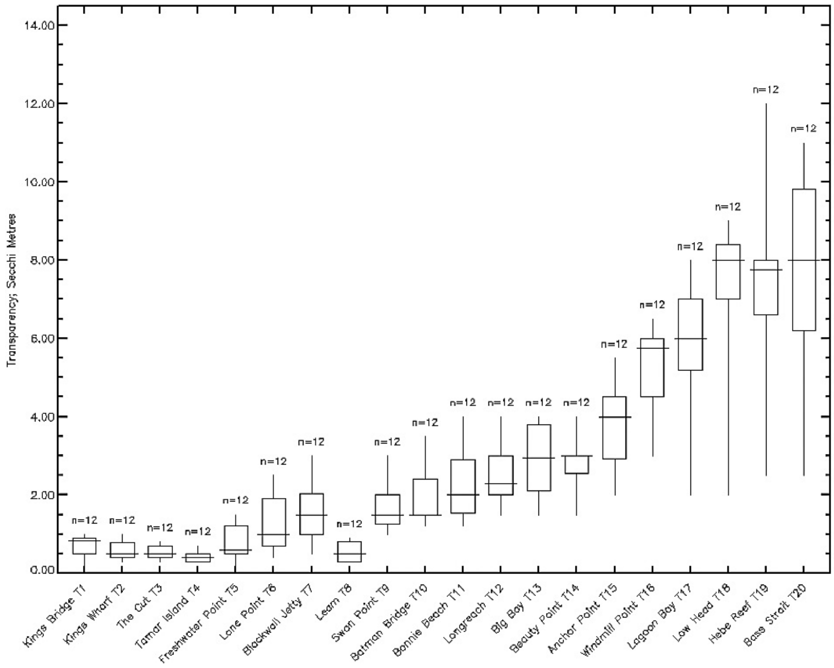


Figure 63. Transparency; secchi disk (metres) for TEER sites 1-20 at surface waters for the 2010-2011 study period.

Secchi depth increases towards the mouth of the estuary, where there are greater inputs of clear oceanic water (Figure 63). The upper estuary shows low Secchi depths mainly due to the influence of high TSS and turbidity decreasing the ability of sunlight to penetrate the water column. Leam (T8) continues to show inconsistencies when compared with the whole data set, with a comparatively low Secchi depth compared to adjacent sites. Trends between the two different sampling periods (2009/10 and 2010/11) remained the same.

Key findings: Total suspended solids and turbidity are substantially higher in Zone 1 than in other areas of the estuary, due to the interaction of salt and freshwater and tidal influences in this part of the estuary. Secchi depths reflect this with much higher depths in the clearer waters of the lower estuary. Site specific water quality objectives that recognise the natural processes occurring in the estuary need to be developed to gain a better understanding of trends in sediment measures.

3.7 BACTERIAL PATHOGENS-ENTEROCOCCI

Water contaminated by sewage and animal faeces may contain pathogenic micro-organisms (bacteria, viruses, protozoa), which pose a health hazard when the water is used for recreational activities, particularly those involving total immersion. During these activities, there is a risk that water could be swallowed, inhaled or come into contact with ears, nasal passages, mucous membranes and cuts in the skin, allowing pathogens to enter the body (NZMFE, 2002).

The most common types of illnesses that have been associated with primary contact (i.e. full immersion) are gastrointestinal disorders, respiratory illnesses, eye, nose and throat infections and skin diseases. Consumption of shellfish collected from areas contaminated with pathogens may also pose a significant health risk (Aquenal and DEPHA, 2008).

The National Health and Medical Research Council (NHMRC) recommend the sampling of *Enterococci* bacteria as the indicator for bacteriological pathogens in marine and estuarine waters used for recreation. The *Enterococci* group is a sub-group of the faecal streptococci found in the faeces of warm-blooded animals.

This report and both the 2010 and 2011 Tamar estuary report cards use the trigger value of 140 *Enterococci* /100mL as the guideline to measure bacterial impacts and assess ecosystem health in the Tamar estuary.

While the TEER EHAP uses the *Recreational Water Quality Guidelines* (RWQG), Public Health Act, 2007, for the purpose of establishing a bacterial guideline to use in the Tamar estuary, it is in no way aligned to a regulatory requirement or an indication of sites suitability for recreational use.

The TEER Program includes *Enterococci* in the Ecosystem Health Assessment process, as it is an excellent indicator of human inputs, particularly stormwater and wastewater. *Enterococci* is also a valuable indicator of pathogen and potential infection risk to recreational users of the Tamar estuary especially where high bacterial loads have previously been identified as an environmental issue impacting on the upper Tamar estuary.

Recreational water quality is currently monitored by local councils as a requirement of the RWQG. Councils are required to monitor the levels of bacteria (*Enterococci* indicator) at swimming sites between the summer months of December through to March.

The guidelines state that where *Enterococci* counts in a single water sample are greater than 140 *Enterococci*/100mL a resample is required within 48 hours. Where two consecutive water sample results are greater than 280 *Enterococci*/100mL, the public users of the water body are to be advised of the recreational health risk and that the water may be unsuitable for primary contact. This is usually achieved through appropriate signage. Home Reach in the upper estuary around the city of Launceston has permanent signage advising of the health risks associated with primary water contact even during the winter period.

TEER partner Ben Lomond Water manages drinking water, stormwater and waste water in the Tamar catchment. BLW is actively undertaking monitoring, analysis and modelling to assess impacts from STPs on the Tamar River estuary. This information will be used to inform decisions on management and future upgrades of STPS in the Tamar Estuary.

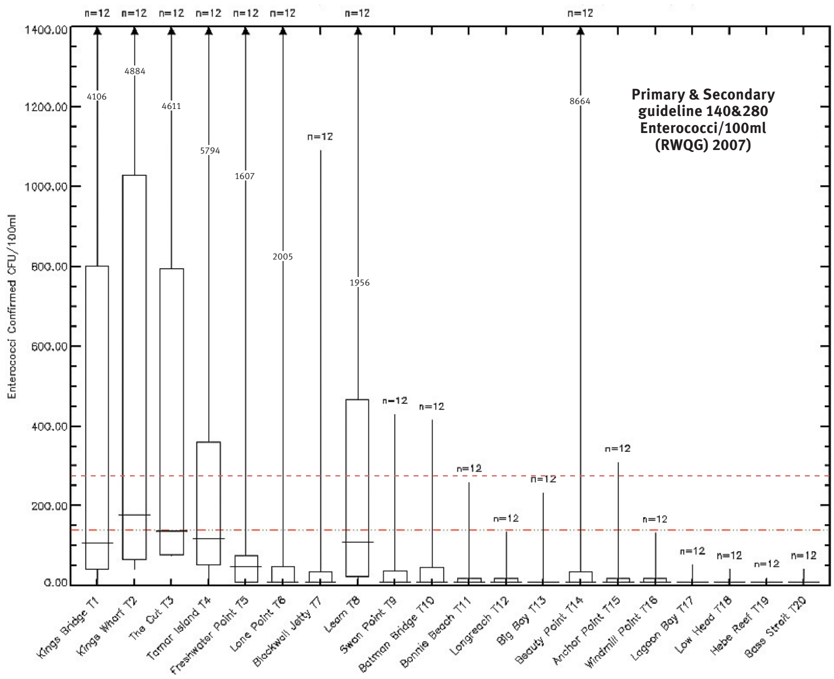


Figure 64. Enterococci Confirmed /100ml for TEER Sites 1-20 at surface waters for the 2010-2011 study period. Dashed lines represent the primary and secondary guidelines for enterococci 140 & 280 Enterococci / 100ml as adopted from the (RWQG) 2007).

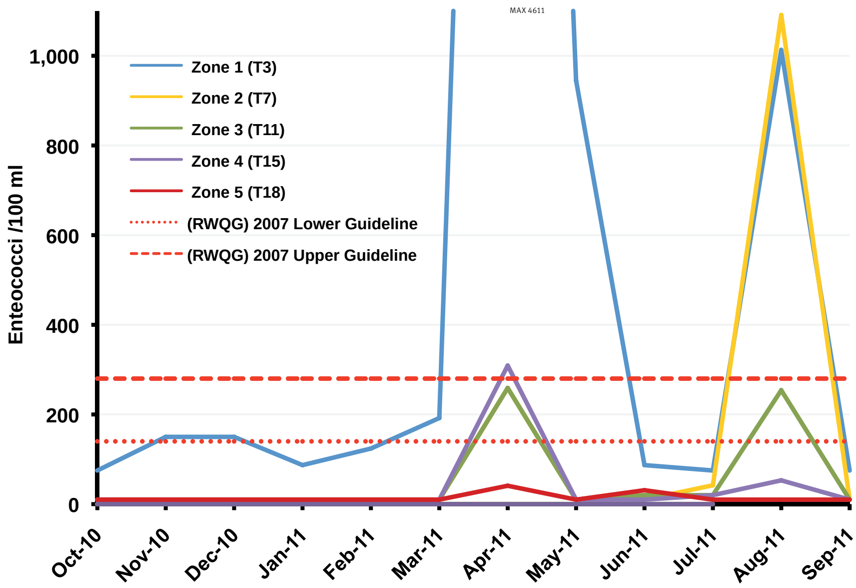


Figure 65. Enterococci Zone1-5 Proxy Sites Monthly surface samples.

Enterococci results from sampling the Tamar estuary from 2010-2011 show that Zone 1 in the upper estuary recorded the highest *Enterococci* numbers. Although this sampling period recorded increased maximum numbers of *Enterococci* due to the frequency of flood events, median values only exceed the guideline for *Enterococci* (140/100ml) at the Ship lift site T2 (Figure 64). These results are markedly different to the previous sampling period where all of Zone 1 median values exceeded the *Enterococci* guidelines. On some sampling occasions, Enterococcus was detected in the thousands per 100mL. *Enterococci* numbers generally decrease further down the estuary and start to rapidly decline after Leam (T8).

Seasonality had a marked impact on bacterial levels in the estuary as in winter, with increased rainfall and flows; increased bacterial loads are delivered from tributaries, stormwater runoff and wastewater treatment plants. There were peaks of *Enterococci* in April and August in Zone 1, well above the guidelines (Figure 65). Whilst increased flows in a catchment can contribute to higher bacterial loads, there is also a point where dilution of bacterial numbers can occur as high flows continue. Other zones are generally below guidelines, with the exception of Zone 2 in winter and spring, when the guidelines were exceeded. On rare occasions, downstream some sites experience very high *Enterococci* results (e.g. T14 in April 2011, Figure 65).

The mid to low areas of the Tamar estuary are more commonly used for swimming, diving and water skiing. In the upper estuary rowing is the most common activity where people may come into contact with the water.

The high levels of *Enterococci* detected in the upper reaches of the estuary correspond with the highly urbanised and impacted areas in and around Launceston where there are a number of upper catchment, WWTPs and stormwater inputs. As much of the older parts of Launceston's sewerage networks are combined with stormwater inflows, the largest WWTP at Ti Tree Bend sometimes becomes overloaded with increased volumes of incoming sewage and stormwater. In times of high rainfall, the Ti Tree Bend WWTP has the potential to discharge semi-treated effluent into the Tamar estuary.

Key findings: Median bacteria levels are highest in the more urbanised Zone 1, and this zone occasionally experiences very high loads of bacteria. Zone 2 also exceeds guidelines for wetter autumn and winter months. Median bacteria levels generally decrease further down the estuary. Median bacteria levels in the marine Zone 5 were always within guidelines for the 2010-2011 monitoring period.

3.8 METALS

Metals in aquatic systems maybe present naturally or generated by anthropogenic activities. Natural sources include the weathering of rocks and leaching from soils, while anthropogenic sources include automobile emissions, power plants, waste water treatment plants, mining and industrial wastes (particularly smelting, refining and electroplating) (Aquenal and DEPHA, 2008). Metals readily adsorb to particulate matter, so tend to accumulate in bottom sediments of estuaries and shallow coastal marine systems. Many estuarine organisms, particularly filter feeders such as mussels and oysters, accumulate metals from seawater, bottom sediments, interstitial waters and their food supply. The uptake and accumulation of metals by marine organisms depends on temperature, salinity, diet, reproductive and life stages, with larval and juvenile stages more vulnerable to contaminants (Kennish, 1996).

Metals are persistent in the aquatic environment. If they are present above guideline concentrations, they pose potentially hazardous conditions due to their toxicity to estuarine and marine organisms. Metals may be subdivided into two categories: i) transition metals (e.g. cobalt, copper, iron, manganese) which are essential to metabolism at low concentrations but may be toxic at high concentrations, and ii) metalloids (e.g. arsenic and tin) which are generally not required for metabolic function and are toxic at low concentrations (Kennish, 1996).

An approximate order of decreasing toxicity of common metals is: mercury, cadmium, copper, zinc, nickel, lead, chromium, aluminium and cobalt, however toxicity can vary significantly between different organisms (Kennish, 1996). Mercury and cadmium are highly toxic to aquatic organisms at very low concentrations, and also represent significant health hazards to humans. Inorganic forms of mercury have a relatively low toxicity to biota but are readily converted to more toxic organo-mercury forms (Aquenal and DEPHA 2008). The most toxic form of mercury is methyl-mercury which is highly toxic, resistant to environmental degradation and is rapidly taken up by aquatic organisms. Physio-chemical conditions in the water column and sediments influence the specific form or 'species' of metals, which in turn determines their potential to enter biological food webs.

The main sources of metal contamination in the Tamar estuary include historic inputs from past mining activities (Aberfoyle and Storys Creek tin mines in the South Esk Basin and Beaconsfield on the West Tamar), anthropogenic inputs from past and present industrial activities, urban run-off and stormwater. Tin and tungsten mining in the upper South Esk catchment is probably the main source of cadmium in the Tamar (Pirzl and Coughanowr, 1997), whilst zinc present in the South Esk River is the likely result of mining activity in the catchment of a tributary (Norris *et al.*, 1981). Current industrial activity in the Tamar estuary includes Bell Bay aluminium smelter, the BHP Billiton TEMCO ferroalloy plant and the Beaconsfield Gold Mine operated by BCD Resources. Both Bell Bay Aluminium and BHP Billiton are situated in the Bell Bay industrial zone on the lower estuary and the Beaconsfield gold mine is situated on the West Tamar. Historically, liquid emissions from the TEMCO and Bell Bay Aluminium sites were discharged at Deceitful Cove in the mid lower estuary. Bell Bay Aluminium (previously Rio Tinto) ceased discharge to Deceitful Cove in 1987 and BHP Billiton TEMCO ceased discharge in 1993. Beaconsfield Gold Mine liquid emissions also discharge in the lower estuary at Middle Arm. Lead concentrations in mine discharge water have decreased significantly in recent years, compared to historic mining activities, to almost undetectable levels. Stormwater run-off from TEMCO still discharges into Deceitful Cove after passing through a wetland stormwater treatment system. In addition to point source discharges, diffuse sources such as industry-contaminated groundwater may also contribute to the metal load in the estuary (Aquenal and DEPHA, 2008).

3.8.1 NATIONAL WATER QUALITY GUIDELINES FOR METALS

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC guidelines) for toxicants specify trigger levels for the protection of marine and freshwater aquatic ecosystems at four different protection levels: 99%, 95%, 90% and 80%, whereby the protection level signifies the percentage of species expected to be protected with a 50% confidence limit. The highest protection level (99%) is chosen as the default value. For ecosystems with high conservation value or for those toxicants which can cause bioaccumulation effects and secondary poisoning the 95% trigger value apply to ecosystems classified as slightly-moderately disturbed systems (ANZECC, 2000). For ecosystems that can be classified as highly disturbed it may be appropriate to apply a less stringent trigger value, such as 90%, or perhaps even 80%, depending upon the management goals for the particular ecosystem. For the TEER EHAP, the 95% level of protection for marine waters is applied to Zones 1 through to 5 (Table 6). Interim site-specific guidelines for the Tamar have been developed for Arsenic and Aluminium as the default trigger values in ANZECC guidelines are only indicative interim working levels derived from limited marine data. They are considered low reliability trigger values with low confidence levels. With the current review of the national guidelines and the increase of available data since 2000 when guidelines were released, high reliability default trigger values may be provided in the future. In the interim site specific trigger values have been derived by considering levels at reference condition locations in marine waters near the mouth of the Tamar estuary. These guidelines will be reviewed as part of the Water Quality Improved Program currently being planned for the Tamar estuary.

The TEER EHAP monitors dissolved metals in both surface and bottom waters; total metals concentrations were not measured in the last monitoring program. Dissolved metals concentrations (0.45 μm) can be compared to the ANZECC trigger values, and provide a surrogate measure of bio- available metals that could impact organisms that are exposed to metals via the water soluble uptake pathway This approach is consistent with the decision tree for applying trigger values for assessing toxicants in ambient waters as set out in the ANZECC 2000 guidelines Organisms that reside in the sediments, or feed on particulate material may be exposed to bioaccumulation or toxicity by second uptake pathway. Ultimately though it is the biological measurement, another line of evidence, that will provide confirmation of adverse environmental effect from an elevated level of a toxicant above a determined trigger value.

Table 6. ANZECC (2000) guideline trigger values for metals (μg/L) in marine systems (water column).

Metal (μg/L)	Trigger values for marine waters			
	99%	95%	90%	80%
Copper	0.3	1.3	3	8
Lead	2.2	4.4	6.6	12
Mercury (inorganic)	0.1	0.4	0.7	1.4
Zinc	7	15	23	43
Cadmium	0.7	5.5	14	36

Table 7. Dissolved metal concentrations in Zones 1 and 4 from Oct 2010- Sept 2011.

RED=Above guidelines **GREEN=Below guidelines**

Dissolved Metals	Zone 1 Range (T1-T4) μg/L	Zone 4 Range (T13-T17) μg/L	ANZECC Marine guidelines μg/L 95% Level of species protection and site specific guideline(*)	Minimum Reporting Limits μg/L
Copper	**< 1**	**1 - 2**	1.3	1
Lead	**5 - 7**	**< 5**	4.4	5
Mercury	**< 0.05**	**< 0.05**	0.1	0
Zinc	**1 - 2**	**1 - 2**	15	1
Cadmium	**< 1**	**< 1**	5.5	1
Iron	**< 20 - 254**	**<20 - 36**	300 (IWL)	20
Manganese	**5 - 8**	**1 - 16**	80 (IWL)	1
Aluminium	**< 20 - 178**	< 20	*6	20
Arsenic	<1 - 2	**< 5 - 6**	*2.3	<1** & < 5***
Selenium	< 10	< 10	3 (IWL)	10

ID= insufficient data to determine high reliability trigger value but default interim working levels (IWL) have been provide by the ANZECC guidelines in the absence of derived site specific data.

* Interim water quality guidelines from combined ANZECC and Tamar River estuary data **Low salinity ***High salinity.

Limited sampling metals for the 2010/2011 TEER EHAP occurred bi-annually in Zone 1 at sites T1-T4 and in Zone 4 at sites T13-T17. These zones were chosen as, they are either the most urbanised or industrialised zones in the Tamar estuary with documented elevated metal concentrations in sediments and the water column. Note there is an area in Zone 4 with historic deposits of tailings in sediment from mining activities, namely Middle Arm. Both surface (0.1m below water surface) and bottom (1m above bottom of estuary) samples were taken at six-monthly intervals (two sampling events for metals from October 2010 to September 2011).

Dissolved metals results for 2010/2011 are consistent with results shown in the State of the Tamar Estuary Report 2008, where the highest metal concentrations were found in both the upper section of the estuary and the mid lower section of the estuary in zones where there are known inputs from past industrial activities.

Table 7 shows the range in concentration of dissolved copper, lead, mercury, zinc and cadmium at Zones 1 and 4 and compares them against the high and low (IWL) reliability ANZECC guidelines for marine water. This comparison uses the 99% and 95% ANZECC trigger levels, which represent the percentage of marine species expected to be protected with a 50% confidence level in a slightly to moderately disturbed ecosystem.

The laboratory, Analytical Services Tasmania undertook the metal analysis and has conservatively applied minimum reporting limits for metals in saline waters by inductively coupled plasma atomic emission spectroscopy method (ICP-AES) (Table 7).

The upper level of the range of dissolved copper concentrations in zone 4 of 1-2 µg/L exceeds the ANZECC guideline of 1.3 µg/L whereas dissolved copper concentration in Zone 1 (‹1µg/L) fell below the ANZECC trigger value (Table 7).

Lead was a metal that exceeded guidelines, with results for Zone 1 ranging from 5-7 µg/L compared to the ANZECC trigger guideline of 4.4 µg/L. Due to the limit of reporting value of 5.0 µg/L from the analysing laboratory for lead, and the small number of samples, it is difficult to determine whether the results for dissolved lead in Zone 4 are above or below the 4.4 µg/L guideline.

Dissolved mercury, cadmium and zinc ranges for both Zones 1 and 4 were below the ANZECC guideline concentrations (Table 7). Interim water quality guidelines from combined ANZECC and Tamar River estuary data were developed and applied for aluminium and arsenic levels. Compared to ambient values in Zone 1, aluminium exceeded the guideline and arsenic is below the guideline. In Zone 4 arsenic on occasions exceeded the guideline whereas aluminium was under the limit. Iron and manganese are below the IWL trigger value representing low risk, while the selenium limit of reporting value is above the IWL trigger value. These levels show a similar trend to the previous year's (2009/2010) monitoring results with higher levels in Zone 1 than in Zone 4. The upper Tamar estuary around Zone 1 is influenced by freshwater inputs between sites T1-T3 in the form of the South and North Esk Rivers and also the redirected Lake Trevallyn hydroelectric release which occurs at the Tail Race. During this sampling period, Zone 1 had salinity ranges of 0.5-6 ppt and as such the marine ANZECC guidelines have been applied. However due to the complex mixing between fresh and marine waters in this part of the estuary, freshwater ANZECC guidelines could at times be considered for metals. The development of zone/site specific water quality objectives or triggers for estuarine waters will aid in better describing the impacts of metals in Zone 1.

Key findings: Metals were only tested in Zones 1 and 4, where previous sampling had indicated impacts were likely to be found. Zone 1 was within guideline levels for all metals except lead and aluminium. Zone 4 exceeded ANZECC guidelines for copper and arsenic at the recorded upper levels. Metal concentrations are likely to be due to historic use of the catchment and estuary (mining and other industries) as well as coming from the heavily urbanised areas of the upper estuary. The TEER has conducted a study into seafood safety of the Tamar to investigate the levels of metals found in finfish and oysters and will communicate the results to the public including any health issues related to consumption of seafood.

4 TAMAR ESTUARY REPORT CARD

The Tamar estuary report card aims to report on the ecosystem health of the estuary and measure change by collecting relevant water quality and biological data to enable the assessment of the ecosystem. Ecosystem health is determined by the response of the environment to natural and human inputs and is defined as the degree to which the actual state of the ecosystem diverges from its ideal state (Pantus and Dennison, 2005). The report card uses a grading system of "A" through to "F" for the five zones within the estuary (Table 8). The range of the Ecosystem Health Index (EHI) used to define each letter score is also given. The method used to calculate these scores is discussed further below.

Table 8. Report card grade meanings

Letter	Grade	EHI range	Description
A	Excellent	0.86-1.00	Conditions meet all the ecosystem health values more than 85% of the time
B	Good	0.70-0.85	Conditions meet all set ecosystem health values in most of the reporting region
C	Fair	0.60-0.69	Conditions meet some of the set ecosystem health values in most of the reporting region
D	Poor	0.50-0.59	Conditions are unlikely to meet set ecosystem health values in most of the reporting region
F	Fail	‹0.50	Conditions meet set ecosystem health values less than 50% of the time

4.1 METHODS FOR TEER REPORT CARD GRADE DETERMINATION

Report card grades have been calculated using the monitoring data described in the previous sections. The basic approach used to derive scores is given below. A more detailed description is given in Appendix 1.

1. Five functional zones were identified based on differences in critical habitats (e.g. seagrass, rocky reefs, wetlands), key processes (phytoplankton abundance; Chlorophyll-a), human impacts, nutrient levels (e.g. total nitrogen), metals (e.g. zinc) and salinity within the estuary.
2. TEER EHAP monitoring data (October 2010-September 2011) was analysed. Indicator parameters were chosen and grouped into two categories: ambient water quality; and, recreational water quality.
   - Water quality indicators consist of dissolved oxygen, pH, total nitrogen, total phosphorus, turbidity, chlorophyll a and metals.
   - The recreational indicator is the bacteria *Enterococci*.
3. Data were spatially analysed and assessed against ANZECC (Australian and New Zealand Environment Conservation Council) guidelines for Fresh and Marine Water Quality and the Tasmanian Public Health Act *Recreational Water Quality Guidelines*.
4. Exceedance scores were calculated for each indicator from each category, for each of the five zones. These used a 1 to 4 categorisation of distance from the guideline value.
5. An Ecosystem Health Index (EHI) is calculated for each category in each zone by averaging indicator exceedance scores. EHI is then converted to a letter grade for each category in each zone.
6. The EHI range is used to generate a report card grade for each zone as given in Table 9 (note detailed values for +/- scores are given in Appendix 1). The letter grade represents the overall health of that zone.

5 TAMAR ESTUARY ECOSYSTEM HEALTH GRADES

Figure 66. 2012 Tamar Estuary Report Card grades

The TEER has produced three Tamar Estuary report cards 2010, 2011 and 2012 (Table 9). The first Tamar estuary report card published in 2010 used historical data dating back 10 years (1999-2009) to derive the grades; data from 2007 was also incorporated to give a standalone grade snapshot for one year. The 2011 and 2012 report cards differ from the 2010 report card as it incorporates specifically collected TEER EHAP data described in this report, which was collected monthly at 20 Tamar estuary sites from September 2009 - October 2011 to develop the grades for the functional zones in the estuary. The 2012 report card incorporates the 10-year average (1999-2009) and the 2011 grades as a comparison between the two reports. Care should be taken when comparing the 10 year historical (1999-2009) grades to the 2011 and 2012 grades as they were derived from a different data set, (differences in sites, collection methods, analysis and quality of the data). The 2011 and 2012 report card grades are directly comparable as the same data was collected from the same sites and the same sampling methodology was used. The EHI score increments (Table 10) show how the EHI scores are converted into letter grades.

Table 9. 2010 and 2011 Report Card Grades

Tamar Estuary Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
2010 Report Card Grades (Using historical data 1999-2009)	D	B-	B	B+	A-
2011 Report Card Grades (Using 2009-2010 EHAP data)	D+	B-	B+	B+	A-
2012 Report Card Grades (Using 2010-2011 EHAP data)	C-	B-	B	B	B+

Table 10. EHI to letter grade conversion

EHI	Letter Grade
0.950-1.000	A+
0.900-0.949	A
0.850-0.899	A-
0.800-0.849	B+
0.750-0.799	B
0.700-0.749	B-
0.675-0.699	C+
0.625-0.674	C
0.600-0.624	C-
0.575-0.599	D+
0.525-0.574	D
0.500-0.524	D-
<0.500	F

The grades derived for the 2012 Tamar estuary report card differ slightly to the 2010 and 2011 grades for the five different functional zones of the Tamar estuary.

The 2012 grades show a marginally improved grade in Zone 1 in the upper estuary, no change in Zone 2, and slightly declining grades for Zones 3, 4 and 5 in the mid to lower estuary.

- Zone 1 the EHI grade has improved from D in 2010 to a D+ in 2011 and then to a C- in 2012.
- Zone 2 EHI scores have remained consistent over the report card years with a score of B-.
- Zone 3 has fluctuated between B and B+.
- Zone 4 has also fluctuated between B and B+ and scores for 2012 have decreased slightly from B+ in 2011 to a B in the 2012.
- Zone 5 has had the highest grades in the estuary over the reporting years with an A- in both 2010 and 2011, however in 2012 the grade scores decreased and changed slightly from an A- to a B+.

The data collection and reporting period of September 2010-October 2011 was characterised by above average catchment rainfall and flows (See figures 16, 17 and 18 in climate and flow section 2.4) especially compared to the previous reporting year. Over the 12 month sampling period 10 out of the 12 months experienced flood events, Trevallyn dam which is located on the South Esk at the bottom of the catchment spilled during these flood events. It is likely that the flood events captured during sampling have influenced the 2012 report card grades as increased catchment pollutant loads were delivered to the estuary.

Poorer grades in Zone 1 are largely due to high levels of pathogens and nutrients, as well as metals exceeding guidelines. This poor water quality is likely due to the heavily urbanised nature of Zone 1, unquantified major inputs from the North Esk and South Esk rivers and accumulated pollutants from historic land use practices, such as mining, in the catchment. Water quality generally improves as you move downstream, with greater flushing of the estuary, and reduced intensity of land use.

The following section of the document describes where changes in EHI indicator parameters have occurred between the sampling years, causing the report grades of the zones to change.

Caution must be used when interpreting small changes in grades between report cards. Small changes in report card grades can be driven by natural variation in climate and flows during different reporting periods.

5.1 ZONE 1 ECOSYSTEM HEALTH GRADES

D
2010 REPORT CARD GRADE

D+
2011 REPORT CARD GRADE

C-
2012

Fair ecosystem health

Conditions meet some of the set ecosystem health values in most of the reporting region

SUMMARY

In the 2012 report card an ecosystem Health grade of C- was generated for Zone 1. The grade was generated from data collected at four sites within Zone 1 during the 2010/2011 sampling period. The 2012 Zone 1 score of C- shows a slight improvement in score from D+ in 2011.

WHAT HAS CHANGED THIS YEAR?

Comparison of the data between the 2009/10 and 2010/11 monitoring years (Table 11) show where differences in indicator parameters have occurred. *Enterococci*, dissolved cadmium, copper, mercury and arsenic all showed improvements in scores whereas levels of Chlorophyll-a caused a significant decline in 2012 compared to 2011. Other results such as TN, TP, Aluminium, Lead and turbidity continued to exceed ANZECC guidelines, but did not contribute to changes in the overall report card score. Dissolved oxygen and pH remain within expected values for estuaries

WHY HAVE EHI SCORES CHANGED?

The 2010/11 sampling period was characterised by capturing more frequent high flow events compared to the sampling period of the previous year. Although the overall grade in Zone 1 marginally improved between the 2011 and 2012 report cards, a significant change in chlorophyll levels is of concern. Improvements in concentrations of *Enterococci* and some dissolved metals have offset declined chlorophyll-a score. Whilst *Enterococci* results in the upper estuary are poor, there has been an improvement in the grade for this parameter.

Table 11. Zone 1 difference between 2009/10 and 2010/11 indicator parameter scores.

Improved Score
Declined Score
No change in Score

ZONE 1					
Category	Indicator Parameters	2009/10 Grades		2010/11 Grades	
Water Quality (WQ)	Total Nitrogen	F	D+	F	D
	Total Phosphorus	F		F	
	Dissolved Oxygen	A+		A+	
	Turbidity	F		F	
	Chlorophyll-a	A-		F	
	pH	A+		A+	
	Cadmium	D		B-	
	Copper	D-		B-	
	Mercury	C		A+	
	Zinc	A+		A+	
	Aluminium	F		F	
	Arsenic	F		D	
	Lead	F		F	
Recreational (REC)	Enterococci	D+	D+	C	C
WQ+REC / 2 = EHI Grade			D+		C-

5.2 ZONE 2 ECOSYSTEM HEALTH GRADES

B- 2010 REPORT CARD GRADE | **B-** 2011 REPORT CARD GRADE | **B-** 2012

Good ecosystem health

Conditions meet all set ecosystem health values in most of the reporting region

SUMMARY

An ecosystem health grade of B- was generated from data collected at four sites within Zone 2 during the 2010/2011 sampling period. The grade of B- generated for Zone 2 during the 2010/11 sampling period did not differ from the previous year's grade, although changes in parameter values were observed.

WHAT HAS CHANGED THIS YEAR?

Comparison of the data between the 2009/10 and 2010/11 monitoring years (Table 12) describes where differences in indicator parameters have occurred. The *Enterococci* score in Zone 2 improved slightly from B to B+, turbidity scores slightly declined from D- to an F and the Chlorophyll-a values, similar to Zone 1 declined from A- to an F compared to the previous year. The remaining indicator parameter values did not vary between the reporting years, TN and TP continuing to exceed ANZECC guidelines and DO and pH remained within expected estuarine guidelines (Table 12). Metals are not sampled within this zone

Although turbidity and chlorophyll a showed declining scores the improved *Enterococci* scores and the other indicator parameters that did not change kept the overall score at the lower end of the B- score category.

The sampling period between 2010 and 2011 on the Tamar estuary was characterised by high catchment flows and as a result more flooding and high flow events were captured while sampling. Some variation in parameter values may be due to differences in climate and in-turn catchment flows between the reporting years.

Table 12. Zone 2 difference between 2009/10 and 2010/11 indicator parameter scores.

ZONE 2					
Category	**Indicator Parameters**	**2009/10 Grades**		**2010/11 Grades**	
Water Quality (WQ)	Total Nitrogen	F	B-	F	D
	Total Phosphorus	F		F	
	Dissolved Oxygen	A+		A+	
	Turbidity	D-		F	
	Chlorophyll-a	A-		F	
	pH	A+		A+	
Recreational (REC)	Enterococci	B	B	B+	B+
WQ+REC / 2 = EHI Grade			B-		B-

Key
Improved Score
Declined Score
No change in Score

5.3 ZONE 3 ECOSYSTEM HEALTH SCORES

B	B+	B
2010 REPORT CARD GRADE	2011 REPORT CARD GRADE	2012

Good ecosystem health

Conditions meet all set ecosystem health values in most of the reporting region

SUMMARY

In the 2012 TEER report card an overall ecosystem health index grade of B was generated for Zone 3. The 2012 Zone 3 score of B shows a slight decline from the score of B+ derived in 2011 report card. The score was generated from data collected at four monitoring sites within Zone 3 (T9-T12) during the 2010/2011 sampling period.

WHAT HAS CHANGED THIS YEAR?

Comparison of data between the 2009/10 and 2010/11 monitoring years (Table 13) describes where differences in indicator parameters have occurred. The parameters responsible for the decline in the 2012 grades were TP and Chlorophyll- a, while grades for all other parameters remain the same as seen in the 2009-10 monitoring period. TN continued to exceed ANZECC guidelines whereas DO, pH, turbidity and *Enterococci* remained within guidelines. Metals were not sampled for in Zone 3.

WHY HAVE EHI SCORES CHANGED?

The 2012 EHI scores for Zone 3 have declined slightly due to a dramatic decline in Chlorophyll a scores and a slight decline in TP scores. The 2010/2011 sampling period was characterised by capturing more frequent high flow events compared to the sampling period of the previous year and although the overall grade in Zone 3 marginally declined between 2011 and 2012 these changes may be due to climate and flow variation between the years.

Table 13. Zone 3 difference between 2009/10 and 2010/11 indicator parameter scores.

ZONE 3					
Category	**Indicator Parameters**	**2009/10 Grades**		**2010/11 Grades**	
Water Quality (WQ)	Total Nitrogen	F	B	F	B-
	Total Phosphorus	D		F	
	Dissolved Oxygen	A+		A+	
	Turbidity	B		B	
	Chlorophyll-a	A		C	
	pH	A+		A+	
Recreational (REC)	Enterococci	A-	A-	A-	A-
WQ+REC / 2 = EHI Grade			B+		B

Improved Score
Declined Score
No change in Score

5.4 ZONE 4 ECOSYSTEM HEALTH SCORES

B+ 2010 REPORT CARD GRADE | **B+** 2011 REPORT CARD GRADE | **B** 2012

Good ecosystem health

Conditions meet all set ecosystem health values in most of the reporting region

SUMMARY

The 2012 TEER EHAP report card shows an EHI grade of B for Zone 4. The 2012 Zone 4 score of B shows a slight decline from the score of B+ in 2011. The score was generated from data collected at four monitoring sites within Zone 4 (T13-T16) during the 2010/2011 sampling period.

WHAT HAS CHANGED THIS YEAR?

Comparison of data between the 2009/10 and 2010/11 monitoring years (Table 14) describes where differences in parameters have occurred. Turbidity and mercury showed improvements in scores whereas levels of TP, chlorophyll-a and copper were elevated in 2012 compared with 2011 results. Other parameters such as TN, aluminium, arsenic and lead continued to exceed ANZECC guidelines and did not vary between the sampling periods. Dissolved oxygen, pH, *Enterococci*, cadmium and zinc scores did not change between the sampling years and continued to perform well against guidelines in Zone 4.

WHY HAVE EHI SCORES CHANGED?

The 2010/11 sampling period was characterised by capturing more frequent high flow events compared to the sampling period of the previous year. Although the overall grade in Zone 4 marginally declined between 2011 and 2012 it has been identified that these changes can be due to natural variation in climate and flow between monitoring years.

Table 14. Zone 4 Difference between 2009/10 and 2010/11 parameter scores.

ZONE 4					
Category	**Indicator Parameters**	**2009/10 Grades**		**2010/11 Grades**	
Water Quality (WQ)	Total Nitrogen	F	B-	F	C
	Total Phosphorus	C		D	
	Dissolved Oxygen	A+		A+	
	Turbidity	B		A+	
	Chlorophyll-a	B-		F	
	pH	A+		A+	
	Cadmium	D+		D+	
	Copper	B		D-	
	Mercury	C		A+	
	Zinc	A+		A+	
	Aluminium	F		F	
	Arsenic	F		F	
	Lead	F		F	
Recreational (REC)	Enterococci	A+	A+	A+	A
WQ+REC / 2 = EHI Grade			B+		B

Improved Score
Declined Score
No change in Score

5.5 ZONE 5 ECOSYSTEM HEALTH SCORES

A-	A-	B+	
1999-2009	2011	2012	**Good ecosystem health** **Conditions meet all set ecosystem health values in most of the reporting region**

SUMMARY

The 2012 TEER EHAP report card shows an ecosystem health index grade of B+ for Zone 5. The 2012 Zone 5 grade of B+ shows a slight decline from the score of A- derived in 2011. The score was generated from data collected from four sites within Zone 5 (T17-T20) during the 2010/2011 sampling period.

WHAT HAS CHANGED THIS YEAR?

Comparison of data between the monitoring years (Table 15) describes where differences in indicator parameters have occurred. In Zone 5 turbidity showed improvements in scores whereas scores for TP and *Enterococci* declined slightly while chlorophyll-a scores declined significantly in 2012 when compared with 2011 results. TN scores remained the same continuing to exceed guidelines and did not vary between the sampling periods. Other indicator parameter results such as DO and pH scores did not vary greatly between the sampling years and continued to perform well against the ANZECC guidelines in Zone 5. Metals were not sampled for in this zone.

WHY HAVE EHI SCORES CHANGED?

Zone 5 is located near the mouth of the Tamar estuary and experiences good marine flushing from Bass Strait, and as a result this Zone 5 has good ecosystem health scores. The 2012 grades for Zone 5 were slightly declined due to freshwater influences from high flows and how that impacted on slightly declining scores in *Enterococci* and TP. Similar to all other zones chlorophyll a scores significantly declined. Although the overall grade in Zone 5 marginally declined between the 2011 and 2012 report cards, these changes can be attributed to natural variation in climate and flow between the sampling years.

Table 15. Zone 5. Difference between 2009/10 and 2010/11 parameter scores.

ZONE 5					
Category	**Indicator Parameters**	**2009/10 Grades**		**2010/11 Grades**	
Water Quality (WQ)	Total Nitrogen	F	B	F	C+
	Total Phosphorus	C		C-	
	Dissolved Oxygen	A+		A+	
	Turbidity	A-		A+	
	Chlorophyll-a	B+		F	
	pH	A+		A+	
Recreational (REC)	Enterococci	A+	A+	A	A+
WQ+REC / 2 = EHI Grade			A-		B+

Improved Score
Declined Score
No change in Score

6 SUMMARY, KEY FINDINGS AND FUTURE DIRECTIONS

This report describes data from the TEER EHAP monitoring program used in the 2012 report card for the Tamar estuary. Methods used to generate the report card scores are described in Appendix 1. This is the second report card that has been produced using data specifically collected as part of the TEER EHAP monitoring program. As the 2011 and 2012 report cards use the same data from the same sites the two report cards are directly comparable. The 2010 report card used a historical data set and as such there are some differences between the data underlying the 2010 report card grades. In addition to this climate varied over the different monitoring periods. These factors do impact on scores and mean that caution must be used when interpreting changes in score between report cards. However it is possible to make conclusions from this analysis:

- Water quality improves as you travel along the Tamar estuary towards the ocean. This is partly due to the well flushed nature of the lower estuary, as well as the proximity of a major urban centre, Launceston, and significant tributary inputs to the upper estuary. Urban areas generate elevated loads of nutrients, sediments, pathogens and metals which are delivered to the estuary through stormwater systems and wastewater treatment plants. Tributaries bring pollutants such as sediments and nutrients generated across a large catchment area and deliver these to the estuary.
- The current health status of the estuary has been maintained compared with the 2010 and 2011 report cards even though the 2012 report card is based on data from a wetter period. Scores and grades were slightly improved in zone1, remained the same in Zone 2 and declined marginally in Zones 3, 4 and 5. Overall the changes observed were of small magnitude and can be attributed to natural variation and higher catchment flows. Wetter periods, occurring during winter months, generally correspond to poorer water quality as pollutant loads to the estuary increase during these times. This is as expected given the higher flows and more erosive events during these times. Higher rainfall is also associated with more overflow events for wastewater treatment plants.
- Bacteria levels are within the adopted RWQG guideline values in the lower estuary (Zones 3, 4, 5) but are above guideline values some of the time in the upper estuary (Zones 1, 2). This is because of high levels of bacteria in the upper catchment corresponding to urban areas, large tributary inputs and wastewater treatment plants which overflow into the estuary. It is also due to the poorly flushed nature of these parts of the estuary when compared with downstream zones. The 2012 results show decreased median *Enterococci* numbers in the upper estuary compared to the 2011 results.
- Elevated nutrient and bacteria levels are key drivers of poor grades in the upper estuary. These grades correspond to highly urbanised, poorly flushed areas of the estuary.
- Elevated copper and lead levels in Zones 1 and 4 are due to historic mining activities and other industry, as well as urban runoff. No data was collected in other zones given previous studies had not found significant problems with metals in these areas.

6.1 ZONE 1 TEER & BEN LOMOND WATER MONITORING PROGRAM

A Zone 1 study, conducted during the off-years, was identified as beneficial to investigate impacts in the upper reaches of the Tamar estuary. In partnership with Ben Lomond Water the TEER have developed an ambient water quality monitoring program concentrating on understanding the impacts of WWTP on the receiving waters in the upper Tamar River Estuary and Esk Rivers. The program samples mid outgoing tides to capture the inputs sequentially in an effort to determine mass loads of pollutants. Sampling is carried out within the plants and also upstream and downstream of the plant discharge points at Prospect, Norwood, Hobblers Bridge, Riverside, Ti Tree Bend and Newnham. TEER EHAP sites T1 at Kings Bridge and T2 at the ship lift have also been incorporated into the program. The monitoring program will also support any possible future infrastructure upgrades and decision-making in the upper reaches of the estuary around the city of Launceston. The study will also allow for continued up-to-date information on the processes occurring in the upper Tamar estuary. Sampling locations may be modified to capture the impact of acid sulphate soils, dredging, silt raking and stormwater. Monitoring commenced in June 2012.

6.2 MASS LOADS STUDY

Due to the large catchment areas contributing flow to the Tamar estuary, the need for a mass loads study has been identified as beneficial and complementary to the TEER EHAP. The mass loads study will provide a much greater understanding of the link between the estuary and the freshwater tributaries that enter the system. Mass loads will be calculated using flow data obtained from Hydro Tasmania and Launceston City Council flow meters stationed on the North Esk and South Esk rivers. Flow data will be used in conjunction with water quality data to estimate the loads being delivered to the estuary. Mass loads monitoring collects monthly samples for the same parameters sampled for in the EHAP except for Secchi disk and chlorophyll a at seven sites on the North Esk and South Esk rivers.

6.3 SEAFOOD SAFETY

Natural concentrations of metals in aquatic environments pose minimal threats to human or environmental health however; metal levels can be significantly elevated by human activities, particularly in estuaries with industrial, agricultural and urbanised catchments. The Tamar River estuary is an example with high levels of anthropogenic inputs, historic and current, impacting on not only aquatic health but human health. Bivalve molluscs, such as the Pacific oyster, *Crassostrea gigas*, are filter feeders which remove and digest particles from large volumes of water, and are consequently exposed to metals available in the aquatic environment. *Crassostrea gigas* is abundant along the shoreline of the Tamar estuary and has the ability to assimilate and store levels of contaminants through a process called bioaccumulation, resulting in increased concentrations compared to the surrounding environment. Oysters tend to bio accumulate these contaminants and can pass them on to humans and other predators when consumed.

The Department of Health and Human Services (DHHS) has a long standing advisory warning against the harvesting of wild shellfish for consumption in the Tamar estuary due to the risks from these contaminants as well as microbial risks. Currently, there is no signage in public access areas along the estuary communicating these warnings and strong anecdotal evidence suggests people are continuing to eat the oysters.

A study was conducted by the Tamar Estuary and Esk Rivers (TEER) program to investigate levels of metals in *Crassostrea gigas* and four species of recreationally targeted fish; cod, *Pseudophycis bachus*, flathead, *Platycephalus bassensis*, green back flounder, *Rhombosolea tapirina*, and yellow eye mullet, *Aldrichetta forsteri*. Excessive levels of cadmium (Cd), copper (Cu) and zinc (Zn) were found in oysters far exceeding the Food Standards Australia New Zealand (FSANZ) limits set for these metals, and therefore are considered a risk to public health. All four targeted fish species were found to be within acceptable FSANZ limits.

The findings of this study support the DHHS advisory warning against consuming wild shellfish. TEER intends to install signs to communicate this message to those who use the Tamar estuary. Fish species assessed do not pose a risk to human health, however it is recommended recreational fishers follow FSANZ advice on fish consumption; two to three serves per week of non-pelagic species.

6.4 FRESHWATER ECOSYSTEM HEALTH ASSESSMENT PROGRAM (FEHAP)

A FEHAP has been developed to complement the estuarine EHAP and gain a catchment-to-coast understanding of the TEER region, its catchments and waterways. Data collected over a 10 year period, 2001-2011, from key stakeholders; NRM North, DPIPWE, UTAS, Hydro Tas, Forestry Tas, BLW, local councils and Inland Fisheries, has been used to develop a baseline report card due for release in 2013.

Reporting is based around waterway health from two different reporting zones in each of the six catchments, Meander, Brumby's-Lake, Macquarie, South Esk, North Esk and Tamar estuary catchments. Waterway health was calculated using three categories; water quality analysis (ANZECC), macroinvertebrate assessments (Ausrivas) and streamside zone vegetation assessment (TRCI). All categories were weighted equally and combined to produce a letter 'grade', between 'A' and 'E', to indicate the health of the catchments.

A monitoring framework has been established for potential future report cards that is reliant on the existing monitoring programs of the region's key organisations; NRM North, DPIPWE, UTAS, Hydro Tas, Forestry Tas, BLW, local councils and Inland Fisheries, with added resources from TEER.

6.5 DEVELOPING WATER QUALITY OBJECTIVES

In conjunction with the EPA and utilising the data gained from the TEER EHAP the program aims to develop Tamar estuary specific water quality guidelines to enable increased rigour when applying trigger levels and allow for more sensitive analysis and understanding of estuarine issues and processes. This process requires 24 months of monitoring data, which is now available.

6.6 BIOLOGICAL INDICATOR FOR THE TAMAR ESTUARY

TEER is exploring any opportunities of a partnership with the University of Tasmania and Australian Maritime College for a post graduate study to identify a suitable biological indicator for the Tamar estuary for use in the EHAP monitoring program and report card. Possible indicators that may be suitable include;

- Using the Pacific oyster, *Crassostrea gigas*, and the spotted-shore crab, *Paragrapsus laevis*, to identify sources and provenance of nutrients through stable isotope analysis,
- Using benthic foraminifera community assemblages to identify potential anthropogenic influences,
- Surveying seagrass beds in the lower zones to indicate any decline in estuary health, and
- Annual fish health surveys.

6.7 STORMWATER

Stormwater from urban areas typically contains a number of pollutants identified to impact upon the health of the TEER waterways. To better manage stormwater in this region, a stormwater officer position was created in partnership with local councils and water corporation stakeholders for TEER in early 2011. The officer coordinates stormwater activities in the TEER region and provides expert technical advice to councils and other key stakeholders.

Future directions for stormwater management include the collation of all existing stormwater mapping data in the TEER region and stormwater monitoring. Both projects will help natural resource managers to better understand and evaluate the health and condition of waterways in the TEER region, and help direct future investment and on-ground works. Data collected during stormwater monitoring will also enable natural resource managers to better evaluate effectiveness of activities undertaken to improve waterway health. TEER will also be focusing on stormwater education for both councils and the community.

6.8 TEER WATER QUALITY IMPROVEMENT PLAN (WQIP)

The TEER Water Quality Improvement Plan will integrate water and catchment management knowledge with the aim to improve water quality and protect environmental values of the Tamar catchment.

A WQIP provides an ecosystem based approach to integrated water cycle management, supported by science.

It is designed to:

- Engage state, local government, NRM groups and cooperatively prepare a WQIP and implement interim projects
- Resolve major impediments to Water Quality planning and management through a catchment management based approach
- Address the key priority threats to water quality and environmental flows, and establish methods to continuously improve management knowledge and systems
- Establish governance arrangements that ensure all relevant stakeholders are party to WQIP implementation

6.9 APPLICATION OF TEER EHAP DATA

Information collected from the TEER EHAP and from current projects contributes to the future management, investment and development of the Tamar estuary and Esk rivers by providing up-to-date scientific data to partner and non-partner organisations which feeds into the development of many decision support tools such as:

1. TEER water quality triggers
2. Model building such as hydrodynamic models, sediment and plume dilution models
3. Environmental assessments
4. Development of the TEER Water Quality Improvement Plan
5. Mass loads estimation to the estuary
6. Nutrient source identification
7. Reports and report cards
8. Education and awareness, i.e. website, signage and media launches, and
9. Research.

EHAP monitoring data and associated information also serves as a valuable time stamp allowing for the measurement of change over time in the TEER region.

APPENDIX 1.
METHOD FOR CALCULATING REPORT CARD SCORES

The scores used in the report card are calculated using the general method described in the TEER Report Card Methodology (2010). This Appendix briefly describes the steps used to generate scores for this report card and any assumptions that were used in each step (Figure 67).

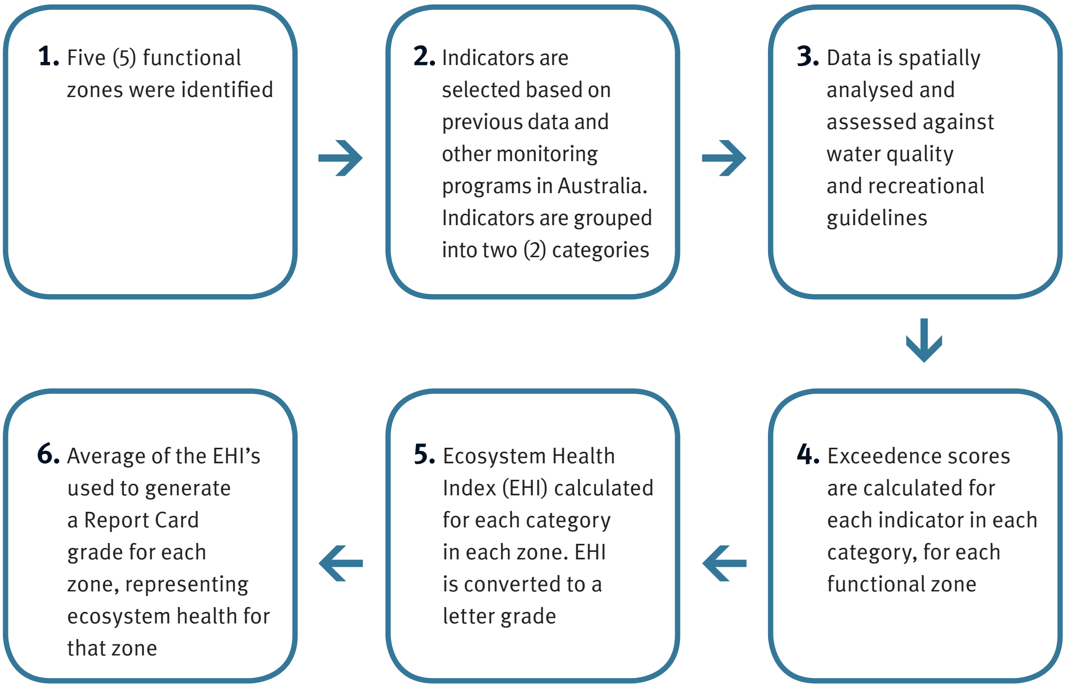


Figure 67. Steps used to generate report card scores (from AMC (2010).

STEPS 1 AND 2: DATA USED IN GENERATING THE SCORES

Two different scores are generated: one for ambient water quality and the other for recreational water quality. The water quality score is based on a set of indicators: TN, Chl-a, mercury (Hg), TP, aluminium (Al), lead (Pb), pH, arsenic (As), zinc (Zn), turbidity, cadmium (Cd), dissolved oxygen (DO), copper (Cu). Recreational scores are based on bacterial counts of *Enterococci*.

All data has been checked for completeness and all values below the minimum detectable level (‹x) are replaced with the largest value below the minimum detectable level to the appropriate number of decimal places. For example, ‹4 is replaced with 3.9 if values are given to one decimal place or 3 if values given in integers.

Zones are the same as were defined for the 2010 report card. The analysis for water quality in this report card is not directly comparable to any of the previous years' analyses because of limited metal data and possible problems with chlorophyll a measurements. Datasets for all parameters other than chlorophyll a are largely complete for all months and river zones. Chlorophyll-a data is missing for most zones in January to April.

Metal data is only available for April and October in river Zones1 and 4. Metal data is collected from surface and bottom water samples.

With the exception of metals, only surface data was used. Where multiple observations of a parameter were taken for a single time step at different water levels (i.e. a vertical profile of the water column is provided), the value used for that time step is the mean of the values over that part of the water column of interest at the site. For example where a 'surface value' is required, all observations in the top 25% of the water column at that site and time step are averaged to generate a single value. Apart from duplication through vertical profile measures, a single measurement for each parameter was available in each month.

A LOWESS regression was then fit to each parameter for each month to produce the data set used to calculate the final scores for each zone of the river.

STEP 3: LOWESS REGRESSION

LOWESS is a data smoothing method in which a regression is performed in a moving range around each X value with the values in the range weighted according to their distance from the X value (see for example NIST/SEMATECH, 2006) This means that no explicit model equation is produced. Regressions can be either linear or higher order polynomials. Figure 68 shows an example of a point being estimated using LOWESS. A weighted linear regression is performed using values inside the marked range. Values closest to the point of interest are given the highest weighting. The estimated value is that predicted by the weighted linear regression for the specified X value. The range is then moved to the right and different observations and weights used for linear regressions to produce estimates across the full range of X values.

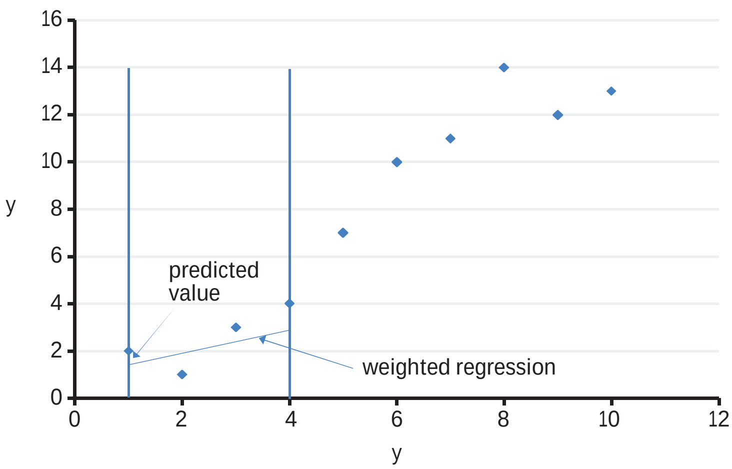


Figure 68. Example of a value fit by LOWESS regression (note a linear regression is used in this case).

For the estuary report card, LOWESS regression is used to create a smoothed data series along the length of the river. The X value in this case is the distance along the estuary. Each observation point is associated with a distance along the estuary. Lagoon Beach is the mouth of the Tamar estuary or zero distance. Seaward points are given a negative value (to -7) and points up the estuary are given positive values (to 67). The distance from the mouth of the estuary used to define the extent of each zone is given in Table 16.

Table 16. Distance from mouth of Tamar estuary for each zone.

Zone	Distance from Mouth km
1	>54
2	35-54
3	20-34
4	5-19
5	<5

A smoothing weight of approximately 0.5 is used for all parameters, although this varies slightly depending on the parameter and month based on goodness of fit to the data. The LOWESS model provides a predicted value for each parameter for each kilometre of the estuary for each month. The LOWESS smoother is only used over the distance range of the data collected, so the start and end point of the estuary varies from parameter to parameter and month to month, depending on where on the estuary the data was collected (e.g. Figure 69).

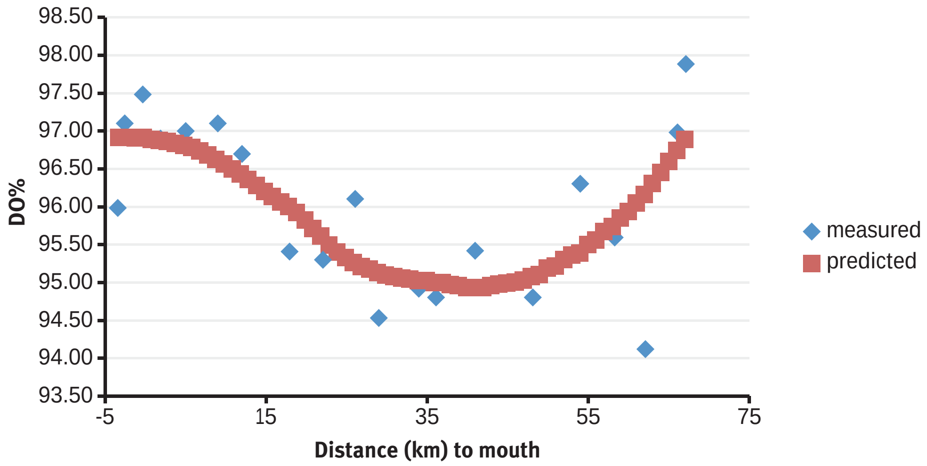


Figure 69. Dissolved oxygen in the month of August from the mouth (-3.5 km) to the head (67 km) of the Tamar estuary, with a LOWESS smoothed function fitted.

STEP 4: EVALUATING EXCEEDANCE OF THE GUIDELINE VALUES

A set of guideline values is used for each parameter (as described in the main body of this report) to decide whether or not the parameter value is indicative of a healthy estuary section. The LOWESS models are used to predict a value for each one kilometre section of the estuary. These points are then assigned a category value of 1 to 4 based on the distance of the smoothed LOWESS value of that point to the threshold value (Table 17).

Table 17. Rules used to assign category values to 1 km points along the estuary using LOWESS smoothed valued (parameters other than pH)

LOWESS smoothed value	Category value
› 50% above guideline value	1
0-50% above guideline value	2
0-50% below guideline value	3
› 50% below guideline value	4

For example, if the guideline value is 10 then a LOWESS smoothed value of 3.5 would be more than 50% below the guideline value (i.e. below 5) so would be given a category value of 4. This means that for this parameter the estuary can be considered to be in a very healthy condition. If instead the LOWESS smoothed value was 12 then this is less than 50% above the guideline value, so the category value of 2 is assigned, indicating a somewhat impaired condition.

Data for pH is managed differently as values both less than and greater than the exceedance value are viewed as detrimental to the ecosystem. In this case values within the range provided are given a score of 4, indicative of a value that is not detrimental to the ecosystem. So far, all pH data collected in the estuary has been within the range provided, and as a result no consideration has been given on how to allocate a score to values outside of the range. This may need to be done in the future.

STEP 5: CALCULATING THE EHI

For each parameter, a category value for each zone is then calculated as the mode of all relevant category values. A separate category value is calculated in this way for each month. For example, if the January observations were given category values such that 5 observations had a value of 1, 2 had a value of 2, 3 had a value of 3 and 1 had a value of 4, then the mode, or most frequent, category value is 1 so January is assigned a category value of 1 for this parameter (Figure 70).

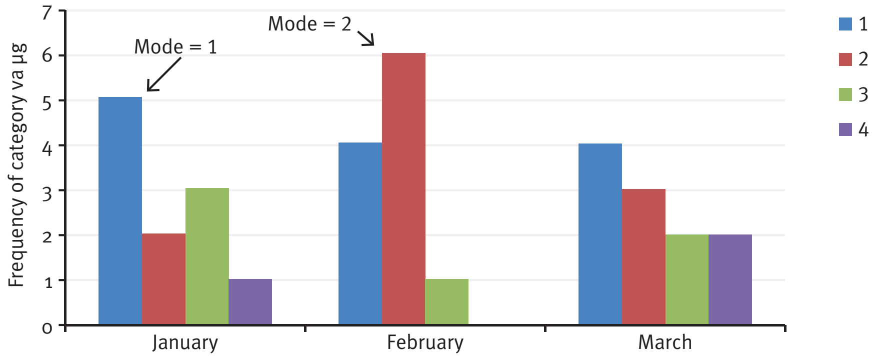


Figure 70. Example showing calculation of monthly category value for a parameter.

The Ecosystem Health Index (EHI) is a measure of how much of a waterway's area complies with the defined water quality objectives (EHMP, 2008). The EHI for an indicator (water quality, recreation) in a zone is calculated by averaging the category values across all relevant parameters then converting this value to a proportion (by dividing by 4).The list of parameters used for water quality and recreational EHIs is given in the first section of this Appendix. Table 18 shows an example of how the EHI for a parameter is calculated using synthetic data for *Enterococci* as an example.

Table 18. Calculation of the Ecosystem Health Index (EHI) for Enterococci.

		Zone				
Indicator	**Month**	**1**	**2**	**3**	**4**	**5**
Enteroccoci	**Jan**	1	3	3	1	1
	Feb	2	3	3	2	2
	Mar	2	2	3	1	1
	Apr	1	3	3	1	1
	May	1	2	3	1	2
	Jun	1	1	1	1	.
	Jul	1	2	2	1	3
	Aug	1	1	2	1	2
	Sep	2	3	3	3	3
	Oct	.	3	3	1	1
	Nov	1	2	3	2	2
	Dec	1	2	3	1	1
	Average	1.27	2.25	2.67	1.33	1.73
	EHI	0.32	0.56	0.67	0.33	0.43

STEP 6: REPORT CARD GRADES

A letter grade is then assigned for each indicator based on these EHI values. The relationship between EHI values and letter grades is given in Table 19. For example an EHI of 0.51 would be given a letter grade of D- indicating a poor condition while a letter grade of 0.955 would get a letter grade of A+ indicating an excellent condition.

Table 19. Relationship between EHI and letter grade used in the report card.

EHI	Letter Grade
0.950-1.000	A+
0.900-0.949	A
0.850-0.899	A-
0.800-0.849	B+
0.750-0.799	B
0.700-0.749	B-
0.675-0.699	C+
0.625-0.674	C
0.600-0.624	C-
0.575-0.599	D+
0.525-0.574	D
0.500-0.524	D-
‹0.500	F

The report card grade for each zone is generated using the average of the water quality and recreational EHIs.

APPENDIX 2.
EHAP SAMPLING DATA DESCRIPTION

Table 20 gives a description of flow and rainfall conditions for each of the monthly sampling dates taken as part of the EHAP.

Table 20. EHAP sampling day conditions description.

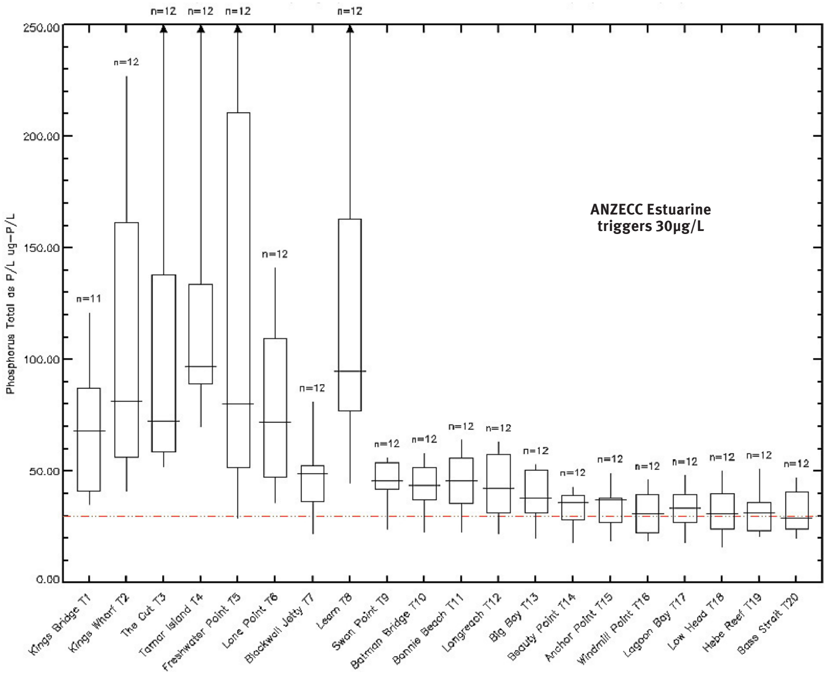
Sampling Date and commencement of sampling run time	Estimated flows into the Tamar estuary 7 days prior to sampling (cumecs)	Estimated monthly flows into Tamar estuary (cumecs)	Field Comments and climate description	Tidal stage at start of sampling run
27/10/2010 07:30	411	1849	Average rainfall with heavier falls at the end of the month	07:30 Low Head low tide
24/11/2010 07:00	623	2816	Average rainfall with hot days	07:00 Low Head low tide
16/12/2010 07:20	1598	3669	Wettest December for 20 yrs. Flooding in Tamar catchment mid month. Trevallyn dam spill	07:20 Low Head high tide
20/01/2011 07:30	1896	3737	Heavy rain mid month. Flooding in Tamar Catchment. Trevallyn Dam spill 6 days prior to sampling	07:30 Low Head low tide
10/02/2011 07:05	443	1811	Wetter than usual February. Small spill at Trevallyn Dam	07:05 Low Head mid ebb tide
10/03/2011 07:30	248	5540	Average rainfall leading up to sampling with heavy rain and flooding at the end of the month	07:30 Low Head mid ebb tide
13/04/2011 08:15	320	4081	Heavy rain 24 hrs prior. Heavy rain with localised flooding in Tamar Catchment	08:30 Low Head mid ebb tide
11/05/2011 07:40	237	941	Drier than usual. First month of 2011 without heavy rainfall	07:40 Low Head mid ebb tide
16/06/2011 07:50	2315	5902	Above average rainfall. Trevallyn dam spilled between 10th and 29th June	07:50 Low Head mid flood tide
13/07/2011 09:20	1637	3435	Below average rainfall for Launceston although Trevallyn dam had small spills 7 days prior to sampling estuary	09:20 Launceston high tide
10/08/2011 08:15	664	12766	Heavy rainfall and major flooding in catchment. Heavy spill at Trevallyn dam for 20 days	08:15 Low Head high tide
06/10/2011 07:10	271	2349	Average rainfall-No flooding during Sept & Oct	07:10 Low Head high tide

Australian Bureau of Meteorology 14/09/10

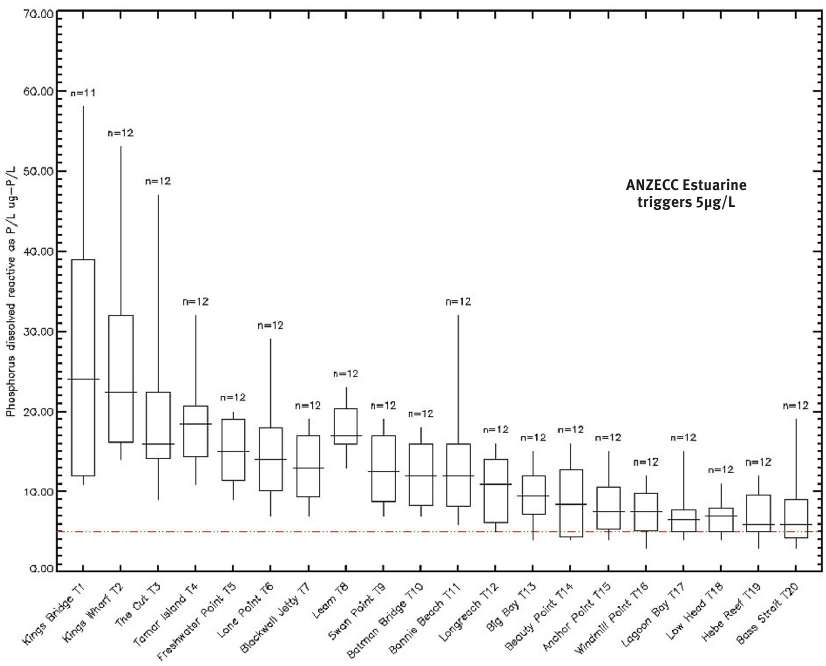
http://www.bom.gov.au/climate/current/month/tas/archive/index.shtml

APPENDIX 3.
NUTRIENT BOX-AND-WHISKER PLOTS

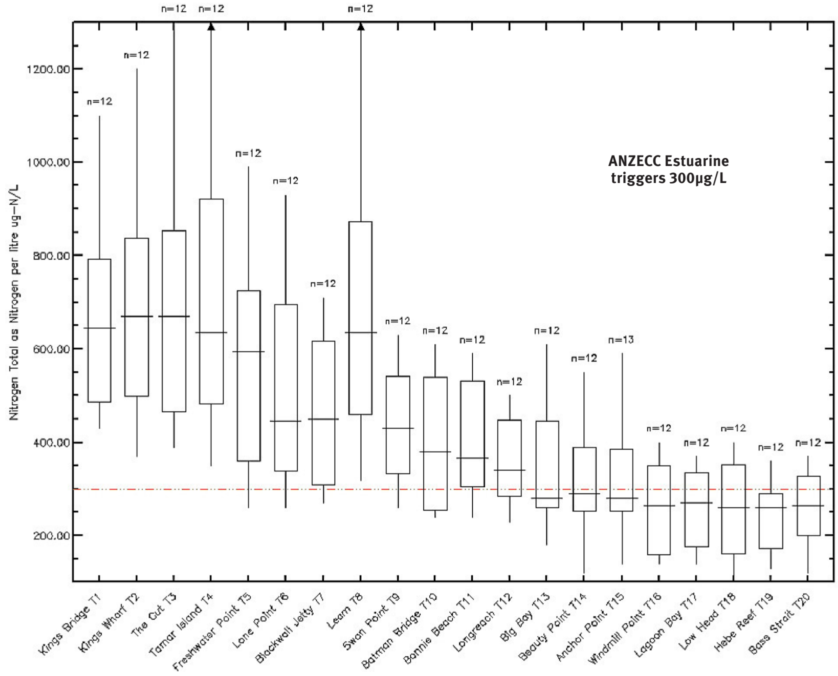
Appendix 3 provides the box-and-whisker plots for the bottom or deepest nutrient samples. These correspond closely to trends observed in surface samples shown in Section 3.3



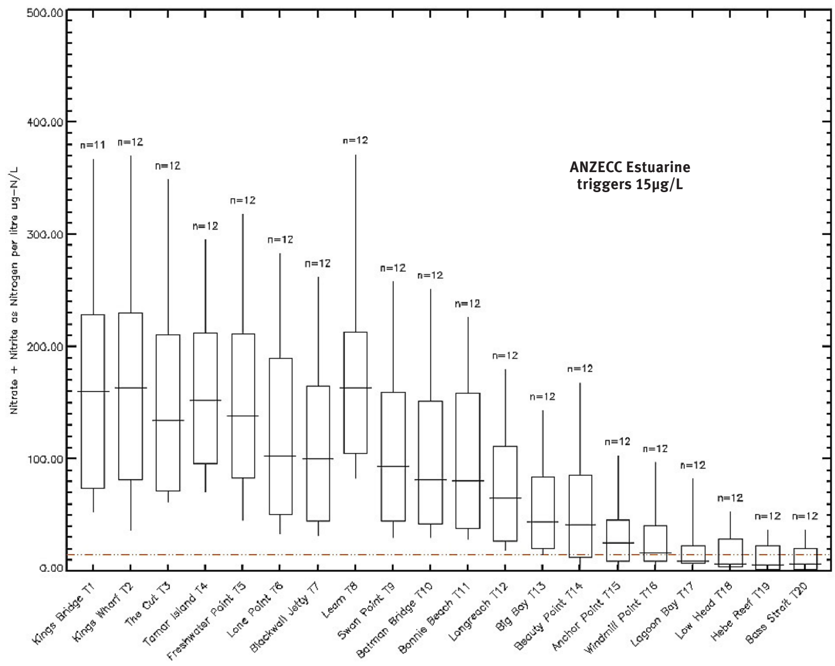
Phosphorus Total as P/L µg-P/L for TEER Sites 1-20 at bottom waters for the 2010-2011 study period.



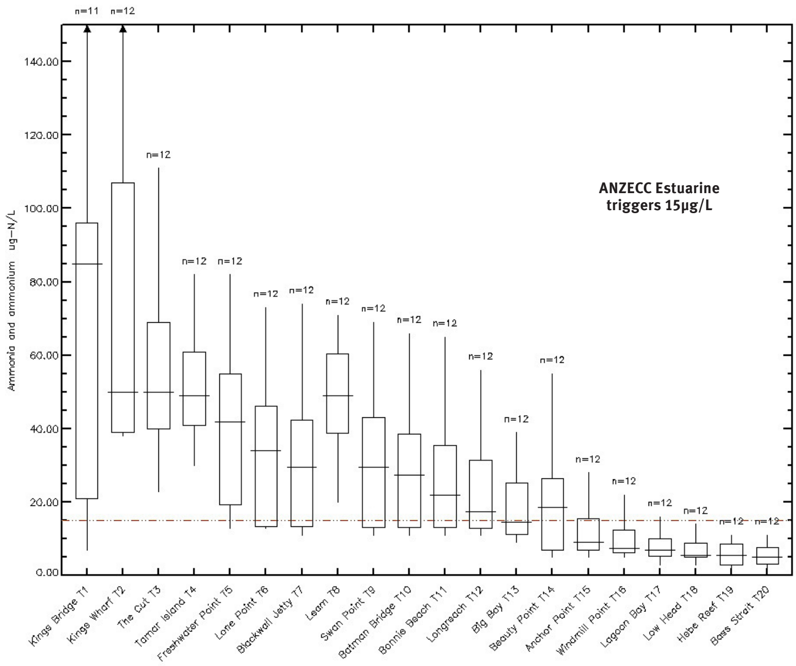
Phosphorus dissolved reactive as P/L µg-P/L for TEER Sites 1-20 at bottom waters for the 2010-2011 study period.



Nitrogen Total as Nitrogen per litre µg-N/L for TEER Sites 1-20 at bottom waters for the 2010-2011 study period.



Nitrate + Nitrite as Nitrogen per litre µg-N/L for TEER Sites 1-20 at bottom waters for the 2010-2011 study period.



Ammonia µg-N/L for TEER Sites 1-20 at bottom waters for the 2010-2011 study period.

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