Smart Cities Plan
Launceston
City Deal

Combined System Overflow Investment Plan
Combined System Overflow Working Group

City of LAUNCESTON

taswater

Ray Dodson is a Civil Engineer with GHD, with over 40 years' experience in the engineering of water and wastewater projects and general civil and hydraulic infrastructure works. Ray undertook the original Wastewater Rationalisation Assessment for the City of Launceston, and has been part of the project teams which have undertaken subsequent reviews/assessments for TasWater including the recent Launceston Sewerage Improvement Project (LSIP).

Cameron Jessup is a Senior Engineer in the Treatment Asset Performance team at TasWater. In this position Cameron has a particular focus on the performance and operation of sewage-treatment plants and their impact on the receiving environment. Cameron has also worked extensively on the combined system for a number of years and completed his engineering dissertation on the combined system.

Randall Langdon is the Senior Asset Management Adviser at the City of Launceston. Randall has a Bachelor of Engineering in Civil Engineering. His focus over the last decade has been on asset management and he has 40 years' experience working at many levels with Launceston's combined drainage, sewer and stormwater systems.

Michael Newby is a Hydraulic Engineer at the City of Launceston. Michael has a Bachelor of Engineering, Civil (Hons). In his role at the City of Launceston, Michael has gained extensive knowledge about drainage performance and system modelling. He is also currently undertaking a Master of Infrastructure Engineering and Management.

Kathryn Pugh is the Environmental Scientist at the City of Launceston. Kathryn has extensive experience in landscape water quality and aquatic habitat monitoring, impact assessments and threatened species management. Kathryn has a Bachelor of Science (Hons), majoring in Geography and Environmental Science, and Zoology. She is a Certified Environmental Practitioner.

Richard R. Roll received his B.S. and M.S. degrees in civil engineering, is a registered professional engineer, and is board certified in water supply and wastewater collection. He worked for the Niagara Falls water and sewer utility for 30 years, with the last 13 as its technical services director. He is currently employed as an environmental engineer in the USA office of GHD at Buffalo, New York.

Executive Summary

The Smart Cities Plan: Launceston City Deal, signed on 20 April 2017, stipulates the formation of a Tamar Estuary Management Taskforce (TEMT) to facilitate a coordinated and evidence-based approach to address the health of the Tamar River. TEMT was given responsibility to oversee development of a River Health Action Plan by the end of 2017. Although the scope of the River Health Action Plan is at a catchment level, a key direction in the City Deal refers to mitigating the effect on the kanamaluka/Tamar Estuary of Launceston's combined sewerage and stormwater system (combined system). Two working groups were formed to investigate mitigation options and potential investment strategies to improve water quality in Zone 1 of the kanamaluka/Tamar Estuary (Launceston to Legana), with decreased pathogen concentrations as the primary goal.

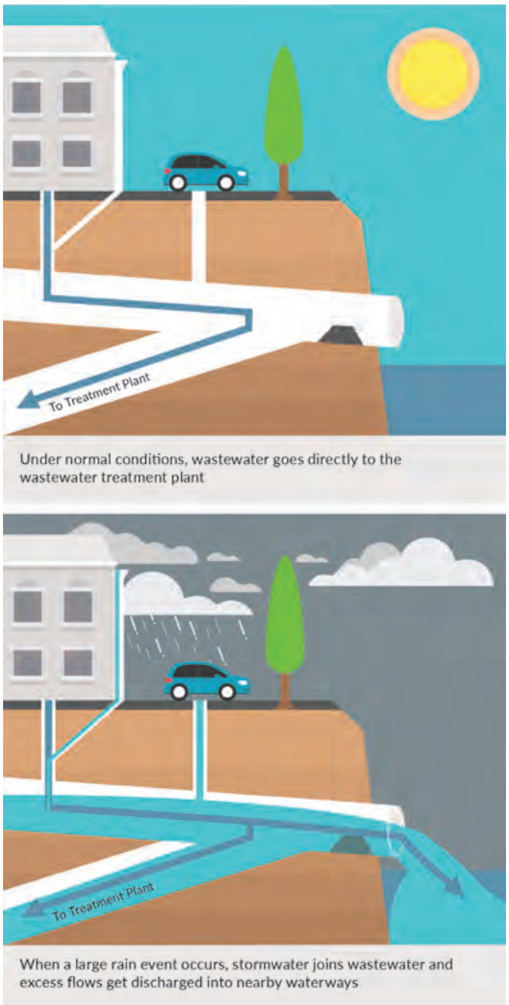
The two groups and their respective study areas are:

1. Catchment Action Working Group — catchment-wide diffuse loads

2. Combined System Overflow Working Group — the impact on Estuary health of the Launceston combined sewerage and stormwater system

This report summarises the work and documents the findings of the Combined System Overflow Working Group which was formed to support the work of the Tamar Estuary Management Taskforce (TEMT) in developing the River Health Action Plan.

The area now known as Launceston was first settled by a British garrison in 1806 and development followed English trends. Launceston Council was formed in 1853. With the population approaching 10,000 it was time to ensure a fresh water supply and then a drainage system to enable the city to develop further. The drainage system adopted followed European practice of the time, ie, combined sewerage and stormwater drains. There have been four major iterations of the system over 160 years, each a major generational improvement. The 1960s version of the drainage system in the combined area is complicated by the need to pump the stormwater flows from the low-lying areas up and over the levee system built to protect the urban area from South and North Esk river floods. Each of the system iterations moved the major sewer outfalls further away from the city centre and down the Estuary where the larger body of water was better able to cope with the introduced pollutants. Sewage treatment did not commence in Greater Launceston until the 1960s and secondary treatment including disinfection was not achieved until the early 1990s.



Under normal conditions, wastewater goes directly to the wastewater treatment plant

When a large rain event occurs, stormwater joins wastewater and excess flows get discharged into nearby waterways

Figure 3 A typical combined system

With Launceston's inner city local stormwater flooding problems reduced, and the river banks beyond the levees reopened to the public, the next step in improving the estuary is to lower the levels of pathogens in the river in and around Launceston. The improvements in this report aim to achieve this by significantly reducing the amount of sewage entering the waterways from Launceston's combined system.

The scope of work surrounding the combined system improvement does not provide for the reduction or removal of the naturally occurring estuarine mudflats. The diverse and productive ecosystem in the Estuary is characterised by a three to four metre tidal range and large freshwater inputs from the North Esk and South Esk rivers. The combination of a large sediment load from the catchment and strong tidal currents results in rapid sedimentation in the upper reaches of the estuary. The natural process for drowned river valleys is to infill and eventually become alluvial plains and deltas.

The Tamar catchment includes urbanised areas, agricultural activities, industrial operations and recreational pursuits, and has rich and diverse aquatic ecosystems. The estuary supports a range of uses and environmental values, including a large industrial area at Bell Bay, salmon farming, fishing, swimming, tourist boats, highly valued waterfront commercial and residential areas, sponge gardens, a shark and ray nursery, and important wetlands for bird habitat.

Water quality in the North and South Esk rivers is generally good or moderate in the cleared foothills and lowland plains, with variable grades (from poor through to very good) in the forested hills and highlands. Recreational water at sites on the North and South Esk rivers are generally suitable for swimming, unless there has been rain in the catchment in the days prior to testing.

Water quality parameters have been monitored in the Estuary and the North and South Esk rivers since the 1970s, with historical data predating the Ti Tree Bend Sewage Treatment Plant. Thermotolerant coliforms in the North Esk River at Hoblers Bridge and in the Estuary at the Tamar Yacht Club were observed to be present in the millions of cells/100mL in the 1970s. Mirroring global observations, analysis of historical and current data indicates a strong trend of significantly improved water quality since the construction of wastewater treatment plants.

Poor water quality in Zone 1 of the Estuary is generally a result of diffuse sources from the whole catchment, sewage treatment plants and Launceston's combined system contributing faecal contamination, suspended sediments, nutrients, heavy metals and hydrocarbons to the estuary. Strong incoming tides tend to trap these pollutants in Zone 1 exacerbating these issues. Light rainfall events (≥1mm) cause a significant increase in faecal contamination in the Estuary.

The water quality data indicate that water quality in Launceston's waterways very often meets the recreational water quality guideline. However, despite coliform counts in the Estuary being much lower than in previous decades, they are still observed to peak, rendering the water in Zone 1 unsuitable for primary recreation activities for a few days. Rainfall has a significant effect on the water quality in the upper estuary, with pollutants coming from the catchment, the stormwater networks and Launceston's combined system.

The water quality analysis establishes that while Launceston's combined system has a significant impact on water quality it is not the only cause of poor water quality in Zone 1 of the Estuary. In order to affect substantial water quality improvements, solutions are needed for diffuse catchment and urban stormwater inputs, as well as the combined system overflows.

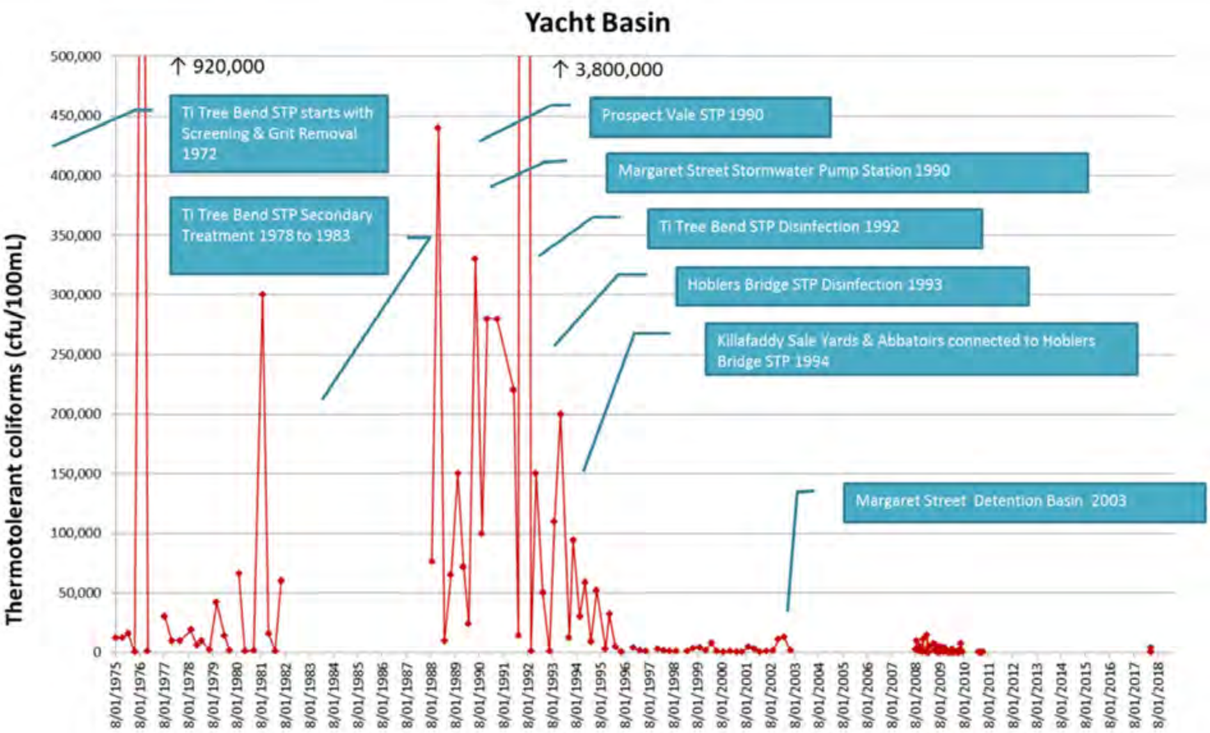


Fig ii) Progressive reduction in coliforms at the Yacht Basin

In developing mitigation options for the combined system it is important to recognise that the discharge of combined flows to the Estuary from the combined system may occur via three distinct methods:

- overflow from the sewage treatment plant at Ti Tree Bend
- pumped to the Estuary via combined rising mains during wet weather conditions
- gravity overflows to the Estuary via links between the sewer or combined network to the separated stormwater system

Overflows occur at 15 locations at varied frequencies and concentrations of sewage contamination. These locations are displayed below.

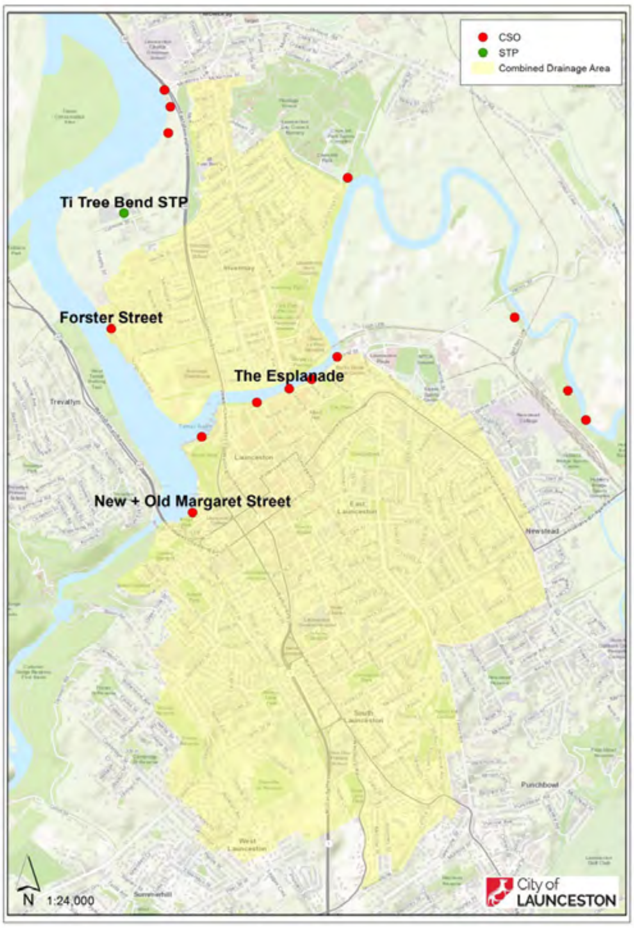


Fig iii) CSO locations

Hydraulic modelling of the system indicates that of these 15 locations, three distinct catchments and associated facilities contribute approximately 95 per cent of the sewage loading to the Estuary. These facilities and catchments are:

1. New + Old Margaret Street Pump Stations located in Kings Park off Paterson Street
2. Esplanade (including the Shields Street, Tamar Street and Willis Street pump stations)
3. Forster Street Pump Station

Therefore, these three sites are the focus of this study.

In developing mitigation options to decrease pathogen concentrations, the Combined System Overflow Working Group sought an international perspective from a person experienced with combined systems and current trends towards improvement of the outcomes of such systems. The group was fortunate to gain the services of Richard Roll, Environmental Engineer from GHD, Buffalo, New York, USA from 18 to 24 October 2017. Richard provided an additional peer review role for the group's work. Richard's review found that the mitigation options proposed were consistent with the approach in the United States.

The feasibility of separating the combined system, ie, separated sewer and stormwater systems, was evaluated. In theory, the full separation of the combined system will eliminate sewage discharge to the Estuary (ie, 100% reduction in sewage discharge to the Estuary at all locations). However, removing the sewage from the combined system will not remove all the pollution from the catchment as there is a significant pollution load in stormwater — particularly in the "first flush" of stormwater after dry periods, where oil and grease, sediment, dog and animal faeces, papers, cans etc are washed from roads and surrounding surfaces into the stormwater-pipe network. Ideally this situation should be treated, as it is a significant pollution load. A well-performing combined system would "catch" this stormwater first flush and transport it to the sewage treatment plant. This would not happen in a conventional separated sewerage and stormwater system. Wholesale separation of the combined system would also be tremendously disruptive and financially prohibitive. Construction cost would be approximately $435M. Recognising this, and the inherent disruption of extensive works required within both private and public lands, the group sought to develop more cost-effective and less disruptive mitigation alternatives.

Currently, separation of assets occurs on private property and in roads undergoing major reconstruction if the work requires the disturbance of these underground assets, and it is sensible, feasible and economically viable to do so. While wholesale separation of the combined system is not supported, separation of parts of the system could be progressed in some areas of Launceston. Separation should be considered in areas where the stormwater can be collected, treated and more readily discharged to the waterways; for example parts of Newstead, East Launceston and West Launceston. The decision to separate stormwater from sewer must be on a case-by-case basis, and not implemented as a blanket rule.

Consistent with the international approach, management of combined systems requires a regulatory environment that provides the drivers for the relevant authorities to make timely system improvements. DPIPWE's *Sewage Pumping Station Environmental Guidelines 1999* recommend that every effort be made to minimise the impact of CSOs, however the guidelines have no legal force. It would appear that the CSOs are outside the statutory framework, other than *s23A General Environmental Duty of EMPCA 1994*. Currently there are no regulations to mitigate combined sewage and stormwater system overflows to the Estuary.

In order to decrease contaminants entering Launceston's waterways, it is critical that legislation, regulations and policy be reviewed. It is best practice throughout the western world to regulate combined system overflows with conditions such as:

- elimination of CSOs during dry weather
- pollution prevention programs to reduce containments in CSOs
- public notification to ensure that the public receives adequate notification of CSO occurrences and impacts, and the location of CSO outfalls
- minimisation or elimination of solid and floatable materials' discharge to the receiving environment from CSOs
- proper operation and regular maintenance programs for the sewer system and CSO outfalls
- maximum use of the collection system for storage
- maximised flow to treatment plants
- accurate and timely reporting of all CSO events, including date, time, location, and quality and volume of the effluent discharged, including discharge from gravity overflows
- review and modification of pre-treatment requirements to ensure that CSO impacts are minimised
- ambient monitoring to effectively characterise CSO impacts and the efficacy of CSO controls

It is apparent that there are gaps in the legislation, regulation and policy surrounding the ongoing use, operation and replacement of Launceston's combined system. Ongoing work to resolve the legislative issue needs to be a priority. Furthermore, it is imperative that Launceston's combined system is managed as a complete system that includes Ti Tree Bend STP, the pipe network, pump stations and overflow outfalls (including any future infrastructure).

Recognising the impact of pollutants transported to the Estuary in stormwater, and that the issue of combined system overflows and stormwater inflow are intrinsically linked – ie, better stormwater management upstream – will result in reduced combined system overflows downstream. Therefore, new stormwater management policy is required to ensure that water-sensitive urban design (WSUD) principles are implemented for developments that are:

- new buildings
- extensions to existing buildings where the extensions are 50m^2 or greater, or create substantial new areas of impervious surfaces
- major site redevelopments
- subdivision of land

WSUD policy must be underpinned by objectives, guidelines and targets for urban development. Example objectives include:

- To promote the use of WSUD, including stormwater reuse.
- To mitigate the detrimental effect on downstream waterways with best practice stormwater management through WSUD for new development.
- To minimise peak stormwater flows and stormwater pollutants to improve the health of water bodies, including creeks, rivers and the Tamar Estuary.
- To support the sustainable use of water resources by encouraging best practice in the use and management of water, and to promote safe, sustainable use of rainwater and recycled stormwater.
- To reintegrate urban water into the landscape for a range of benefits including microclimate cooling, local habitat and provision of attractive spaces for community use and wellbeing.

Fig iv) Rain garden in central Wellington, NZ

In order to ensure the success of the WSUD policy, education and training must be developed for the general community and construction industry. Compliance monitoring of the installation and operation of WSUD devices is considered critical for success.

Also consistent with the international approach is to ensure that the existing system is functioning efficiently and to identify the potential for minor capital or operational changes to reduce the frequency and impact of CSO discharges. In summary, this review considered four major improvement areas:

- alteration to existing CSOs — Changes to weir operating heights, network configuration settings, pump arrangements.
- network storage investigation — Scope to make use of live or 'in-network' storage during wet weather events.
- operational changes (below ground) — Increased preventive maintenance in known problem areas to reduce the build-up of silt and grit in pipe assets and ensure that all available system network capacity is used. Making use of predictive weather data to implement a range of operating protocols to either reduce the frequency of discharge or to reduce the characteristic pollutant strength of an overflow event.
- operational changes (above ground) — Changes to maintenance regimes for street sweeping and cleaning of side entry pits. There appears to be significant solids loading of the network occurring due to inadequate maintenance of stormwater assets.

In developing the "hard or engineered" mitigation options, the following strategies were considered most effective based on the results of hydraulic modelling of the combined system:

- diversion of already separated sewer catchments that discharge to the combined system and therefore increase the sewage contamination of CSO
- storage facilities to decrease the frequency and concentration of CSO discharge to the Estuary
- system configuration to increase the rate and quantity of combined flows pumped to Ti Tree Bend to decrease the frequency and sewage concentration of the CSO

The benefits of the projects proposed in this report, quantified through hydraulic modelling, were measured as the decrease of sewage (volume) discharged to the Estuary. The identified mitigation options and the associated construction costs of the individual projects that support the strategies are contained in the table below. Cumulative reduction of sewerage discharged to the Estuary is also presented. These figures are based on hydraulic modelling, and presented as an average from a range of design rainfall events.

Project costings and cumulative sewage reductions

Option No.	Project	Individual project construction costing ($M)	Cumulative construction costing ($M)	Cumulative sewage reductions (%)
1	West Launceston Diversion	4.6	4.6	19
2	(1) + New Combined Rising Main	26.8	31.4	44
3	(2) + The offline storage located at New Margaret Street SPS	10.0	41.4	53
4	(3) + South Launceston Diversion in conjunction with the Esplanade offline storage	24.8	66.2	66
5	(4) + The offline storage located at Forster Street SPS	8.4	74.6	68

The following figure displays the cumulative sewage reduction versus construction costs for the five options. For context, the figure also shows the estimated construction costs and sewage reduction associated with separation.

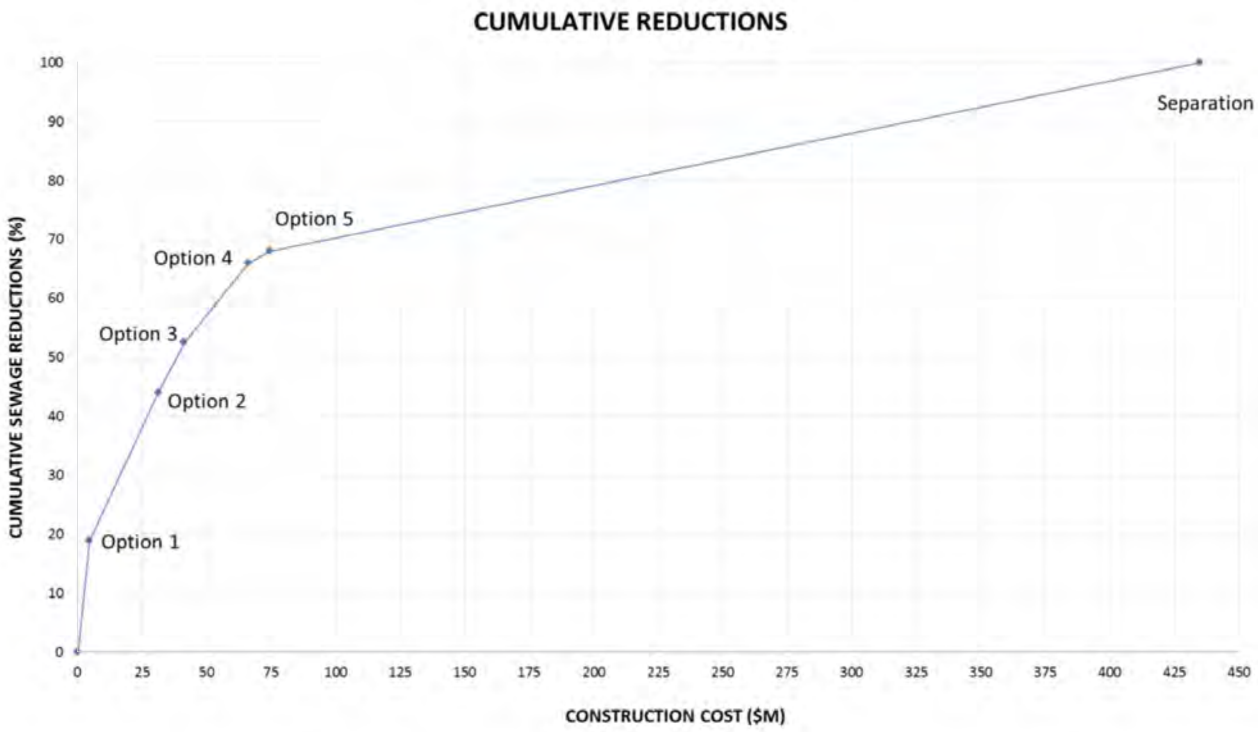


Fig v) Cumulative reduction in sewage discharged to the Estuary from CSOs

Further analysis of the proposed system improvements is displayed below. The figure shows the modelled sewage volume discharged to the Estuary for a range of design rainfall events for both the existing system (dashed lines) and assuming the implementation of the proposed mitigation options (1 to 5) 1 to 5 (solid lines). Implementing the mitigation options substantially reduces the volume of sewage discharged to the Estuary, and eliminates the most frequent CSOs (the 24EY, or twice-monthly, CSOs).

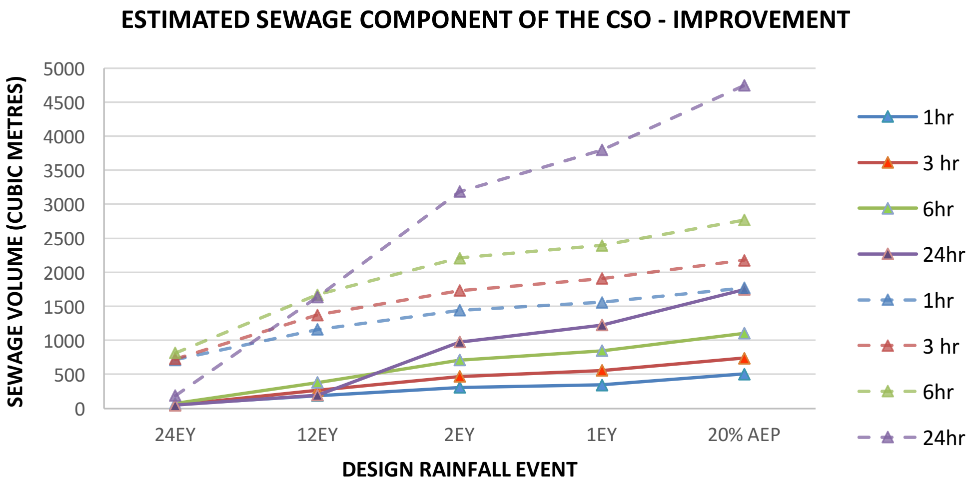


Fig vi) Estimated sewage component of the CSO – Improvement

In summary, it is clear that more cost-effective, less disruptive options than separation are available to mitigate the negative impacts of Launceston's combined sewerage and stormwater network on the Estuary.

The effects of the potential investment options for reducing CSOs were analysed. This analysis first looked at the benefits of individual projects before developing a recommended pathway of preferred options.

The options analysed are:

- West Launceston Diversion – takes the separated sewage from West Launceston and Trevallyn and diverts this directly to Ti Tree Bend STP along the West Tamar highway and directly across the Tamar Estuary via a new main reducing the load on New Margaret St
- New combined rising main – diverts flows to New Margaret St with decommissioning of Old Margaret St, installation of new sewage pumps to increase sewage pump capacity, installation of new rising main works to connect New Margaret St to a storage at Ti Tree Bend and to the Ti Tree Bend STP, reconfiguration of Forster St and St John SPS to increase pump rate to Ti Tree Bend and construction of a storage or wetland at Ti Tree Bend.
- New Margaret St storage – 4.2ML storage in Kings Park adjacent to New Margaret St Pump Station
- South Launceston Diversion – takes the separated sewage from South Launceston including Kings Meadows/Newstead and Boland St direct to Ti Tree Bend away from the Forster St Pump Station
- Esplanade storage – 3 ML storage located in the vicinity of Black Bridge/Boland St
- Forster St storage – 2.5ML underground storage adjacent to Forster St Pump Station

A preferred pathway of investment was developed from the analysis which maximises benefits with minimal costs and disruption.

The potential for avoided CSOs to put additional pressures on treatment at Ti Tree Bend was explored together with the potential benefits of an additional $10 million investment in upgraded nutrient treatment capacity at Ti Tree Bend.

The preferred pathway of investment for reducing CSOs can be expected to have large significant benefits in terms of reduced Enterococci concentrations in the upper estuary. As shown in Figure vii investment in Option 5 can be expected to decrease Enterococci concentrations by 37 per cent, which can be expected to have significant benefits for recreational users of the upper estuary.

With upgrades to Ti Tree Bend, it is estimated that total phosphorus concentrations would decrease by 18 per cent and total nitrogen by 26 per cent. This investment option allows the benefits of reduced CSOs in terms of Enterococci to be retained while substantially decreasing nutrient concentrations, avoiding the potential decline that could be expected without such an upgrade.

Based on the analysis in this report:

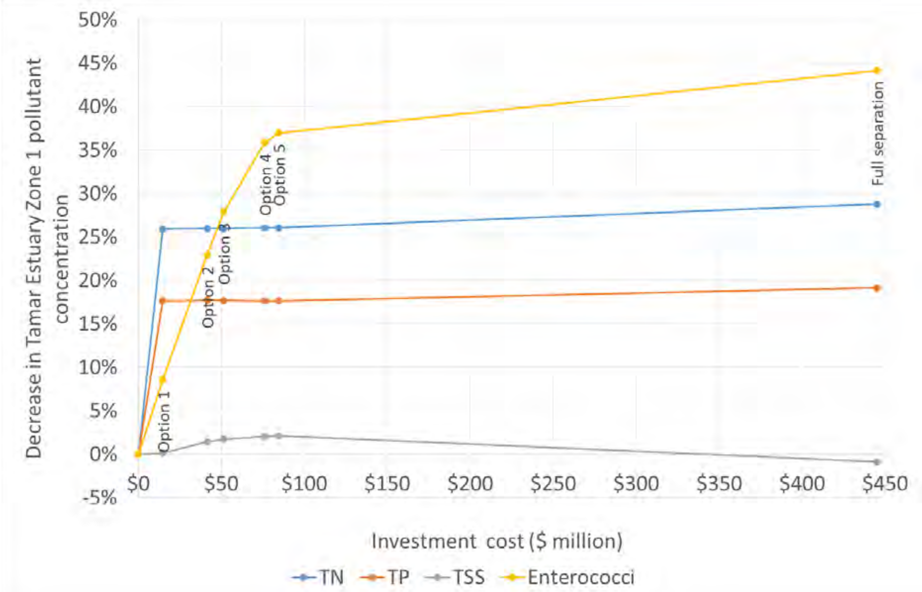


Fig vii) Cost versus estimated pollutant decrease in Tamar Estuary Zone 1 (diffuse and point source loads)

- There is a clear pathway of investments in reduced CSOs that has the potential to provide large improvements in Enterococci (and other pathogen) concentrations in Zone 1. These investments could be undertaken using a staged approach, progressively capturing the benefits of full investment. Decreasing returns to the scale of investment mean that this approach captures most of the benefits in the early stages of the investment pathway. Investment in Option 5 is expected to lead to a 37 per cent decrease in Tamar Estuary Zone 1 Enterococci concentrations for a total cost of roughly $75 million. This represents 85 per cent of the total benefit that could be achieved by fully separating sewage and stormwater in the combined system at 17 per cent of the cost. Full separation is considered to be infeasible given the enormous disruption it would cause over many years to businesses and residents in the combined system. These results demonstrate that this option is not needed to achieve very large decreases in pathogen concentrations in the upper estuary.

- Increased influent volumes to Ti Tree Bend STP from avoided CSOs have the potential to increase nutrient concentrations in the upper estuary. Very little data are available to accurately estimate this impact but significant trends in treatment effectiveness with increased influent volume are observed in the data that are available. Ti Tree Bend was not designed to effectively reduce nutrient concentrations. It is recommended that nutrient treatment upgrades at Ti Tree Bend are considered as part of the investment pathway to reduce CSOs. TasWater already has some preliminary investigations of upgrade options that can be further developed in the design phase of any investment in CSOs. The analysis here shows this type of upgrade in conjunction with the CSO investment options could lead to significant water quality benefits in the upper estuary with concentrations of TN and TP decreasing by 26 per cent and 18 per cent respectively.

The implementation of the proposed mitigation options and the required investment strategy should be primarily based on Estuary health and the expectations of the community. Options should be considered in conjunction with the proposed mitigation options as presented by the Catchment Action Working Group. Proposed operational improvements and changes to the legislative and regulatory environment should be undertaken for best practice management of the combined system.

In conclusion, significant and cost effective improvements to both recreational and ecological water quality can be made in the kanamaluka/Tamar Estuary by implementing a staged program of works in combination with policy change rather than embarking on the disruptive and expensive full separation of Launceston's combined system.

Contents

Figures and tables

List of figures

List of tables

1 Introduction

This report summarises the work and documents the findings of the Combined System Overflow Working Group which was formed to support the work of the Tamar Estuary Management Taskforce (TEMT) in developing the River Health Action Plan.

There were three distinct bodies of work by separate but coordinated parties related to improving the health of the Tamar Estuary:

- land-use management led by the Tamar Estuary and Esk Rivers Program (TEER Program)
- Launceston Sewerage Improvement Program
- combined system and other stormwater influences

The TEER Program was established in 2008 and is a regional partnership between the agencies responsible for management of the kanamaluka/Tamar Estuary and the Esk Rivers waterways. The TEER Program aims to provide a coordinated approach to management, and guidance for solutions and investment to protect, maintain and enhance the Tamar Estuary and Esk Rivers systems from "catchment to coast"[1]. The TEER Program's Scientific and Technical Committee is tasked with examining the effects of diffuse[2] pollutants over the wider Tamar catchment as shown in Figure 1.

Figure 1 Tamar Estuary catchment and municipal boundaries

[1] TEER (Tamar Estuary and Esk Rivers) website http://www.nrmnorth.org.au/teer

[2] Diffuse pollutants are those from a wide range of activities across the catchment that enter the environment which individually have little effect but when combined and concentrated by the waterway can have a significant effect.

The TEER Program's associated catchment modelling of the effect of both diffuse and point- source pollutant loads (from this report) is a key part of the overall body of work. This report builds on the catchment–estuary modelling in the TEER Program's Water Quality Improvement Plan.

TasWater's Launceston Sewerage Improvement Program (LSIP) is a proposed program of work over time that will result in the upgrade or rationalisation of the seven sewage treatment plants (STP) that currently serve the Greater Launceston area — refer TasWater's *Report #12 Preliminary Design Report*, February 2016 displayed in Figure 2.

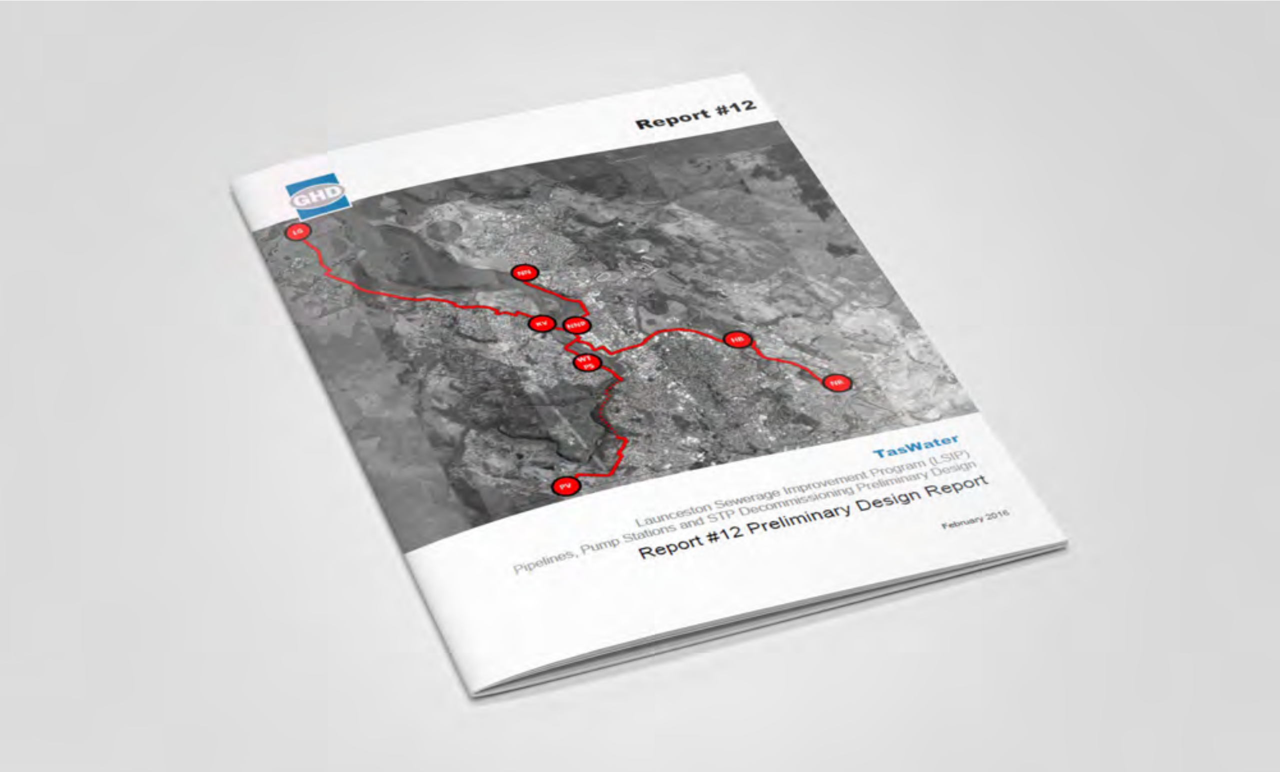


Figure 2 TasWater's *Report #12 Preliminary Design Report, February 2016*

The current status of LSIP is that the preliminary design work completed by consultants GHD and CH2M is undergoing further review and refinement to determine the most effective upgrade approach going forward. The primary motivation for the project is reduction in environmental impact for both near and far field impacts. The secondary driver is consideration of asset management aspects including asset condition, capacity and performance. A strategic business case that considers all of the existing documentation and the current review process is scheduled to be considered by the TasWater Board in March 2018. The review will provide a suggested path forward to effectively address the primary and secondary drivers through either upgrade of STPs in place or through some form of rationalisation in a cost-effective manner. The LSIP is relevant to the work completed by the Combined System Overflow Working Group as one of the areas of infrastructure upgrade, flagged in the design work completed by GHD, was the diversion of separated sub-catchments that currently drain into the combined system to the new proposed STP. These works, or a variation thereof, were considered as options in the Combined System Overflow Working Group's work on infrastructure solutions and the associated combined system modelling, and subsequent catchment modelling. The potential benefits of LSIP for water quality in the Tamar Estuary were explored in the TEER Water Quality Improvement Plan.

This segment of the project to support the development of the River Health Action Plan was planned for July to December 2017. Work immediately commenced on building the sewer and stormwater hydraulic model for the Ti Tree Bend Sewage Treatment Plant catchment; river water quality testing was ramped up and background information gathered locally and internationally. The Combined System Overflow Working Group was fully resourced by mid-August and the final report presented to TEMT by 17 December 2017.

1.1 Purpose and scope

The purpose of the combined system project was to:

- understand the public health impacts of the combined system on the Tamar Estuary
- identify mitigation solutions considering overflow frequency and cost of solutions
- support the setting of public health targets in the Tamar Estuary as part of the River Health Action Plan
- provide an investment strategy to support the targets set

The focus was on the three types of discharge from the combined system:

- storm water ejector and combined pump-station flows that pump directly to the Estuary
- Combined Sewer Overflows (CSOs) where the sewer network is connected to the stormwater system via overflow weirs designed to spill in wet weather and discharge, via gravity, diluted but untreated to the Estuary
- flow that bypasses the sewage treatment plant once capacity to treat is exceeded

As a minimum the investigation was to address:

- combined pump and stormwater detention stations — separation, detention, Water Sensitive Urban Design (WSUD), upgrading main to sewage treatment plant and optimising the system
- CSOs — upgrade of sewer network, rationalisation and separation
- sewage treatment plant bypass flow — separation, detention, WSUD, optimising the system, duplication of sewage treatment plant and review of operation

The investigation also considered national and international experience to help identify other solutions and current best practice in similar combined systems.

The key part of the analysis was to identify engineering solutions for the combined system to improve the Tamar Estuary health that will reduce the frequency of the river water quality exceeding the Recreational Water Quality Primary Contact Guideline[3] threshold of less than 140 Enterococci/100mL.

1.1.1 Exclusion from the scope of work

The focus of this project is improving river water quality that benefits public health. Therefore there are a number of exclusions from the body of work:

- sedimentation
- ecological health
- amenity and access
- river flows

The sedimentation process and associated mudflats in the upper reaches of the estuary are a natural phenomenon. Mudflats are a significant ecological community and provide habitat for a large number of species.

It is well understood that the natural operation of a tidal estuary, through the mixing of the outgoing sediment-laden fresh water with the incoming saltwater, results in the formation of mudflats. It is not the role of this report to justify the past or continued presence of the mudflats in the Estuary.

Launceston's combined system does not contribute significantly to the sediment load in the Estuary; the majority of the sedimentation is catchment driven. Removing the sewage flow from the combined system overflows will not make an appreciable difference to the extent of the mudflats.

Further information about estuaries in general is available from the following YouTube clips presented by Simon Haslett, Professor of Physical Geography at the University of Wales and author of *Coastal Systems (2016, University of Wales Press):*

- How mudflats form in an estuary: https://www.youtube.com/watch?v=J5C3JRWrQWo
- How vegetation builds up the mudflats: https://www.youtube.com/watch?v=wrRRgRXA-yI

While the focus of this project is recreational water quality, changes to the ecological health of the Estuary may occur as a result of improvements to the combined system — for example changes in nutrients delivered to the waterways and creation of habitat in constructed wetlands. Similarly, public amenity may be improved by the removal of litter washed into the waterways with the CSOs. However, the project is not focused on improving the look of the river banks at low tide. The extension of the built river edge – for example, the "Board Walk", or the stone and concrete retaining walls found along the Yarra River in Melbourne and the Thames River in London – are a matter for consideration by others.

[3] Department of Health and Human Services, *Public Health Act 1997, Recreational Water Quality Guidelines 2007*

1.2 Context — Regulatory and ownerships

1.2.1 kanamaluka/Tamar Estuary and the tidal reaches of the Esk rivers

The Tamar Estuary in Launceston generally has separate cadastre parcels (titles) that cover to the low-water mark, and low-water to high-water marks. The parcels are listed as unattributed Crown Land, and as such are the responsibility of the State. Similarly, the tidal reaches of the North and South Esk rivers are covered by a cadastre parcel to the high-water marks which are also listed as unattributed Crown Land.

The anomalies are the area of the Estuary known as the “Tailrace” which is owned by the Hydro-Electric Commission, and Tamar Island which is also listed as unattributed Crown Land.

Tamar Estuary and the tidal reaches of the North Esk River are covered by the Tamar River Conservation Area which is administered by the Parks & Wildlife Service Tasmania.

The usual tidal range in the Home Reach to Seaport area is three to four metres. Most drainage system outfalls to the Estuary and rivers are within the range of low to high tide. Most outfalls have a tide flap and those within the Launceston Flood Protection Area all have backflow protection devices to prevent water entering the city during a high tide or flood.

1.2.2 Stormwater systems

The local Council, under the *Urban Drainage Act 2013*, is the entity responsible for the public stormwater system in Tasmania.

1.2.3 Sewerage systems and the combined system

TasWater is the entity responsible for the public piped sewerage systems in Launceston under the *Water and Sewerage Industry Act 2008*. Launceston’s combined sewer and drainage system is unique to Tasmania and Australia. For the combined system area it is permissible to have both sewage and stormwater in one rather than the two separate pipes in most other urban areas of Tasmania. The benefit of the combined system is that during light rainfall events stormwater gets treated at the STP. However, during higher rainfall events, the stormwater flow exceeds the capacity of the pumping systems to the STP, causing a mix of stormwater and sewage to discharge to the estuary or river. Stormwater flows are significantly greater than sewage flows and therefore the system is sized (to the design standard) to accommodate stormwater. The pipes and associated assets in the combined system are owned by TasWater. However, for the combined system area the City of Launceston, under the *Urban Drainage Act 2013*, is responsible for the provision of public stormwater systems; hence stormwater service. The City of Launceston is permitted under the Act to enter into a commercial agreement with a third party to provide the stormwater service. The City of Launceston has a commercial service agreement with TasWater for the ongoing operation of the stormwater system in Launceston’s combined drainage area.

A typical combined system is shown in the schematic in Figure 3.

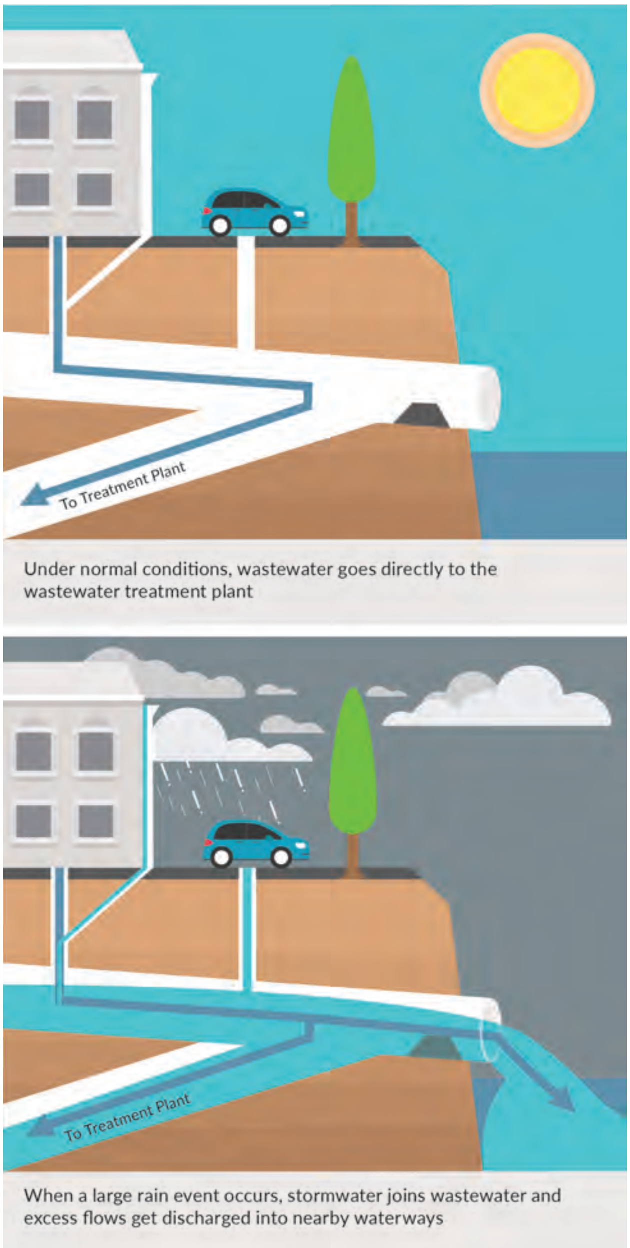


Figure 3 A typical combined system

1.3 Methodology

To facilitate this project City of Launceston allocated three staff to the Combined System Overflow Working Group on a full-time basis for six months from July to December 2017. TasWater provided a staff member as required. The project also funded two consulting engineers as required who had extensive experience with Launceston's sewerage systems to support the Working Group. An experienced engineer, currently practicing with GHD in the United States on the operation and upgrade of combined systems was brought to Launceston to review the proposed work and provide a current international perspective to the Launceston project.

The following framework formed the approach to this project:

1. System study — developed a hydraulic model with the emphasis on outflows from the system. The model was validated against TasWater pump operation and flow-meter records. The outputs of the study were quantity, frequency and percentage sewage of overflows to the Estuary.

2. System management study
    a. Agreed on preferred risk-management strategies for further investigation
    b. Modelled the risk-management strategies and quantification of benefits/reduced overflows or pathogen transportation in conjunction with NRM North's Tamar Catchment CAPER DSS[4] water quality model
    c. Prepared initial/preliminary costings including a Net Present Value (NPV)[5] analysis of infrastructure risk-management strategies

3. System management plan — identified the selected solutions to deliver the desired river health outcome

4. Risk management implementation — provided detail on stages of implementation.

An independent panel of experts was also established to provide technical direction and review each of the above steps. The team comprised:

- Andrew Truscott — Department Manager Asset Planning and Design, TasWater

- Geoff Brayford — Civil Engineer with JMG Engineers and Planners with extensive local engineering and Launceston combined system experience

- Dr Rebecca Kelly — isNRM Pty Ltd specialist researcher, water quality modeller and Chair of the TEER Program's Scientific and Technical Committee

- Shane Eberhardt — Director Infrastructure Services, City of Launceston

- Stewart Sharples — Panel Chair and Manager Economic Analysis, Infrastructure Tasmania, Department of State Growth

Ideally the hydraulic modelling would have been undertaken in 2D (model of the overland flow in conjunction with the pipe network) but due to time constraints a 1D pipe-network model was utilised. The remaining gap is that overflows from the pipe system, say a surcharge through a manhole or gully pit, are either theoretically stored above the manhole or lost from the model which means that the local flooding impacts are less understood. However, this investigation focuses on high frequency events where local flooding is less of a concern.

Good data was available from TasWater's SCADA records for use in checking of the hydraulic model. This included flow meters at the sewage treatment plants and pump-station pumping records. Due to time constraints this data was used to validate the model and provide assurance that it is a reasonable representation of actual operations, rather than full calibration of the model which ensures the model exactly represents actual operations. This was considered sufficient to test different solutions and develop conceptual costings but further modelling will be required in the next detailed design stage.

[4] An integrated catchment-estuary water quality model developed to support the TEER WQIP.

[5] NPV costs include ongoing operational, maintenance and renewal requirements to a thirty year horizon. The NPV financial calculation does not include any intangible benefits or costs associated with the projects.

2 Launceston’s combined system

To better understand the 2017 version of Launceston’s drainage system it is helpful to reflect on the evolution of the system. The much publicised “combined system” is hardly “third world” and is similar to those systems currently found in Paris, London, New York, Chicago and the list goes on. Throughout the world combined systems are considered adequate to provide both sewer and stormwater services. It is not widely appreciated that stormwater is no longer “clean” rain water once it has run over gardens, farm paddocks and roads, where it collects many contaminants and pathogens.

Contrary to opinions documented in local media in recent decades, the drainage system has had several major iterations in its lifetime. Each iteration offered a major intergenerational improvement and at the time was judged the most efficient and affordable solution for the ratepayers of Launceston. Today we can debate the intrinsic rights and wrongs but the system’s progression, in the context of the time and place, is logical considering the different contributing factors over the last 160 years.

2.1 A short history of Launceston’s drainage system

The area now known as Launceston was first settled by a British garrison in 1806 and development followed English trends. Sanitation arrangements in early times were very basic. A visit to the “bush or long drop” might have been a practical solution but as the town developed and the population increased, fresh water supply, sewage disposal and public health became major issues for the local community who were being governed from Hobart. The population in the 1830s approached 7000. Sanitation was a mix of night-cart service for the wealthy, “long drop” and direct disposal to open drains in roadways, streams and waterways. For example, early maps of Launceston show a sizeable stream running parallel to Margaret Street. A newspaper report of the time describes it as “an unwholesome and dangerous stagnant sewer”.

Launceston was proclaimed a municipality on October 30, 1852 and the first Launceston Town Council was elected in January 1853. An early priority was the provision of a clean freshwater supply and this was achieved in 1857 by diverting water from the St Patricks River at Nunamara to Distillery Creek above Waverley, and piping it to new reservoirs around the town. With a piped water-supply in place it was then possible to consider a waterborne (carriage) sewage system that had become necessary and popular in European cities in the 1800s. The Launceston Town Council offered a prize for the design of a drainage system to serve an area bounded by the river to the north, Upton and Burke streets to the west, Tamar and Welman streets to the east, and Howick Street as the southern boundary. The ridge line to the valley through to South Launceston and Glen Dhu provided a natural boundary for the system (High St, Talbot Road, Normanstone Road, Westbury Road, Prospect Street, Cambridge Street, Brougham Street and Hill Street).

The competition entries covered two systems of sewerage schemes: a separate system where sewage and stormwater flows are collected in different pipes, and a combined sewer where everything is collected in one pipe. The Governor of Tasmania made the decision to accept the “combined system” solution. A tender for construction of the first stage along Margaret Street was awarded in 1860. The combined system was gradually extended across the closely settled parts of the town and by 1888, when Launceston was proclaimed a city (10,000 people), the system involved about 40 kilometres of sewers, of which about a quarter were trunk or main sewers. From the outset all sewers discharged directly to the North Esk River or the Home Reach of the Tamar Estuary. Today that would represent environmental disaster but in the context of the 19th century they were following European practice of the day.

As Launceston grew further to the north and to the east, and into the early part of the 20th century, the combined system was further extended to cover Trevallyn, Inveresk, Invermay, Mowbray Hill, the Glebe, East Launceston and Elphin, South Launceston, Sandhill and West Launceston. Construction of dwellings in Inveresk–Invermay and other lower lying areas of Launceston required small earth levees to line the river banks to keep back the extreme high tides and smaller flooding events in the river. The levees necessitated several large pump stations to enable the city to drain during periods of rain and high river-level events. Large pump stations were constructed at the corner of York and Margaret streets, Forster Street and Boland Street. Early reports point to the Forster Street outfall and pump station being designed as a holding basin for the sewage flow which was then released on the outgoing tide. The same reports record the Launceston Marine Board as the regulatory authority for the Estuary and rivers around Launceston.

In the late 1930s the state of the sewerage system in Margaret Street between York Street and the Estuary and around into Royal Park had again become a community issue and a new sewerage system was designed to transfer the main sewage flows from the Margaret Street and Esplanade areas further down the river to the main outfall at Forster Street. Note there was still no "sewage treatment" as such in Launceston. With the threat of hostilities in Europe and then World War II extending to the Pacific region, work did not commence on Margaret Street Pump Station and the City Rising Main (sewage) to Forster Street until 1954. It was completed several years later. The new St John Street Pump Station was also built to pump sewage from the east of the city up into the City Rising Main and on to Forster Street Pump Station and outfall. All sewage discharges were concentrated to a single point under Kings Wharf.

Until about 1950, urbanised settlement was mainly confined to the "bowl" of Launceston — this area coincided with the limits of the water supply area. The combined drainage area was proclaimed in the Government Gazette.

After World War II, with the return of service people and the beginnings of the baby boomer generation, Launceston needed to expand. New suburbs developed: in Trevallyn and down to the Power Station; Summerhill; Newstead/Elphin Rise; Mowbray/Mayfield/Newnham to the north; Kings Meadows and Youngtown Hill to the south; and South Ravenswood, Waverley, Riverside, Alanvale, and a little later Norwood.

As each of these new suburbs developed, sewerage services had to be extended and these were developed as "sewer and drainage districts" with the landowners paying a share of the cost under what was known as "benefiting area schemes". All new suburbs were separated drainage areas. For example, Summerhill did not have a piped sewage-disposal system until the late 1960s; previously septic tanks were used.

Launceston's attention turned to providing a flood levee system to protect the low-lying parts of the city from a probable maximum South Esk River flood event. With the more extensive levees came the need, during the 1960s, to construct a system of ejector stormwater pump stations along the Esplanade (Willis, Tamar and Shields streets). These stations were required to pump stormwater from the city to the river against the tide, or in river flood situations.

At about the same time the rising main was extended north to Ti Tree Bend and the site of the current STP. With all the preparatory pieces of the revised sewerage system in place, work finally began on the initial stages of Ti Tree Bend Sewage Treatment Plant.

The surrounding councils each developed stand-alone sewerage treatment plants within their municipal boundary even though some were less than half a kilometre apart. The first one was Hoblers Bridge in the early 1960s, and Newnham and Riverside followed by the late 1960s.

Launceston began with screening and grit removal along with the new outfall at Ti Tree Bend in 1972. The development of the City of Launceston's expanded suburbs was only possible by connecting the sewerage systems from these separated areas into the boundary of the combined area and hence on to Ti Tree Bend. Additional overflows from the combined area of East Launceston, Elphin and Newstead were necessary by the 1980s. With continued infill development a lot of the combined system's capacity was exceeded and local flooding, with a mix of stormwater and sewage, was a common issue in the older areas of Launceston.

By the late 1980s, the wider Launceston area STPs and the inner city area's combined system were at their limits. Inner city flooding during rain events was a common occurrence; combined area pipes were collapsing and the Ministerial Exemption for secondary treatment and disinfection was to be withdrawn for all the local sewage treatment plants in 1994. Launceston City Council, under the leadership of Mayor Jimmy Tsinoglou, raised the sewer rate by 30 per cent in 1988–1989 to finance a sewer system renewal and expansion program commencing with the New Margaret Street Pump Station and associated pipework. Disinfection followed at Ti Tree Bend, and Hoblers Bridge sewage treatment plants and Council's Killafaddy Sale Yards & Abattoirs were connected to Hoblers Bridge sewage- treatment plant in 1994. The Margaret Street Detention Basin (undercover sewage and above-ground combined stormwater) was commissioned in 2003 and, together with the extensive pipe-renewal and improvement program, it has put an end to the frequent and extensive local flooding in and around the Margaret Street and central city areas (Figure 4).

Since 2000, with local flooding due to issues of pump capacity, pipe size or condition under control, only ongoing combined system asset renewal and continued extension of the pipe network has been needed. However, the reopening of the river banks to the community (fenced-in by the levee system since the 1960s) has increased pressure for improvement in the look of the river banks and in water quality in and around Launceston.

Looking back to look forward it is evident that with each new generation in Launceston there has been a community push and need for a big step-improvement in the sewer and stormwater service. Nearly 50 years of river-water quality data (See Section 3.5 and Figure 13) demonstrates the massive improvement in quality (lowering of pathogens) with each new major component of the modernised sewerage and drainage system. Lowering the level of pathogens in the Estuary – another step to enable "full body immersion" (primary contact) – is now achievable and should become the new target.

THE EXAMINER, Friday, December 20, 1991 — 3

Manholes blown off as freak downpour saturates Launceston

Rain causes chaos

By RACHAEL BUFTON

Launceston's motorists would have been more mobile in dinghies yesterday afternoon as intersections disappeared beneath flash floods.

The freak downpour, which began around 4.30 pm, saw major intersections along Bathurst and Wellington streets submerged in water during a heavy traffic period.

The Bureau of Meteorology measured 11mm of rain in the Invermay area from 4.30 pm to 4.40 pm.

The Bureau's Trevallyn reading registered 11mm between 4 pm and 5.30 pm, while 25mm was recorded at the Town Hall between 4.30 pm and 5.10 pm.

A spokesman for the Bureau said that only a trace of rain was recorded at Launceston Airport and that there were no rainfall reports from other areas in the State for the period between 3 pm and 6 pm.

"It is probable that there were other localised downpours but we have no record of them at this stage," he said.

In Galvin St, directly outside Morrison and Bailey, water gushed onto the road as the cover was blown from a manhole.

One car stalled in an attempt to negotiate the resultant swell, while four-wheel drives cruised through with ease.

Manhole covers in Elphin St, on the corner of York and Elizabeth and the corner of Bathurst and Canning were also forced from their holes.

A lone motorcycle policeman directed traffic through the water-choked Bathurst St/Fredrick St intersection.

Water lapped at the doorsteps of houses on the corner of Margaret and Balfour Sts and a number of parked cars were only visible from the tail-lights up.

Some residents waded knee-deep through the floods while others stood grouped in doorways and at windows watching the spectacle.

• ABOVE: Leaving his bike behind, a young boy helps a driver in flooded Galvin St yesterday afternoon.

RIGHT: The home of Marty Gugliotti at the corner of Margaret and Balfour Sts faces the deluge yesterday.

Pictures: PAUL SCAMBLER

One Margaret St resident, Mr Marty Gugliotti, said that yesterday was the fifth time his house had been flooded in eight years.

"I'm not paying my rates," he said, "until the council does something about this situation."

Others took the flooding less seriously — one bystander said it was more entertaining than television as he frolicked, hair stuck to head, amid the rain.

Motorists crossing the Margaret/Balfour St intersection were forced to take the road rules into their own hands, driving across the newly built roundabout to avoid the wash.

Deputy City Engineer, Mr Ken Hose, said that while the flooding was intense in areas downstream of York St, upstream the streets were clear.

"This is a good indication of the success of our new drainage system," he said, "but people have to realise that it will take time to complete."

The Bureau of Meteorology spokesman attributed the heavy rainfall to a complex low centred on the East Coast and moving southward.

He said that moist air associated with the low produced an unstable atmosphere, triggering the downpour as the air moved over the Tamar Valley.

Figure 4 An example of Launceston and the Margaret Street local flooding prevalent from 1970 to 2000 (The Examiner newspaper Friday 20 December 1991 Page 3)

2.2 Launceston's sewerage treatment plants

The Greater Launceston area is currently served by seven STPs. The plant configuration and licensed discharge is shown in Table 1.

Table 1 Launceston's sewage treatment plants and licensed discharge

STP	Licensed discharge kL/d	Treatment type
Legana	540	3-cell lagoon system, inlet works and reuse system
Riverside	2800	Secondary treatment with disinfection
Ti Tree Bend	25,000	Secondary treatment with disinfection, balance of storm flow bypasses through a mixture of coarse screening and grit removal for flows up to 2,300L/s and additional primary treatment for flows up to 1,400L/s
Hoblers Bridge	4500	Secondary treatment with disinfection
Norwood	4050	Extended aeration lagoon (Pasveer)
Newnham	3920	Secondary treatment with disinfection
Prospect	1720	Intermittent Decanted Extended Aeration Lagoon (IDEAL) with polishing lagoons

2.3 Ti Tree Bend sewerage treatment plant

Ti Tree Bend STP treats wastewater from the Launceston combined system, as well as the separated sewer areas in West Launceston and Trevallyn. The plant provides secondary treatment and includes disinfection. The Average Dry Weather Flow (ADWF) to Ti Tree Bend STP is from 12 to 15ML/d.

Currently all inflows to the STP are, at a minimum, screened and de-gritted. Current peak inflows to the STP during rain events appear to be of the order of 1400L/s (120ML/d) however the inlet works are sized for inflows of up to 2200L/s (200ML/d). Following screening and grit removal, flows are pumped into the primary sedimentation tanks for primary treatment. There is a bypass weir at the end of the primary sedimentation tanks that will divert flows greater than 700L/s (60ML/d) to protect the secondary treatment (aeration basins and secondary clarifiers) and disinfection processes. Excess flow for each process stage, as per the original design, overflow to the Tamar Estuary as shown in Figure 5. It is worth noting that bypassed flows are mixed into the final treated effluent so that some form of disinfection is applied to all STP discharges.

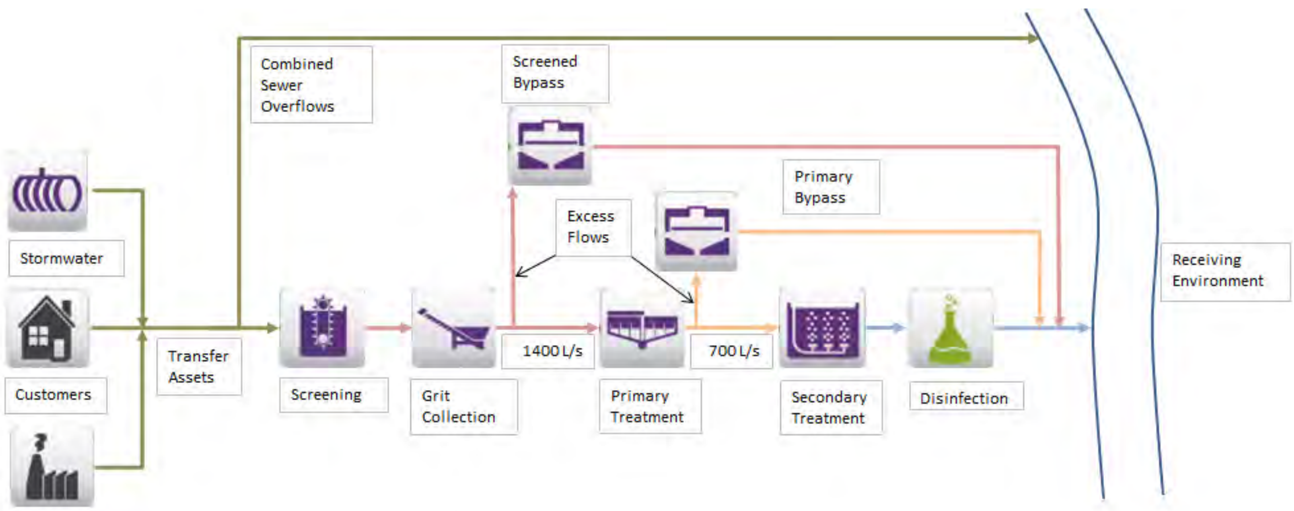


Figure 5 Ti Tree Bend Sewage Treatment Plant bypass flows at progressive stages of treatment

2.4 Service area and collection system

The combined system area (Figure 6) makes up the vast majority of the Ti Tree Bend STP catchment. The plan view of the Ti Tree Bend STP catchment, and schematic layout of the sub-catchments associated infrastructure, is shown on TasWater Drawing Nos. TWA-16-0411 Sheets 1 and 2 included in Appendix A. There are currently about 22,576 equivalent tenements (ETs) in the Ti Tree Bend STP catchment. Within this catchment there are significant sub-catchments which have a separated sewerage system but these sub-catchments discharge back into the combined system. During dry periods all flows (sewage and permanent groundwater infiltration) are pumped to the Ti Tree Bend STP for treatment; however, during rain events, flows in excess of the collection system or pumps' capacity are discharged (as combined sewer overflows) to the rivers or estuary.

The breakdown of the sub-catchments is summarised in Table 2.

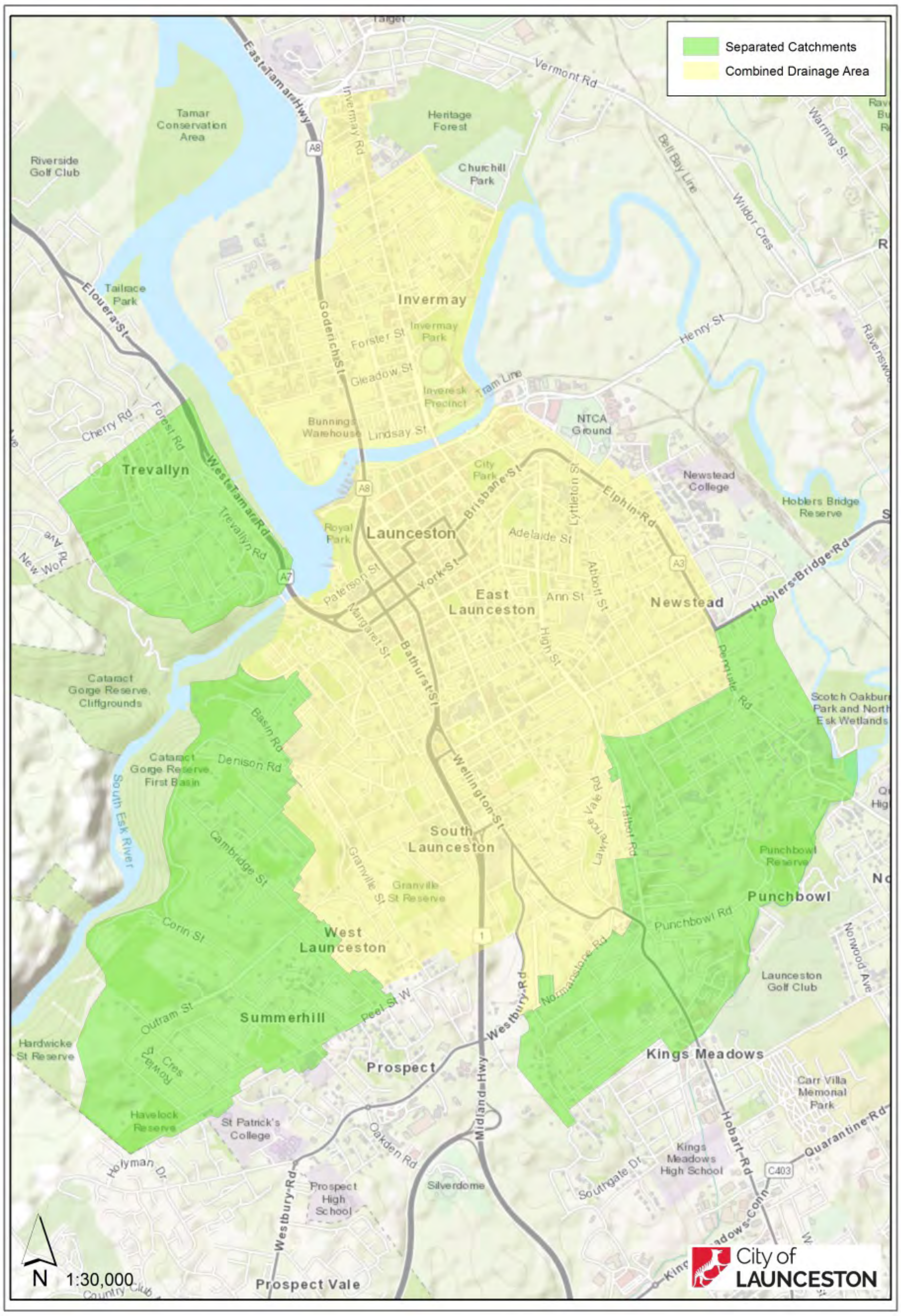


Figure 6 Launceston's combined drainage area

Table 2 Ti Tree Bend STP Catchment's Major Pump Station Sub-catchments

Sub-catchment	Total ETs in sub-catchment	Separated ETs in sub-catchment	% Separated ETs in sub-catchment	Comments
Margaret Street	10,590	3371 (West Launceston and Trevallyn)	32%	Can be directly connected to the STP (diverted from combined system).
Esplanade/ St John Street	8257	3101 (Kings Meadows/ Newstead and Boland Street)	38%	Can be directly connected to the STP (diverted from combined system).
Forster Street	2526	45	2%	
Hope Street	1202	961	80%	
TOTALS	22,575	7,478	33%	

3 kanamaluka/Tamar

Estuary

The public generally associates the term estuary with the mouth of a river — the location where the river meets the sea. However, an estuary is more accurately defined as "a semi-enclosed or periodically closed coastal body of water in which the aquatic environment is affected by the physical and chemical characteristics of both fluvial drainage and marine systems" (Edgar et al. 1999)[6], that is, the area where freshwater and marine waters mix. Tides carry marine waters from Bass Strait upstream into the Estuary as far upstream as St Leonards on the North Esk River and the Cataract Gorge on the South Esk River. Thus, the Tamar River Estuary is formed at Launceston by the confluence of the South Esk and North Esk Rivers, some 70km upstream from the estuary mouth at Low Head. The Tamar is one of the longest estuaries in Australia.

The Estuary is a drowned river valley that formed between 6,500 and 13,000 years ago when sea level rose around 60m to near its current level (Foster et al. 1986)[7]. The main channel is quite deep in the lower estuary, reaching 45m in depth near Bryants Bay; however, upstream of Swan Point at Paper Beach, the estuary is subject to rapid infilling by sediments and becomes very shallow near Launceston. Tidal mudflats border the main channel of the estuary throughout its length.

At 214km, the South Esk River is the longest river in Tasmania. The South Esk basin, consisting of Macquarie, Brumbys Lake, Meander and South Esk catchments, is the main source of freshwater flows and sediments to the Tamar. At 98km, the North Esk River is considerably shorter. The topography of the Tamar catchment varies from low hills and plains characterised by agriculture in the Northern Midlands, to plateaus of the Western Tiers, Ben Lomond and Eastern Highlands. Together the Tamar and its tributaries drain a catchment area of approximately 10,000 square kilometres, or 15 per cent of the state of Tasmania, and span seven local government areas (Figure 1).

The Tamar catchment supports urbanised areas, agricultural activities, industrial operations and recreational pursuits as well as having rich and diverse aquatic ecosystems. The estuary supports a diverse range of use and environmental values, including a large industrial area at Bell Bay, salmon farming, fishing, swimming, tourist boats, highly valued waterfront commercial and residential areas, sponge gardens, a shark and ray nursery, and important wetlands for bird habitat.

3.1 Environmental conditions

Climate

The Tamar is located in the cool temperate zone, with mean daily maximum temperatures ranging from around 12°C in winter to 24°C in summer. The average annual rainfall is 687mm (BOM Station No. 091237 Ti Tree Bend), typically with higher rainfall in the winter months, and summer storms in January (Figure 7). On average, Launceston experiences 127 rain days each year, of which 89 have a daily total >1mm, and 22 days with 10mm of rainfall or more (Table 3). It is predicted with high confidence that climate change will lead to an increase in the intensity of heavy rain events, an increase in solar radiation and a decrease in relative humidity (Grose et al. 2015).[8]

[6] Edgar, GJ, Barrett, NS & Graddon, DJ 1999 *A Classification of Tasmanian Estuaries and Assessment of their Conservation Significance using Ecological and Physical Attributes, Population and Land Use.* Marine Research Laboratories - Tasmanian Aquaculture and Fisheries Institute, University of Tasmania

[7] Foster D., Nittim, R. & Walker, J. 1986 *Tamar River siltation study Technical Report No. 85/07.* University of New South Wales Water Research Laboratory

8 Grose, M. et al. 2015. Southern Slopes Cluster Report, Climate Change in *Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports*, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia

Table 3 Launceston's rainfall data (Source Bureau of Meteorology)

Station No. 91049 Launceston (1883–1963)													
Climatic element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Mean rainfall (mm)	43.3	37.8	39.9	57.6	69.2	77.6	82.7	75.6	69.1	69.3	48.2	50.2	720.0
Highest daily rainfall (mm)	38.1	84.3	70.4	57.9	93.7	40.4	45.7	49.3	41.1	47.2	32.8	51.6	
Mean number of days of rain >= 1mm	4.5	3.8	4.7	5.4	6.9	7.9	9.0	8.9	8.2	8.0	6.3	5.8	79.4
Mean number of days of rain >= 10mm	1.1	1.0	1.0	1.7	2.1	2.3	2.2	2.0	1.7	1.8	1.3	1.0	19.2
Mean number of days of rain >= 25mm	0.2	0.2	0.1	0.2	0.3	0.2	0.3	0.1	0.1	0.2	0.1	0.1	2.1
Mean number of days of rain	7.6	6.5	8.0	9.6	12.0	14.5	15.9	16.0	14.1	13.6	10.6	9.9	138.3

Station No. 91237 Ti Tree (1980–2017)													
Climatic element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Mean rainfall (mm)	47.7	30.2	38.8	50.9	64.9	67.4	79.0	86.6	66.0	50.1	52.5	47.0	686.9
Highest daily rainfall (mm)	88.0	39.8	40.2	42.0	45.8	34.2	67.6	65.4	53.4	42.0	43.0	46.0	
Mean number of days of rain >= 1mm	5.2	4.1	4.6	6.6	7.6	8.6	10.0	11.3	9.8	8.1	7.0	6.2	89.1
Mean number of days of rain >= 10mm	1.4	1.0	1.2	1.6	2.3	2.2	2.7	2.9	2.2	1.5	1.6	1.6	22.2
Mean number of days of rain >= 25mm	0.4	0.1	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.1	0.3	0.2	2.9
Mean number of days of rain	7.4	6.2	6.6	8.9	11.3	12.6	14.5	15.4	14.0	11.4	10.0	8.6	126.9

Geomorphology

The Tamar Estuary follows a winding path, flowing northwest from Launceston to Bass Strait, with a number of c-shaped bends along its route. It is approximately 45m deep in parts in the lower reaches, but is relatively shallow in the upper reaches.

The diverse and productive ecosystem in the Tamar Estuary is characterised by a three to four metre tidal range and large freshwater inputs from the North Esk and South Esk rivers. The combination of a large sediment load from the catchment and strong tidal currents results in rapid sedimentation in the upper reaches of the estuary (Edgar et al. 1999). The natural process for drowned river valleys is to infill and eventually become alluvial plains and deltas (SFM Environmental Solutions 2008)[9].

[9] SFM Environmental Solutions 2008 *Tamar Estuary Management Plan: a management plan for the natural values of the Tamar Estuary.*

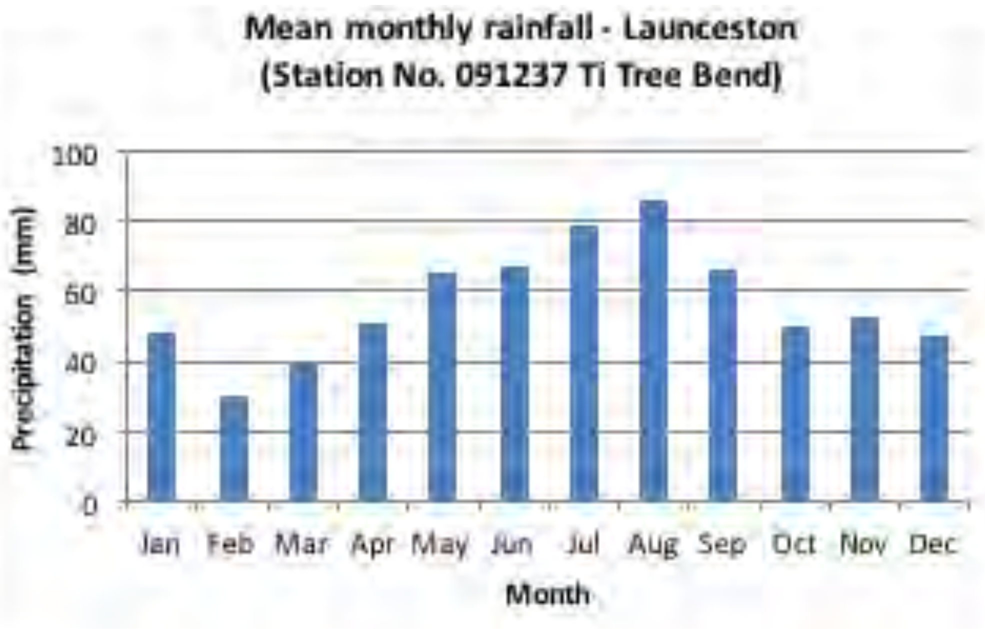


Figure 7 Launceston's mean monthly rainfall

The broad river flats from Launceston to Legana are bounded by rolling hills up to 150m elevation (Figure 8). The underlying geology of the Tamar Valley consists of Tertiary and more recent deposits, with substantial areas of Jurassic dolerite. The estuary is located in the Tamar Graben, which physically defines the Tamar region between the Western Tiers and Eastern Highlands, and from the Northern Midlands to Bass Strait. Drainage patterns in the lowlands and the Tamar Valley tend to be rectangular, reflecting the major lines of faulting and jointing.

Acid sulfate soil underlies much of the Tamar Estuary (Figure 9). These are natural soils that contain sulfides (mostly iron sulfides) formed by bacterial activity in underwater sediments over thousands of years. In an undisturbed and waterlogged state these soils are harmless, but when disturbed and exposed to oxygen through drainage or excavation, a process of oxidation can produce sulfuric acid in substantial quantities (DPIPWE 2009)[10].

Rice grass *(Spartina anglica)* was deliberately introduced to the Estuary in 1947 with the goal of stabilising mudflats, reclaiming intertidal lands and improving navigation. However, it spread uncontrolled throughout the estuary, and now represents Tasmania's largest infestation. Dense stands of rice grass inhibit access to the shoreline, and private boat ramp and jetties have become non-functional. In some areas, sandy beaches (e.g. Gravelly Beach) have been transformed into muddy rice grass meadows (Hedge 2002)[11].

At the time of European settlement in the early 1800s, the upper Tamar Estuary featured extensive mudflats, with a channel that was difficult to navigate (Figure 10). From the late 1870s until the 1960s, the upper estuary channel was dredged to allow ship passage. Dredging ceased when the major port was moved to the lower estuary. After dredging ceased, natural sedimentation processes in the estuary were reinstated and extensive intertidal mudflats reformed. In 2013, the Launceston Flood Authority was granted a five-year permit to undertake silt-raking activities in the Estuary. Silt raking agitates sediments on the bed and the banks of the upper estuary using a converted scallop dredge, with the aim of mobilising sediments during periods of high river flows to remove them from the upper reaches and improve recreational amenity, aesthetics and navigational access.

In some areas, the foreshore has changed dramatically since the early 1800s due to infilling, and reclamation of tidal flats and wetlands, altering the hydrological regime and geomorphological processes governing the Estuary, including the alteration of sedimentation and erosion processes. On the foreshore of Launceston, most of the Tamar Yacht Club, Royal Park and Seaport are constructed on reclaimed land.

---

[10] DPIPWE 2009 *Tasmanian Acid Sulfate Soil Management Guidelines*. Sustainable Land Use Section, Land Conservations Branch, DPIPWE, Hobart

[11] Hedge, P. 2002. *Strategy for the management of rice grass (Spartina anglica) in Tasmania, Australia (2nd edition).* Australian Rice Grass Advisory Group, Tasmania.

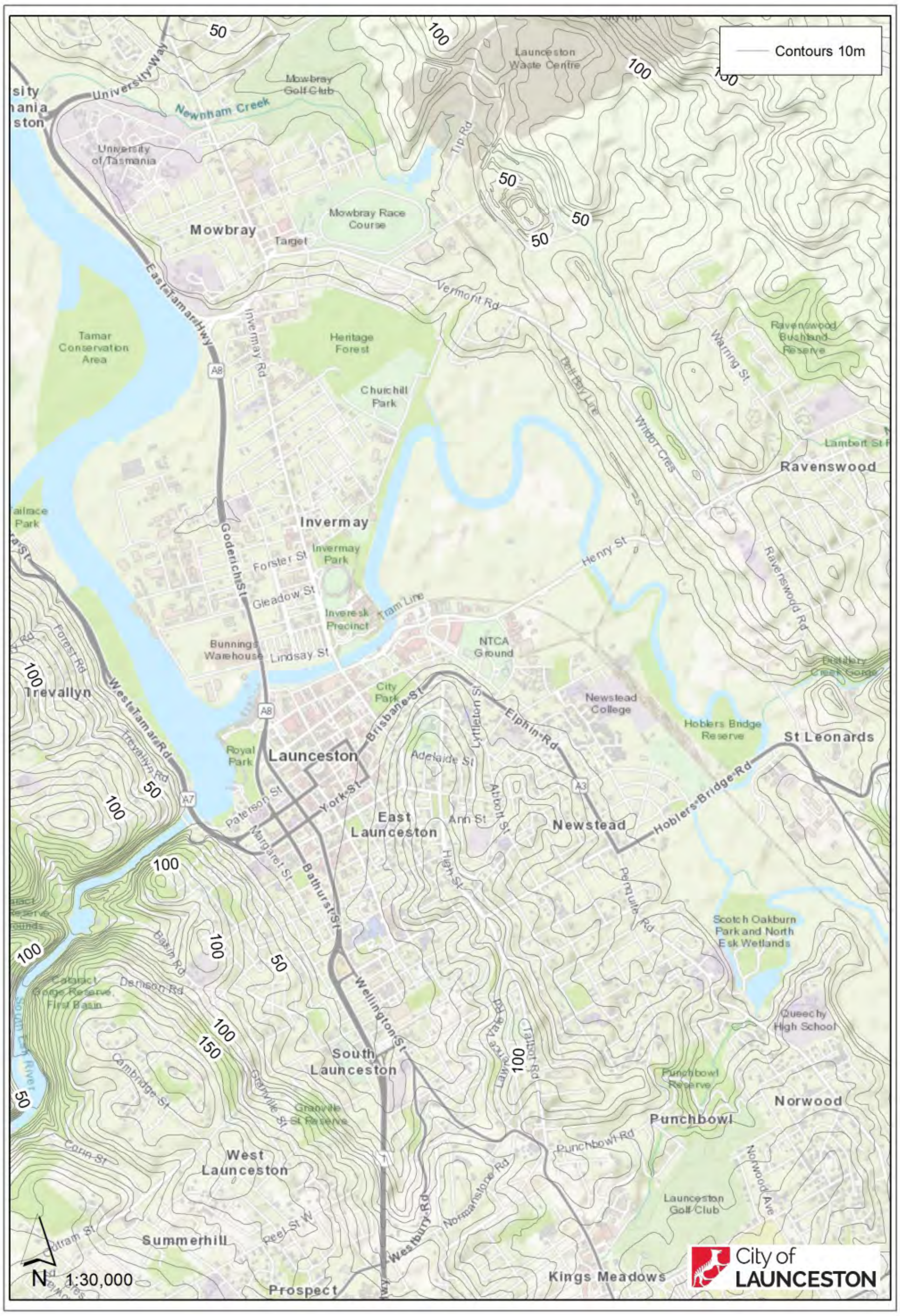


Figure 8 Topography of the upper Tamar Valley

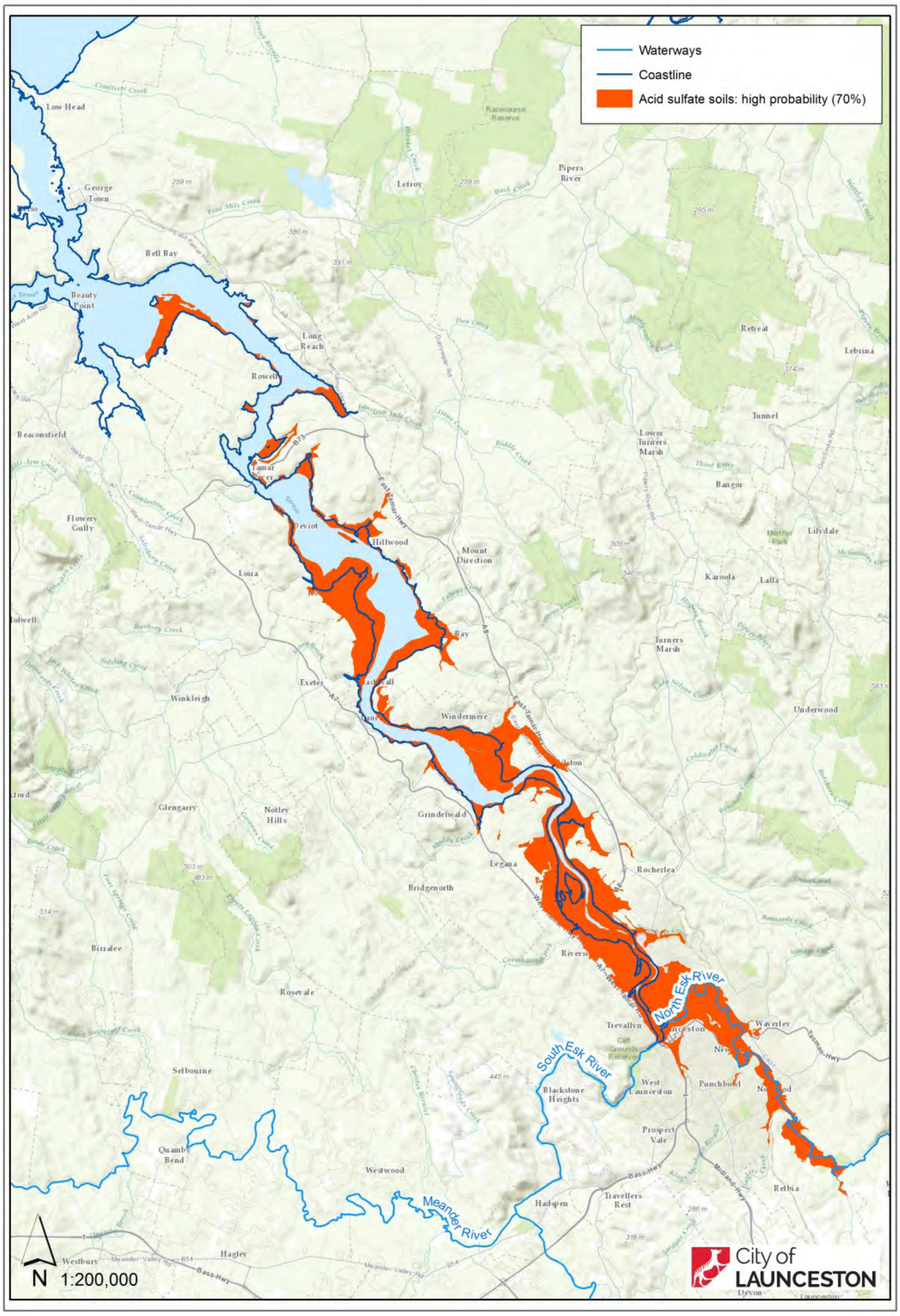


Figure 9 Acid sulfate soil probability

Figure 10 Extent of tidal mudflats in the Upper Tamar Estuary 1833

Conservation reserves and threatened species

There are 21 gazetted conservation areas in the Tamar Estuary catchment, including the 4458ha Tamar River Conservation Area that includes the intertidal zone from St Leonards down to the Batman Bridge. In many areas the riparian strip has been cleared to the high-water mark, leaving no buffer zone between natural and modified land uses. Nevertheless, the Tamar River Conservation Area is a stronghold for coastal paperbark forest, *Melaleuca ericifolia*, a vegetation community listed as threatened under the *Nature Conservation Act 2000*. It has been identified by Birdlife Australia[12] as a Key Biodiversity Area (KBA) (Figure 11).

A total of 153 threatened species, listed under either the Tasmanian *Threatened Species Protection Act 1995* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* are known to occur in the Tamar Valley (NVA 2017[13]). Five of these species have a stronghold in the upper valley around Launceston, including swamp bindweed *(Calystegia sepium)*, a plant thought to be extinct until 2001 (DPIWE 2005)[14].

Marine and estuarine pests

Estuaries are frequently "hotspots" for introduction of marine pest species, primarily because they are often exposed through shipping activities, contain unstable and disturbed habitats, and provide high levels of food resources (Edgar et al. 1999). Although temperate southern hemisphere estuaries are susceptible to marine-pest invasions from northern temperate areas – as they provide comparable conditions (eg, temperatures, salinities) for the species to thrive, but may lack the controls (eg, natural predators) to regulate their populations – the location of port facilities in Bell Bay and Long Reach in the lower estuary help to reduce risks of invasion by way of high velocity currents, sandy (as opposed to muddy) sediments and lack of maintenance dredging in this area (Aquenal & DEPHA 2008[15]).

Species' introductions to the Tamar Estuary are likely to have occurred through hull fouling, ballast-water discharges, fishing and aquaculture activities, and natural range expansions from infection points outside the estuary (Aquenal 2001[16]). Hull fouling is thought to be an important vector for introductions to the Tamar Estuary, with vessels from Victorian ports, temperate regions of Asia and New Zealand posing the greatest risk.

A baseline survey of marine pests was performed in the lower estuary in 2001 compiling data from a literature review and field survey. A total of 29 introduced and cryptogenic species[17] have been identified in the lower Tamar Estuary.

In the upper estuary, the introduced pest fish eastern gambusia *(Gambusia holbrooki)* is a significant predator on the eggs and young of native fish and frogs, including the vulnerable green and gold frog *(Litoria raniformis)*. First recorded in a farm dam in the Tamar Valley in 1991, the species now appears established in the Tamar Island Wetlands.

Extensive rice grass *(Spartinia anglica)* meadows have changed the ecology of the intertidal zone, out-competing and displacing seagrass species and potentially changing fish and/or invertebrate community structure. Fish species such as flounder and flathead are unable to adapt to conditions in infested areas (Gunns 2006[18]). Rice grass introduction has also affected native waterbird habitat, reducing the availability of foraging grounds, although it does provide nesting grounds and shelter for some native waterfowl (Blake and Cannell 2000[19]).

---

[12] Birdlife Australia http://www.birdlife.org.au/projects/KBA

[13] NVA 2017 https://www.naturalvaluesatlas.tas.gov.au

[14] DPIWE 2005 **Calystegia sepium Notesheet** http://www.threatenedspecieslink.tas.gov.au/Pages/Calystegia-sepium.aspx

[15] Aquenal & DEPHA 2008 *State of the Tamar Estuary.* DEPHA Tasmania

[16] Aquenal 2001 *Exotic marine pests survey of the Port of Launceston, Tasmania. Prepared for the Port of Launceston Pty Ltd to meet the requirements of the AQIs Decision support system (DSS) for ballast water management*

[17] cryptogenic = uncertainty whether the species is native or introduced

[18] Gunns Ltd 2006 *Bell Bay pulp mill — Draft integrated impact statement. Gunns Limited Mill operations*

[19] Blake, G and Cannell, R 2000 Foreshore and vegetation management and analysis. In: Watchorn, L., *Tamar Estuary and foreshore Management Plan*, Tamar Estuary 2020

Weeds

Weeds[20] have the potential to substantially reduce habitat availability for native communities. A large number of weeds have been identified across the estuary and associated foreshore environments, including pampas grass, gorse, blackberries, sedges, bracken, crack willow, boneseed, bitou bush, sea spurge, marram grass, boxthorn, English broom, pine, thistles, ragwort and rice grass (Blake and Cannell 2000; Rowland 2001[21]). Rice grass, crack willows and blackberries pose a significant risk to the native vegetation and flora of the upper estuary.

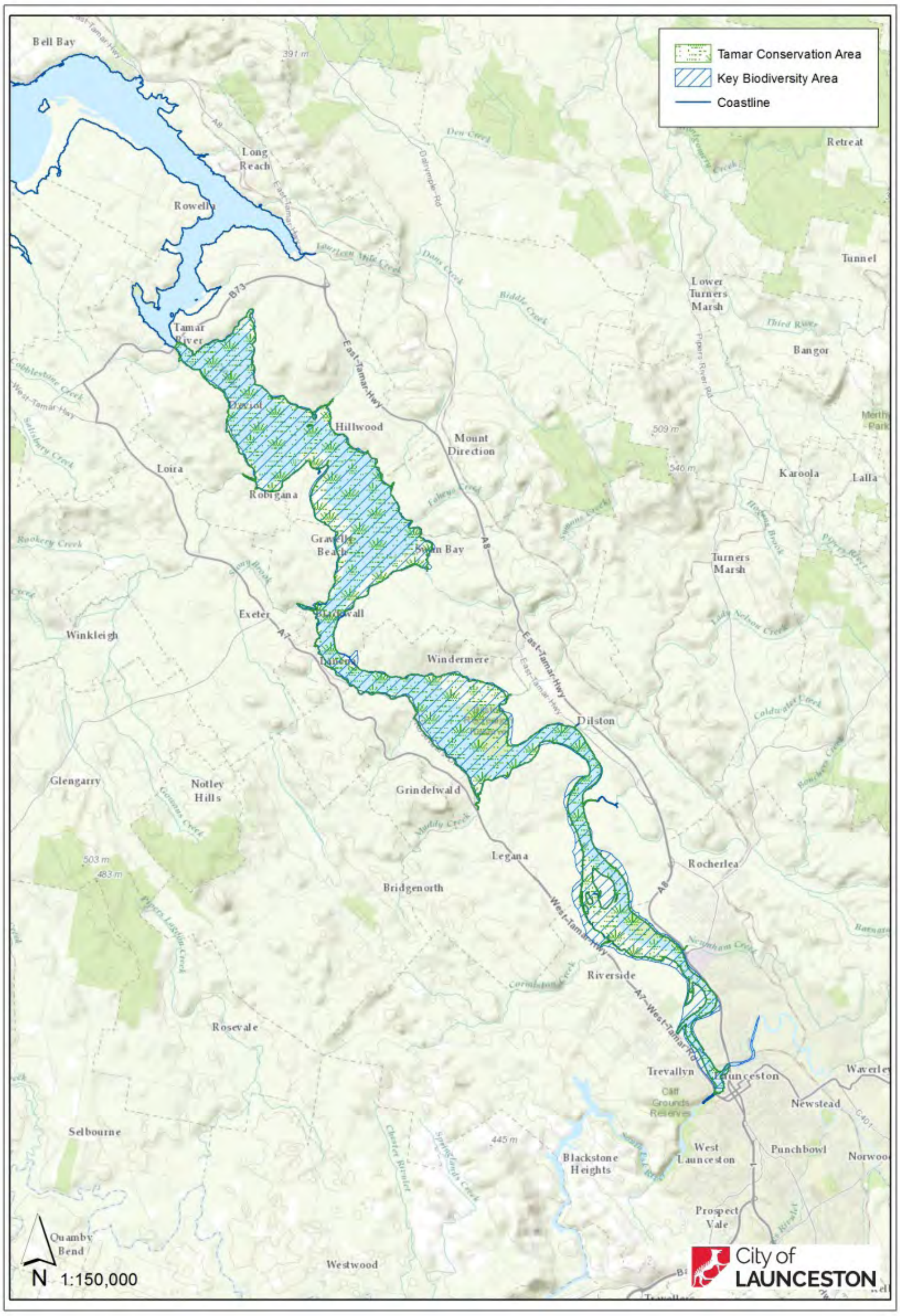


Figure 11 Tamar River Conservation Area and Key Biodiversity Area

[20] Weeds = invasive plant species that compete with and potentially displace native flora

[21] Rowland, C. 2001 *Tamar Region Natural Resource Management strategy. 2nd edition.* Department of Primary Industries, Water and Environment, Hobart

3.2 Demographics

Demographics

In 1860, when the construction of underground sewers for the town of Launceston commenced, the population stood at around 10,000 residents. By 1942, the population had grown to some 34,000 residents. Today, the population of Greater Launceston is more than 83,000 residents (Table 4) and extends from Legana and Rocherlea in the north to White Hills and Relbia in the south (Figure 12). Of these, some 16,000 residents[22] live within the combined system area. The combined network also takes additional load from people visiting and working in the CBD, as well as direct sewage inputs from the separated catchments of Trevallyn, Summerhill and West Launceston.

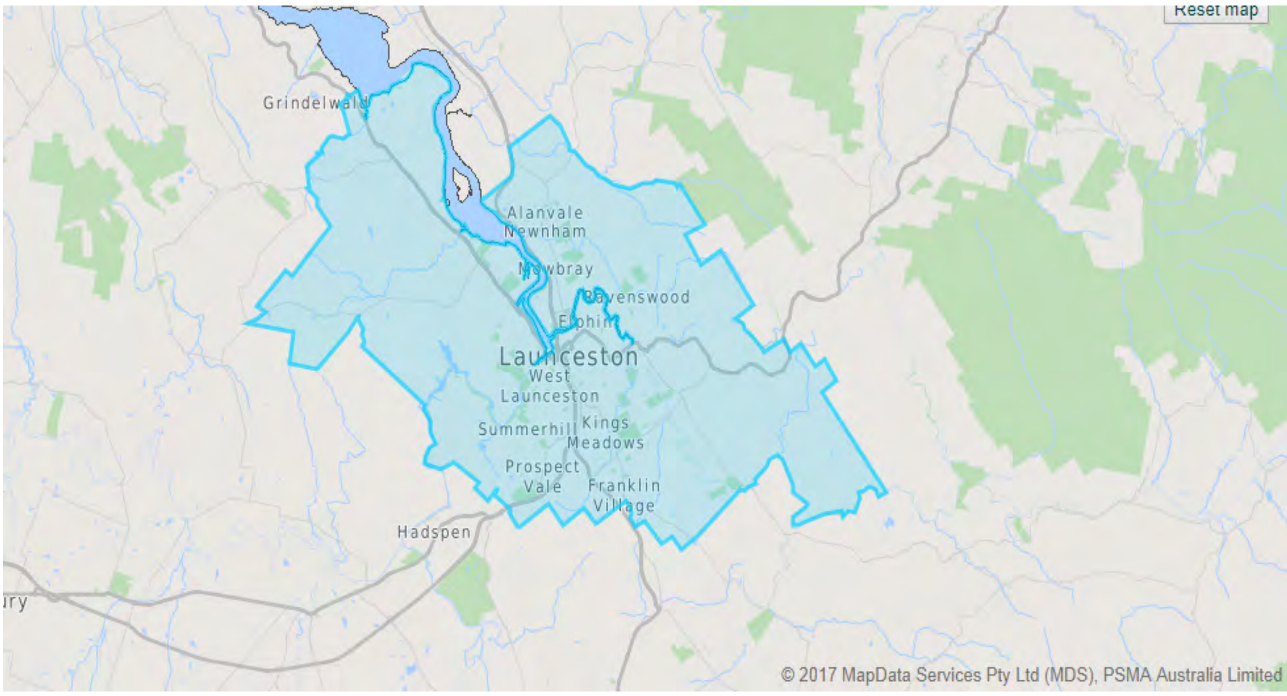


Figure 12 Greater Launceston area (Source: ABS 2017)

[22] The number of residents within the Combined System area does not correspond to equivalent tenements (a measure of sewerage discharge based on a standard residential dwelling)

Table 4 Greater Launceston population

Suburb	Population[23]
Invermay	3170
Launceston	5412
South Launceston	4800
Newstead	5220
West Launceston	4170
Trevallyn	4804
Kings Meadows	4088
Summerhill	4865
Norwood	3950
Youngtown	4891
St Leonards	3636
Ravenswood	3974
Mowbray	3911
Newnham/Mayfield	9009
Prospect/Blackstone Heights	6681
Riverside	6550
Legana	4148
Total	83,279

3.3 Land use

Land use within the Tamar catchment includes mining, agriculture (broadacre and intense cropping, dairy and grazing), production forestry (hardwood and softwood plantations, and native production forests), urban settlements and rural residential settlements (TEER Program 2015[24]).

History of the use of kanamaluka/Tamar Estuary

The sheltered waters and coastlines of estuaries are often significant sites for human settlements (Edgar et al. 1999). kanamaluka/Tamar Estuary has a long history of human settlement, with many artefact scatters and cultural living places identified on the flood plains and tidal flats. The traditional owners of the country on the eastern margin of the Estuary and the area surrounding Launceston are the Letteremairrener people. The confluence of the rivers were also a meeting place, with the Panninher people from the Norfolk Plains and the Tyerrenotepanner people from the Northern Midlands known to frequent the Estuary. kanamaluka/Tamar Estuary provided a rich food source of waterfowl, fish and shellfish.

Estuaries provide an environment for hunting and fishing, marine farms, boating, and other recreational and cultural activities. The sheltered waters are frequently used as ports for shipping and the kanamaluka/Tamar Estuary foreshore has been a focal point for development, although the uses have shifted over time in response to changing economic and social demands (Aquenal & DEPHA 2008). kanamaluka/Tamar Estuary is home to one of Tasmania's largest ports. Once based in the upper kanamaluka/Tamar Estuary, the port was relocated downstream to Bell Bay in the 1990s. Nowadays, vessels using the upper estuary are primarily pleasure craft for recreation (sailing and rowing) and tourism, although several industrial waterfront users remain. Port facilities such as wharves and container terminals often adversely affect estuaries as a result of the land reclamation, pollution, destruction of habitat, faunal disturbance, and the introduction of exotic aquatic organisms. Industry located along shorelines historically degraded waterways through direct discharge of effluent and pollutants.

Dredging and training walls are often necessary in estuaries with port facilities in order to maintain shipping channels. Dredging spoil grounds result in localised smothering of habitat, while training walls – commonly used to stabilise an estuary entrance – result in changes to habitat and alteration of water circulation patterns (Adam 1992 in Edgar 1999).

3.4 Water flow and water quality

Estuaries are complex, dynamic environments with many interacting processes, and they vary both spatially and temporally (AMC Search 2015[25]) and kanamaluka/Tamar Estuary is no exception.

[23] ABS 2017 figures

[24] TEER Program 2015 *Tamar Estuary and Esk Rivers Catchments Water Quality Improvement Plan.* NRM North, Tasmania

[25] AMC Search 2015 *Tracer analysis of sediment redistribution of Tamar Estuary for Launceston Flood Authority.* AMC Search, Launceston

There is a strong twice-daily oceanic tide from Bass Strait that is amplified up the estuary. This results in a "distortion" of the tidal curve in the upper estuary, and an asymmetric tidal curve (shorter flood tide with higher current velocities, prolonged period of high-water slack tide and an extended ebb tide with lower current velocities). This often creates a net up-estuary residual current, which traps pollutants in Zone 1.

Overlaying this are additional processes such as water diversion. Flows of to 28 cumecs of water from the South Esk River pass through the Trevallyn Power Station, which discharges into the Tailrace at Riverside. Of the 28 cumecs, approximately 27 per cent consists of water diverted from the Great Lake via the Poatina Power Station. The statutory environmental flow requirement for the Trevallyn Power Station was set at 0.425 cumecs in 1955, however in 2003 Hydro Tasmania voluntarily increased the daily flow to 1.5 cumecs, and to 2.5 cumecs in 2011, primarily to restore recreational and aesthetic values in the Cataract Gorge. The new valves installed in the dam in 2015 allow for easier releases of high flows (up to 20 cumecs) down the South Esk for recreational activities such as white-water kayaking events.

Water quality in the North and South Esk rivers is generally good or moderate in the cleared foothills and lowland plains, with variable grades (from poor through to very good) in the forested hills and highlands (Newall et al. 2012[26]). Recreational water quality is generally very good, with popular swimming locations on both the North and South Esk rivers. In general, water quality at these sites (eg, First Basin on the South Esk and St Leonards on the North Esk) is suitable for swimming, unless there has been rain in the catchment in the days prior. It is well documented that rainfall in the catchment contributes pollutants and faecal contamination to the waterways from diffuse sources such as livestock and native wildlife.

Water quality parameters have been monitored in the kanamaluka/Tamar Estuary and the North and South Esk rivers since the 1970s, with historical data predating the Ti Tree Bend and Hoblers Bridge STPs. Thermotolerant coliforms in the North Esk River at Hoblers Bridge and in the Estuary at the Tamar Yacht Club were observed to be present in the millions of cells/100mL in the 1970s, with the highest count peaking at 8.8 million cells/100mL at Hoblers Bridge in June 1991.

Mirroring global observations, analysis of historical and current data indicates a strong trend of significantly improved water quality since the construction of wastewater treatment plants (Figure 13; Refer to Appendix F for further information).

Water quality in the Tamar Estuary improves with distance downstream towards the mouth of the estuary. The lower estuary is well flushed, and the volume of water and the tidal marine influence dilutes the concentration of pollutants from the upper reaches (Attard et al. 2012[27]). In Zone 1 of the estuary, from Launceston to Tamar Island, the water quality consistently scores a C or D (Fair — Poor) in the Tamar Estuary Report Cards prepared by NRM North's TEER Program. The grades are generally as a result of poor scores for Enterococci, turbidity, nutrients and metals. Diffuse sources from the catchment, and sewage treatment plants (STPs) and Launceston's combined sewerage system contribute to the pollutant loads. Turbidity (a measure of suspended sediments) is strongly driven by diffuse sources in the catchment, contributing almost 100 per cent of the sediment to the estuary (TEER 2015).

[26] Newall, P., Tiller, D. & Lloyd, L.N. 2012 *Technical report for freshwater monitoring framework & report card for the Tamar Estuary and Esk Rivers Program. Report to NRM North.* Lloyd Environmental Pty Ltd, Victoria

[27] Attard, M., Thompson, M., Kelly, R. & Locatelli, A. 2012 *Tamar Estuary ecosystem health assessment program monitoring report 2012*. Prepared for NRM North

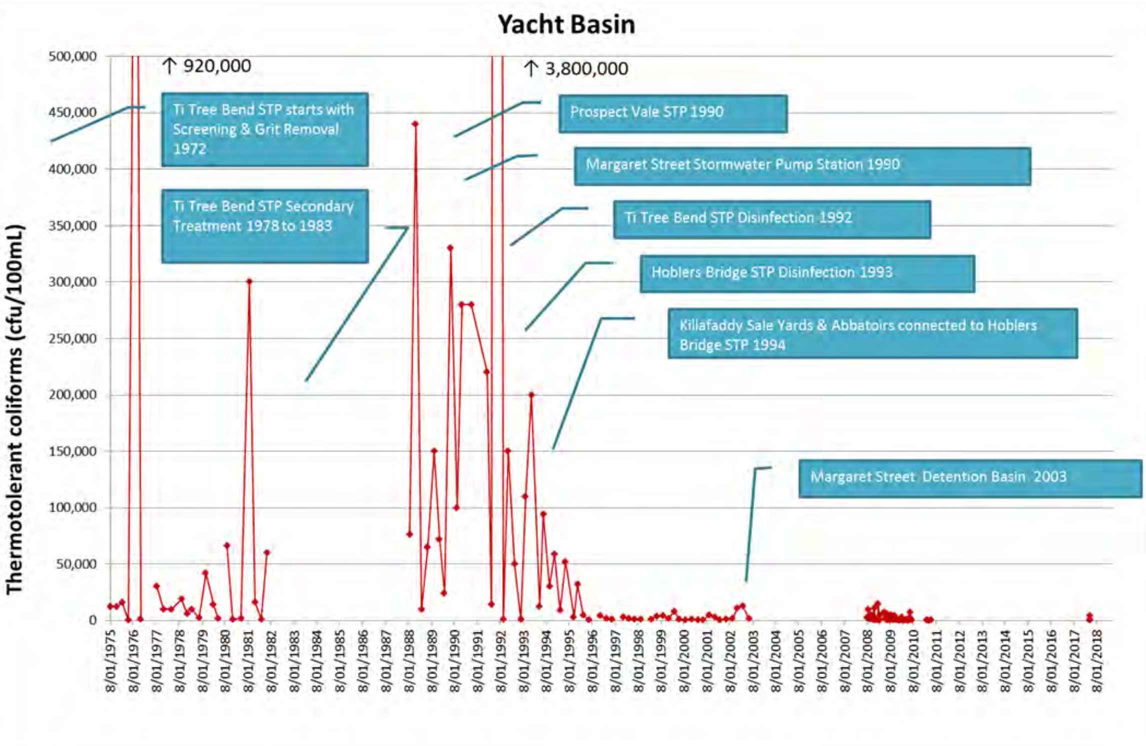


Figure 13: Progressive reduction in coliforms at the Yacht Basin

While coliform counts in the Tamar Estuary are demonstrably much lower than in previous decades, they are still observed to peak, rendering the water in Zone 1 unsuitable for primary recreational contact for a substantial proportion of the time (Figure 14). A monitoring program implemented by the City of Launceston in 2016 collected water quality data from a number of waterways upstream of inputs from Launceston, stormwater sites and downstream sites in the lower North Esk River and within Zone 1 of the Estuary.

In recent years, there has been a move away from using thermotolerant coliforms as an indicator of faecal contamination in waterways. Studies have suggested that *E. coli* and Enterococci are more reliable indicators of pathogens in the water, and as such the United States Environmental Protection Agency recommends that they replace thermotolerant coliforms. While E. coli is a good indicator of faecal contamination in freshwater, it is less reliable in strongly estuarine and marine waters. Enterococci survive for longer periods in seawater and are thus good indicators of the presence of faecal contamination. Enterococci have been adopted asthe indicator of faecal contamination in recreational water quality guidelines and so were included in the monitoring program. Thermotolerant coliform counts were also collected on occasion, to provide a direct correlation with the historical data sets.

Water quality data were collected at representative sites (Figure 15) during the outgoing tide once per week; with additional samples collected in response to rain events to better understand the impact of rainfall delivering pollutants to the receiving environment. Data collected from November 2016 to September 2017 show a strong relationship between rain events and elevated Enterococci levels in the waterways. The difference between “rain event” and “no rain event” is statistically significant at sites in the lower North Esk River and upper Tamar Estuary. Further, this relationship is also evident when rainfall in the catchment exceeds 1mm in a 24-hour period. On average, Launceston experiences 89 days per year where rainfall exceeds 1mm. At sites upstream of Launceston’s urban discharges (eg, the North Esk River at St Leonards), the water quality meets the recreational guidelines most of the time (Figure 14).

For further information, refer to Appendix F.

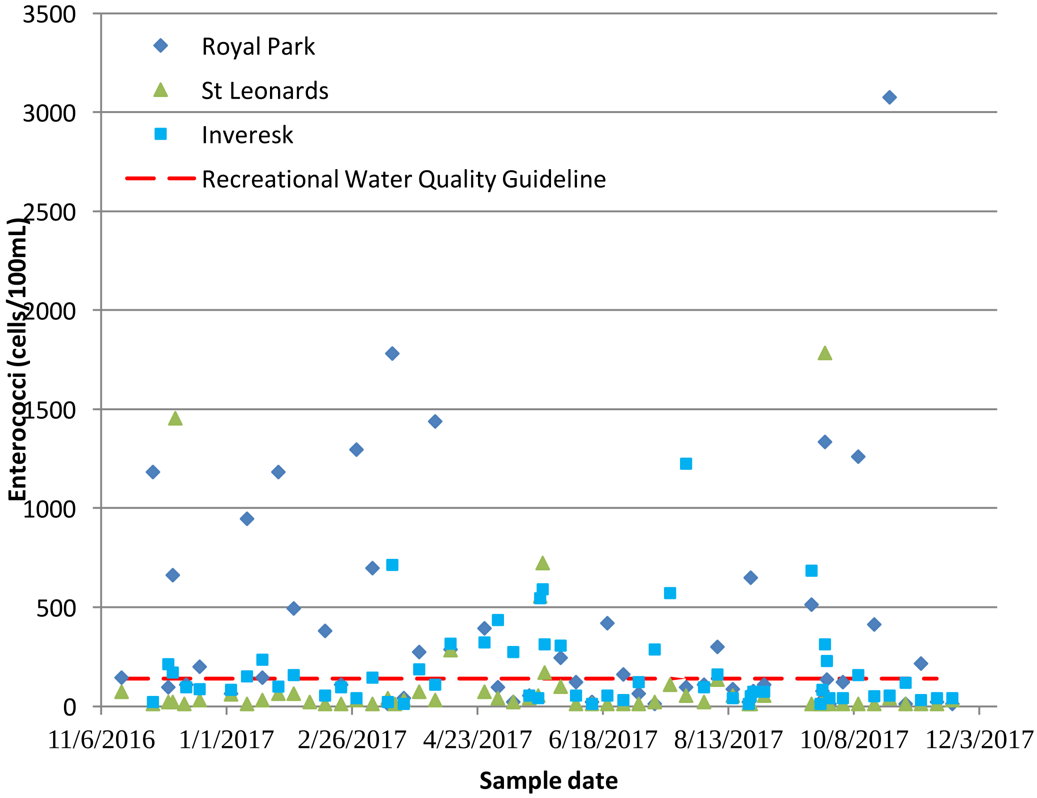


Figure 14 Enterococci cell counts from selected monitoring sites: Performance against the recreation water quality guideline

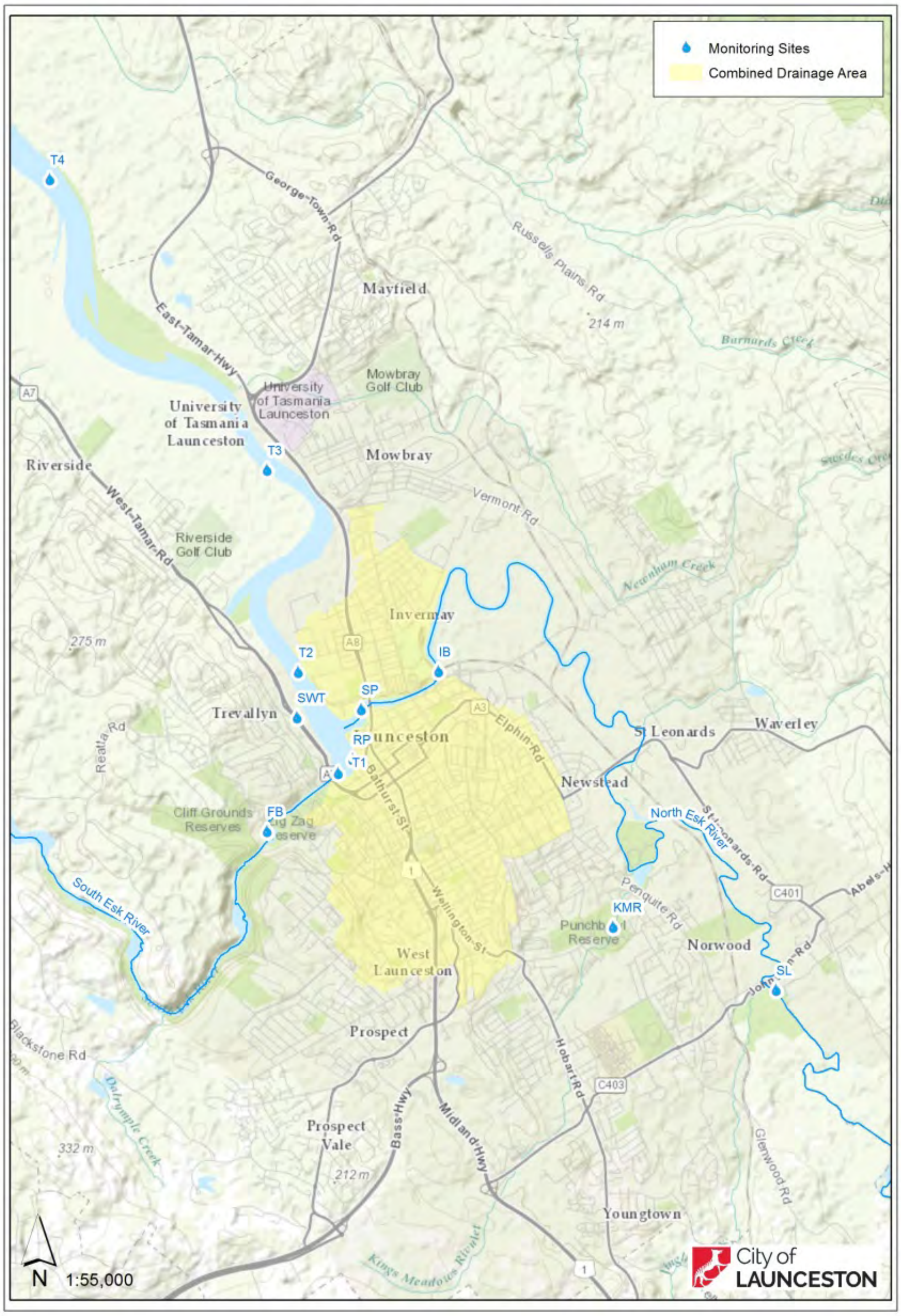


Figure 15 Map of water quality monitoring sites

Samples collected on five consecutive days in September 2017 captured data from 11 sites in waterways in Launceston, including four sites in Zone 1 in the Estuary (down to Tamar Island). A total of 11mm of rain fell during the second day of sampling, causing the New Margaret Street Pump Station to discharge 10.1ML of untreated effluent to the estuary. The rainfall event (and associated CSO) resulted in elevated turbidity and Enterococci on the third day, with levels particularly high at St Leonards and Royal Park (Figure 16). High pathogen load at the upstream site at St Leonards is largely catchment driven, with livestock the likely source of most of the Enterococci. By Day 4, Enterococci counts at most sites had returned to baseline levels, with the exception of North Esk River at Inveresk and Royal Park, and the Tamar Estuary at T2 Kings Bridge (Figure 16). Potentially, these sites remained elevated as the pulse of water from the North Esk catchment mad its way downstream and into the upper estuary. Further detail is provided in Appendix F.

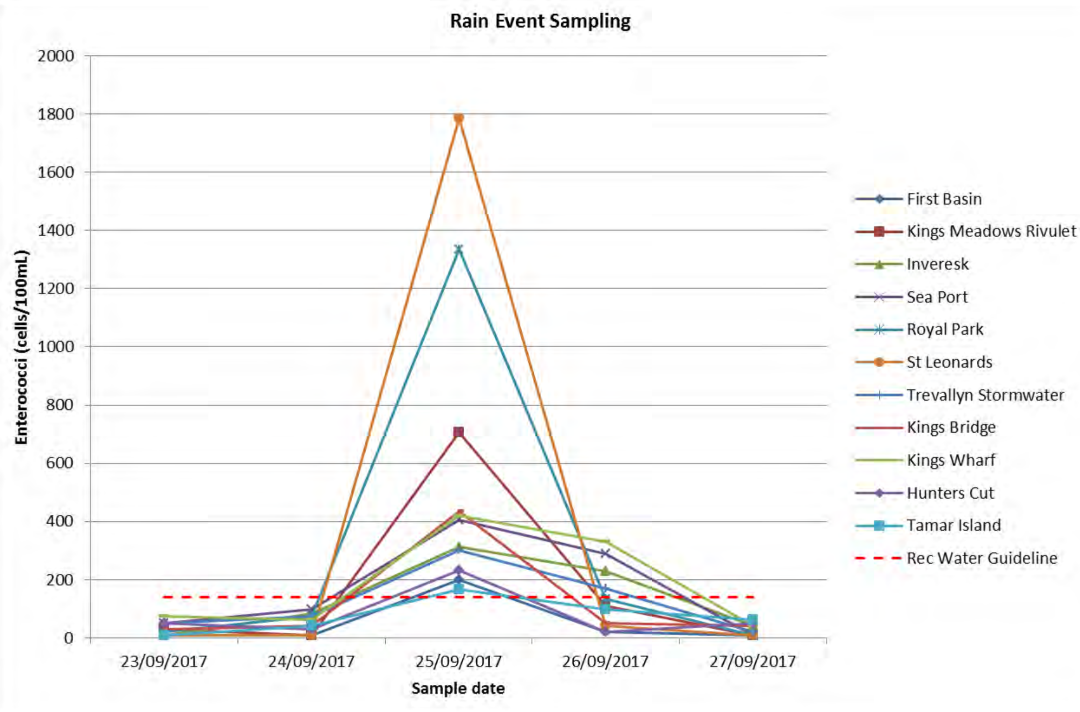


Figure 16 Sampling over five consecutive days in September 2017

From 1 January to 10 October 2017 (a period of 282 day), there were 50 CSOs from the New Margaret Street Pump Station, discharging an estimated 426ML direct to the Estuary. Of these, 30 events overflowed ≤5ML to the estuary, and 11 coincided with water quality sampling. Enterococci counts in the Tamar Yacht Basin (Royal Park) coinciding with discharge from New Margaret Street Pump Station were substantially higher than those with no discharge (Table 5), further supporting the hypothesis that rainfall and CSOs have a direct negative impact of the water quality in the Tamar Estuary. It should be noted that on at least five occasions during the sampling period, elevated bacteria levels and turbidity (and nutrient concentrations where data was available) were observed in the lower North Esk and upper Tamar Estuary with no correlation with rainfall or pump station discharges. Upstream data from St Leonards and the First Basin indicate that the elevated bacteria and turbidity is localised. One cause may be the remobilisation and resuspension of fine sediments from the mudflats and un-vegetated banks of the North Esk River on the outgoing tide.

Table 5 New Margaret Street Pump Station overflow volumes and ambient Enterococci counts at Royal Park (Tamar Yacht Basin)

Date	Overflow Volume (ML)	Rainfall (mm) (in the 48 hrs prior to sampling)	Enterococci (cells/100mL)	
			Overflow	No overflow
24/01/2017	2.8	7.2	1184	
16/03/2017	11.5	7.8	1782	
27/03/2017	0.6	4.6	275	
25/04/2017	3.3	9.0	393	
23/05/2017	3.3	2.4	24,196	
30/05/2017	23.8	12.4	243	
18/07/2017	14.4	13.4	9208	
25/07/2017	1.9	4.6	97	
23/08/2017	1.7	6.4	650	
19/09/2017	8.1	21.0	512	
24/09/2017	10.1	12.2	1334	
Total Overflow (ML)	81.6			
Median			650	129
Mean			3625	357
Standard Deviation			7301	440
Minimum			97	10
Maximum			24,196	1439
80th percentile			1558	439
20th percentile			334	83
Count			11	24

As discussed further in Appendix F, stormwater sites from separated catchments within Launceston (Kings Meadows Rivulet and Trevallyn Stormwater) show elevated pollutant loads during rainfall, indicating that substantial quantities of pollutants are mobilised during rain. These pollutants are delivered directly to the local waterways, where they are then discharged into the Esk rivers and the Estuary.

The water quality monitoring results indicate that water quality in Launceston's waterways is much improved from the 1970s to 1990s, and very often water in Zone 1 in the upper estuary meets the recreational water quality guidelines of 140cells/100mL Enterococci (Figure 14). These results also demonstrate that rainfall has a significant effect on the water quality in the upper estuary, with pollutants coming from the catchment, the stormwater network and Launceston's combined system.

3.5 Water quality improvement plan

NRM North developed the Water Quality Improvement Plan (WQIP)[28] in 2015 for the greater Tamar catchment. The purpose of the WQIP was to provide a comprehensive whole-of-catchment picture of water quality in the Tamar Estuary and its tributaries, to develop an understanding of the drivers of water quality issues and the levers that can be used to address these, and to identify priority activities to address water quality issues.

The WQIP aimed to provide direction to all catchment stakeholders on the role they can play in protecting and improving water quality in the Tamar catchment. Development of the plan involved substantial consultation and engagement with the community and key stakeholders. A major component of the WQIP was the development of a computer-based decision support system, the TEER CAPER DSS, which allowed modelling of the potential impacts of a range of management actions and possible land-use changes on catchment loads and estuary water quality. The DSS was used to develop an understanding of current sources of pollution, as well as the potential impacts of adopting best management practice, dairy expansion and urban development.

[28] Tamar Estuary and Esk Rivers Program 2015 *Tamar Estuary and Esk Rivers Catchments Water Quality Improvement Plan.* NRM North, Tasmania

4 System performance

In order to estimate the quantity of the combined sewage and stormwater discharge to the Estuary and the benefits of any proposed mitigation projects, a validated combined system model was required. Section 4 summarises the validation process undertaken to verify a combined system hydraulic/hydrologic model. Furthermore, this section outlines the process undertaken to identify the frequency and locations of those CSOs that contribute the most significant loadings to the Estuary.

This is further discussed in Appendices B and C.

4.1 Model validation

The SCADA provided by TasWater for two rainfall events in 2016 supported the validation of the combined system model. Selection of appropriate rainfall events was based on the following criteria:

- significant dry period observed prior to rain event (a minimum of four days)
- significant rainfall depth observed (a minimum of 30mm over a 24-hour period, approximately a 1 Exceedances per Year (EY) 24-hour event)
- complementary pump station and rising main flow data available for validation

The data provided by TasWater included:

- pump operation (time/date detail, start, stop and well level)
- rising main flows at:
    - Combined Rising Main (Old + New Margaret Street Pump Station)
    - St John Street Rising Main
    - Combined Rising Main (Ti Tree Bend)

It should be noted that of the two rainfall events, one event was chosen for this process due to time restrictions, general completeness of SCADA records and suitability of the rainfall event.

The validation process included:

1. simulation of a 72-hour ADWF to provide initial conditions for the sewerage/combined networks and altering of the 1D network where surcharge or ponding occurred in the network and/or at surface level under dry weather flow (DWF) conditions
2. interrogation of the combined pump station rising main configuration and altering of the rising main configuration where inconsistencies occurred
3. interrogation of the combined pump operation and configuration (switch on level, duty/stand-by arrangements and pump make, and associated head/discharge curves) and alteration in the model where inconsistencies occurred
4. verification of gravity CSOs (gravity linkages between the sewerage and stormwater networks) modelling configuration
5. selection and generation of the validation rainfall event which occurred on 18 March 2016
6. simulation of the event and comparison between observed SCADA recordings and modelled system outputs

Please note all changes made within the InfoWorks ICM[29] combined system model as part of this process have been tracked using the in-built flagging system under the reference "LCC".

From 4am until 7pm on 18 March 2016, 32.6mm of rain was recorded at the Kings Meadows pluviograph rain gauge. This equates to approximately a 24-hour 1EY

[29] InfoWorks ICM = Corporate software package for hydraulic and hydrological modelling

rainfall event. This rainfall event was simulated using the updated InfoWorks ICM combined system model. The combined City Rising Main recorded SCADA data was then compared with the modelling outputs at three locations to begin validation of the model.

Combined rising main flows were available for the validation process at three locations:

- New + Old Margaret Street Rising Main
- St John Street Rising Main
- Combined Rising Main at Ti Tree Bend

Adjustment was made to the combined system model to ensure a more refined relationship between the observed SCADA flows and the modelled flows. The changes included:

- connection of the New + Old Margaret Street Rising Main to the City Rising Main which resulted in additional losses within the modelled rising main and better reflected observed SCADA from the event
- pump operation (flow rate) at St John Street to better reflect observed SCADA
- pump operation (duty/stand-by configuration) at Forster Street to better reflect pump configuration

Consistent with observed TasWater SCADA, the following (total) pump rates were adopted and applied within the combined system model at the three pump stations that contribute to the City Rising Main:

- New + Old Margaret Street Pump Station(s) – 400L/s
- St John Street Pump Station – 420L/s
- Forster Street Pump Station as per the head discharge table within the InfoWorks combined system model

Please refer to Figure 17 for graphical display of modelled versus observed flows at Ti Tree Bend.

In addition to the refinements applied to the rising main and sewer pump configurations, alterations to the model hydrology were also made. It should be noted that no changes were made to the sewage flows, base flow or infiltration rates.

Alterations made to the stormwater hydrology included:

- stormwater run-off surface definition (percentage of road, roof and ground) assigned to sub-catchments to better reflect current City of Launceston understanding and associated values. Changes were made within the Margaret Street, West Launceston and Esplanade sub-catchments

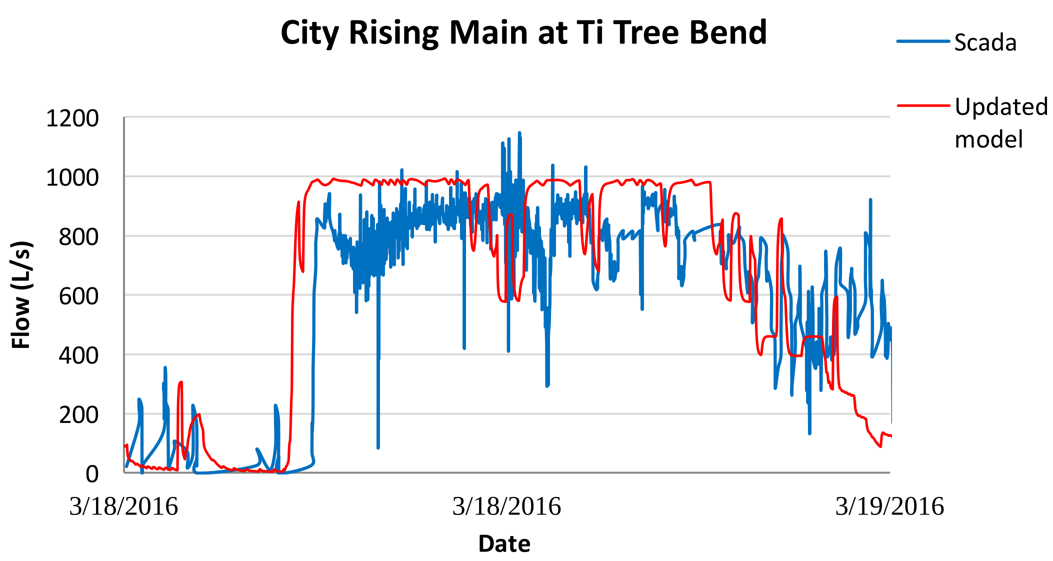


Figure 17 Comparing flow in the City Rising Main at Ti Tree Bend

- stormwater pervious area hydrology parameters (Horton initial 30mm/hr, Horton limiting 2mm/hr and Horton decay 2/hr) as per City of Launceston — Hydrology Parameter Investigation undertaken for the generation of stormwater flood studies

- stormwater impervious area fixed run-off coefficient to a standard 0.90

The model was then run for the March 2016 event and a comparison made between the observed SCADA and the updated model outputs. The resultant outputs displayed adequate correlation between modelled and observed pump operations at all combined pump station sites.

With the changes made to the combined system model hydraulics and hydrology, the model was deemed fit for purpose to estimate location, frequency and magnitude of the CSOs. The model was also used to estimate the reduction of the combined sewage and stormwater discharge to the Estuary of any proposed mitigation projects.

Please refer to Appendix B for the full modelling validation report.

4.2 Overflow frequency

The rainfall patterns selected for the interrogation of the combined system discharges were derived from the 2016 release of Australian Rainfall and Runoff (Ball et al. 2016)[30]. To determine which CSO locations discharge to the Estuary most frequently and contribute significant sewage loading to the Estuary, a range of Intensity Frequency Duration (IFD) design rainfall events were selected. Please refer to Table 6 for the selected events and corresponding rainfall depths.

Table 6 Design Rainfall Depths (mm)

	Exceedance per Year (EY)				Annual Exceedance Probability (AEP)
Duration	24EY (estimated)	12EY	2EY	1EY	20% AEP
60 minutes	3.12	6.24	10.0	12.3	17.8
3 hour	5.0	10.0	15.8	19.0	26.8
6 hour	6.8	13.6	21.6	25.9	36.1
24 hour	9.7	19.3	31.8	38.7	54.2

[30] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

In addition to the selected IFDs, temporal patterns are required to describe how the rainfall is distributed throughout the rain event, ie, the rainfall intensity is not constant for the entire duration. The rainfall is divided into equal time-increments with varied intensities over each increment. For the purpose of identifying which CSOs overflow most frequently, and to estimate the concentration of sewage within the discharge, temporal patterns that most linearly distribute the rainfall were selected. Evenly distributed rainfall was selected so as to not skew the loading results to the Estuary.

To effectively quantify the benefits of any proposed mitigation option designed to reduce the negative effects of combined system discharge to the Estuary, the content of the discharge needs to be estimated, ie, the concentration of sewage within total discharge will vary at each discharge point. InfoWorks ICM has built-in water quality functionality which enables a trace Pollutant Load (PL) to be assigned to flows.

In order to trace sewage flows in the combined system, a PL was assigned to the raw sewage flows (ie, those flows not related to infiltration or rainfall events). It is important to note that this PL enables the estimation of the concentration of sewage within combined flows; it does not represent any “real” pollutant load. A concentration of zero indicates a flow of 100 per cent stormwater and a concentration of one indicates 100 per cent sewage flow. When rainfall is applied in the model, the concentration of sewage within the combined network reduces as the stormwater dilutes the flow. Figure 18 displays this relationship within a combined rising main.

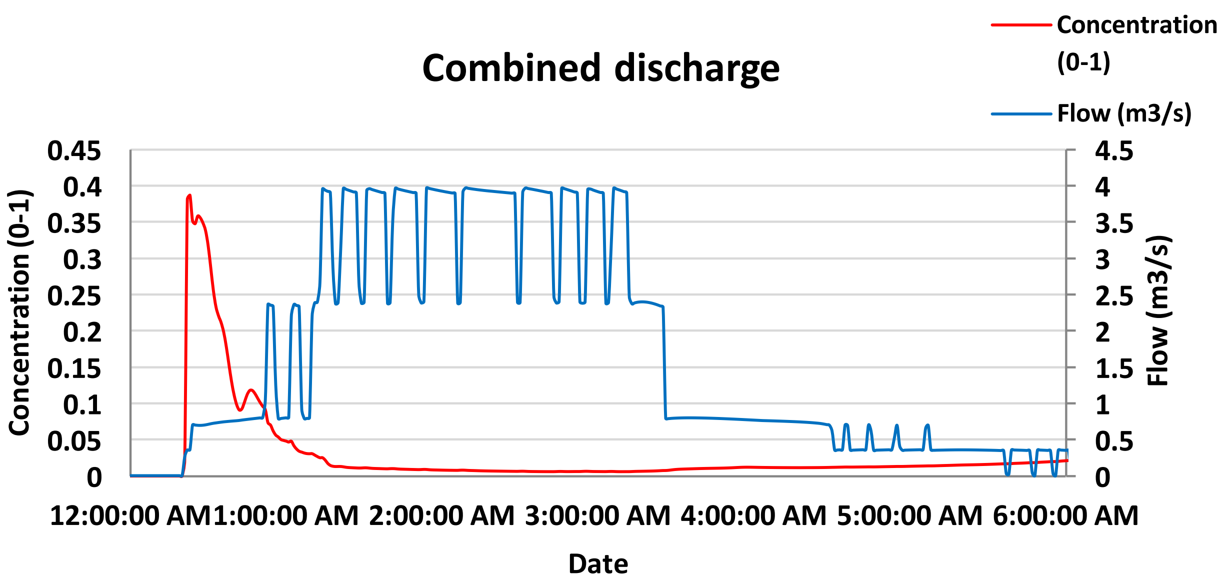


Figure 18 The concentration of sewage within a combined drainage pipe reduces as it is diluted by the stormwater inflow

From Figure 18, it can be seen that when flow within the pipe is zero, the corresponding concentration is also zero. As the combined flow increases due to rainfall, combined pumps operate and discharge to the Estuary.

By tracing sewage flows within the combined system, it is possible to identify those discharges to the Estuary that overflow most frequently and contribute the majority of sewage loading to the Estuary, and therefore become the priority for mitigation options.

Discharge to the Estuary from the combined system occurs via three distinct methods:

- overflow or bypass from the sewage treatment plant (STP) at Ti Tree Bend
- pumped to the Estuary via combined rising mains
- gravity overflows to the Estuary via links between the sewer or combined network to the separated stormwater system

Please note this section does not attempt to quantify the overflow or bypass from the Sewer Treatment Plant at Ti Tree Bend.

In order to identify the discharge points to the Estuary that overflow most frequently, and contribute the more significant sewage loading to the Estuary, the design rainfalls as described above were simulated within the InfoWorks ICM combined system model. It is important to note that overall there are approximately 15 discharge points to the Estuary where overflows from the combined system may contain sewage during wet weather flows as shown in Figure 19.

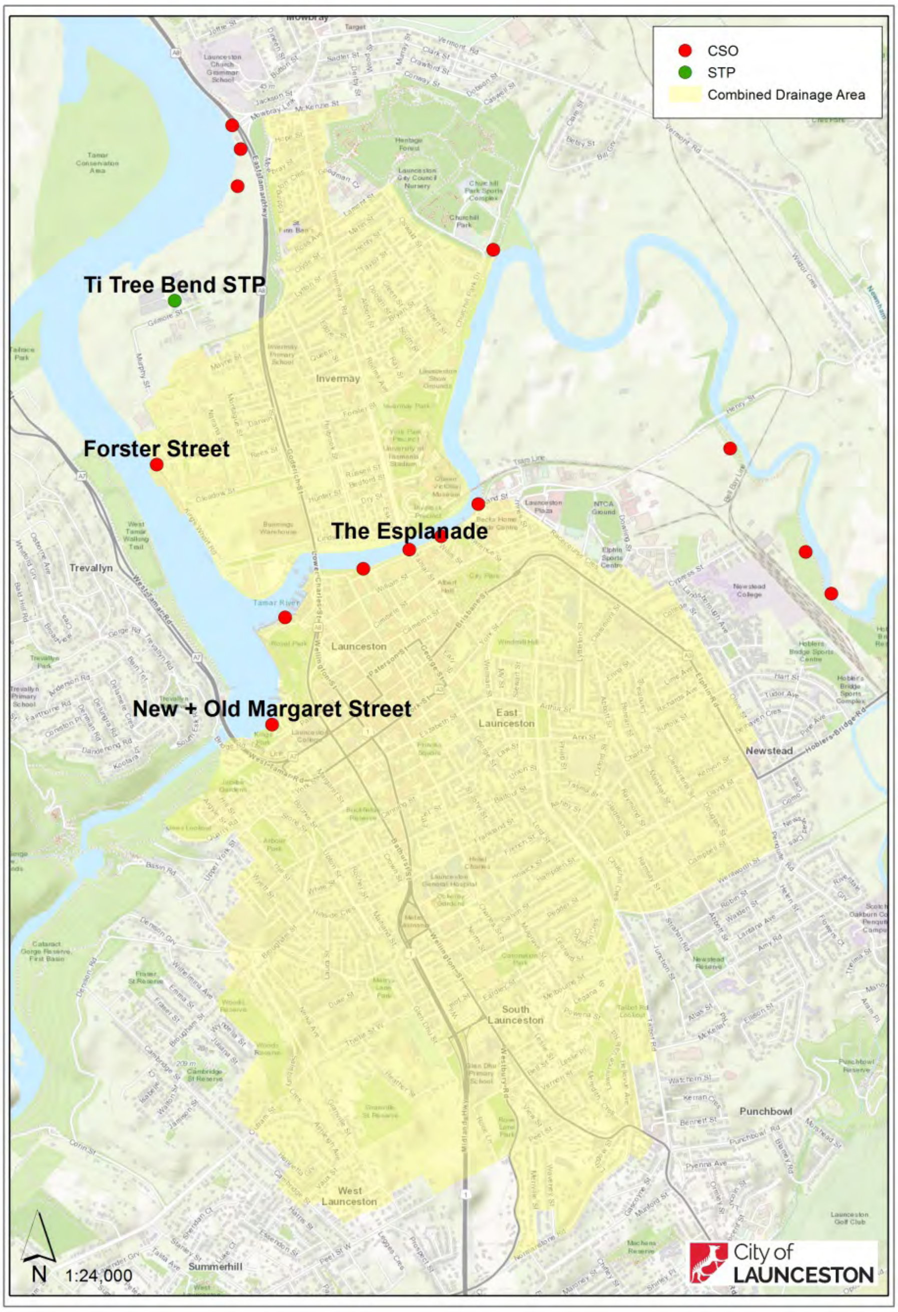


Figure 19 CSO locations

Of the 15 discharge points, three distinct sites were identified that (on average) discharge approximately 95 per cent of the sewage loading to the Estuary (Figure 20). The three sites are:

- New + Old Margaret Street Pump Station located in Royal Park off Paterson Street
- Esplanade (including the Shields Street, Tamar Street and Willis Street pump stations)
- Forster Street Pump Station

These three sites were prioritised for proposed mitigation options.

During periods of dry weather, pump stations associated with these locations transfer sewage to the Ti Tree Bend Sewage Treatment Plant. During wet weather events when combined flows exceed the sewage pumping capacity of the stations, excess combined flows are discharged to the Estuary. This is an essential function of the combined system to mitigate flooding in the city (behind the levees). The concentration and volume of sewage within the combined discharge varies due to the number of properties within the catchment that contribute sewage loading and the catchment response during periods of wet weather. The figure below displays the (modelled) sewage component of the total CSO discharged to the Estuary for the range of design rainfall events as displayed in Table 6.

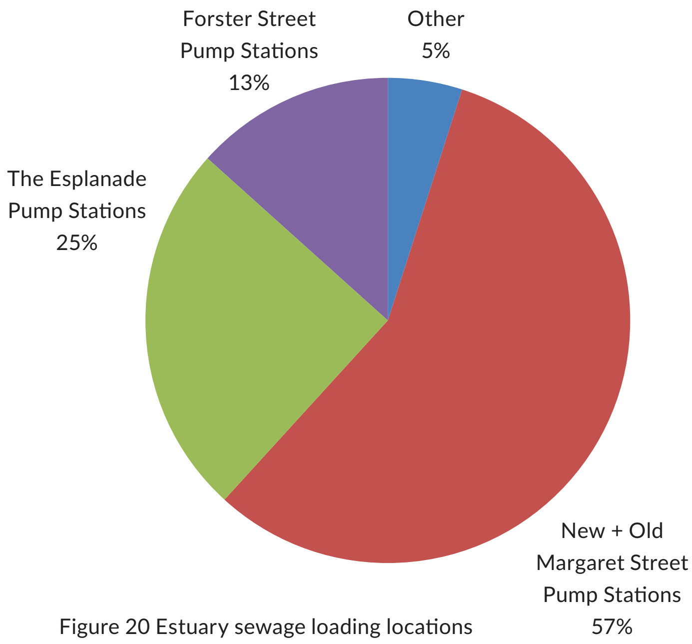


Figure 20 Estuary sewage loading locations

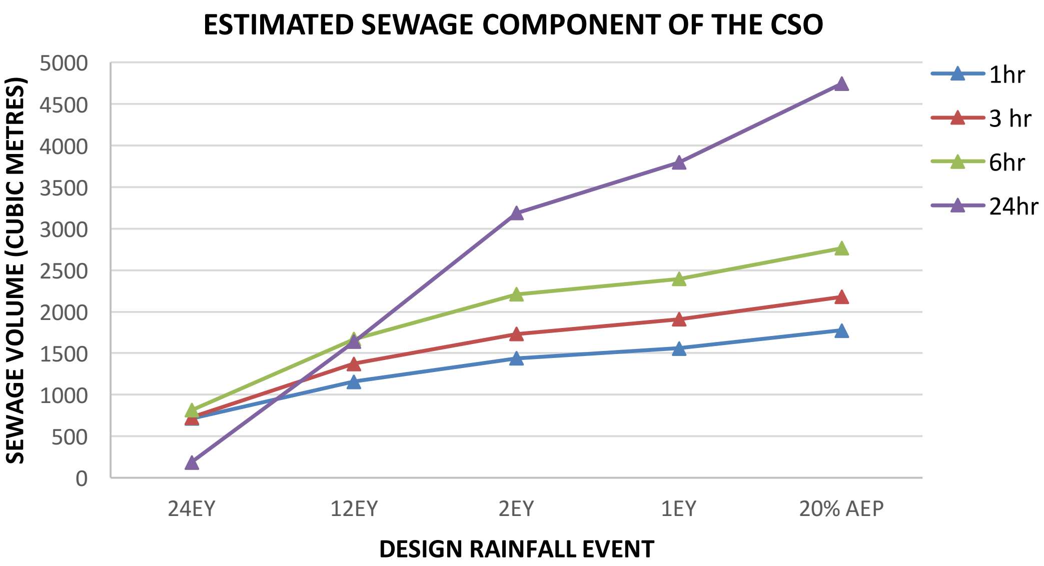


Figure 21 Estimated sewage component of the CSO

Furthermore, a study undertaken by Cameron Jessup (2015[31]) looked at recorded data associated with pumped CSO locations. In summary, this analysis was undertaken by comparing daily rainfall totals and pumped CSO records, and drawing a correlation between the two data sets. The results of this study indicated that for the calendar years of 2013 and 2014, CSOs are highly probable (greater than 95 per cent likelihood) from multiple locations including Forster Street Pump Station and the New Margaret Street Pump Station. However, the study did not quantify the frequency of CSO from gravity locations. The results of this study correlate well with modelled results.

The primary objective of the combined system project is to improve the health of the Tamar Estuary by removing or reducing the volume of sewage discharged from the combined system during wet weather events. Proposed options to achieve this are presented and discussed in Section 5.

[31] Jessup, C. 2015 *Launceston's Combined Sewerage System – Investigation and Strategy Development*. Submitted in fulfilment of the requirements of Courses ENG4111 and ENG4112 Research Project towards the degree of Bachelor of Engineering Honours (Civil), University of Southern Queensland

5 Mitigation option assessment

5.1 Background

The combined system comprises the vast majority of the Ti Tree Bend STP catchment, as shown on TasWater Drawing No. TWA-16-0411 (Appendix A). There are currently about 22,575 equivalent tenements (ETs) in the Ti Tree Bend STP catchment. An ET is a measure of sewage discharge based on a standard residential dwelling. Non-residential, commercial and industrial properties typically discharge more wastewater than a residential property; therefore ETs provide a measurement of discharge scalable for all users[32]. Within this catchment there are significant sub-catchments which have a separated sewerage system, but these sub-catchments discharge back into the combined system. During dry periods, all flows (sewage and permanent groundwater infiltration) are pumped to the Ti Tree Bend STP for treatment. However during rain events flows exceeding the capacity of the collection system or pumps are discharged as CSOs to the Estuary, as discussed in Section 4.

An overview of the combined system is provided in Section 2.4.

It is worth noting that the diversion of some of the separated sub-catchments that currently drain back into the combined system was one of the design aspects considered in the work that TasWater has completed for LSIP. The current implementation timeframe and extent of sub-catchment diversion works that will be completed as part of LSIP are yet to be confirmed. The costing work completed as part of the preliminary design phase suggested that the full cost of implementation for LSIP was of the order of $280M for Stage 1 works, with full implementation in the order of $370M.

LSIP is shown on Drawing Nos. TWP-15-145-002 and 260[33]. It should be noted that there is currently no "firm" commitment from TasWater to the proposed strategy or timeline for implementation.

The issue of CSOs is not unique to Launceston; many cities around the world face a similar problem. This section presents a summary of the actions undertaken around the world to decrease CSO discharge. This section also presents mitigation options appropriate for the Launceston context and the potential estimated benefits of these options in reducing in the volume of sewage ultimately discharged to the Estuary.

The infrastructure-based mitigation options proposed in this section (Section 5.7 to 5.12) were modelled to estimate the potential benefits of the project. The methodology used to assess solutions was benefit–cost ratio analyses. The costs associated with solutions are estimated by comparing both the life cycle (Net Present Value) and construction costs associated with the proposed infrastructure solution.

The benefit of the proposed solutions was estimated by the reduction of sewage loading that is ultimately discharged to the Estuary. The combined system model (presented in Section 4) was utilised to estimate the reduction in sewage loading to the Estuary. The model was updated to reflect those infrastructure changes required to facilitate the proposed solution and wet weather simulations were undertaken to quantify the reduction of sewage ultimately discharged to the Estuary. For the purpose of this section, the benefits are presented simply as a percentage reduction in sewage ultimately discharged to the Estuary.

Section 6 provides grouped projects and benefit summaries.

[32] TasWater, Equivalent Tenement classifications

[33] LSIP Drawing Nos. TWP-15-145-002 and 260

The estimated Estuary benefits derived from the reduction in sewage loading received by the Estuary is presented at catchment scale by the Catchment Action Working Group.

Estimates for the LSIP works (West Launceston/Trevallyn and Kings Meadows/Newstead/ Boland Street separated system) have been taken from the LSIP report. These estimates have been undertaken on the preliminary design of the pipelines and pump stations for the transfer systems and include allowances for design, approvals and construction. The construction cost estimates have been done by John Holland within a ±20% limit of accuracy.

Estimates for non-LSIP options have been prepared based on conceptual designs, using similar construction rates used for LSIP. Estimates include an allowance of 20 per cent (of construction cost) for engineering/approvals, and a 30 per cent construction contingency.

Summaries of the infrastructure mitigation options are presented in this section; additional detail regarding the development of these concepts is presented in Appendix E: Mitigation options development.

5.2 International approach

Combined sewer systems are common in Europe and North America particularly in older cities (Refer Appendix D). Major population centres such as Paris, New York, Toronto and London all have combined sewer systems. It is common practice for CSOs to be regulated by environmental agencies. For example, Winnipeg, Canada, was required under the Environment Act to develop a CSO plan proposal consisting of an evaluation of minimum CSO control alternatives. In the UK, release of CSOs during storms is a course of action regulated and policed by the Environment Agency through the issue of Discharge Consents. CSOs are a major water pollution concern for the 770 cities in the United States of America (USA) that have combined sewerage systems. In response to the pollution concerns, in 1989, the USA's EPA Office of Water issued a National Combined Sewer Overflow Control Strategy to address the impacts of combined system overflows on amenity, the environment and recreational water quality. The strategy confirmed CSOs as point-source discharges that were subject to National Pollutant Discharge Elimination System permit requirements and to the requirements of the Clean Water Act (CWA).

The water quality impact of effluent discharges has spurred a tightening of regulations; in many instances requiring public education efforts, illicit connection detection and correction, construction project run-off control, first-flush mitigation, as well as small, distributed treatment modules prior to stormwater discharge.

5.3 Preliminary assessment of options

In August 2017, representatives from the City of Launceston, TasWater and GHD met to list potential mitigation options appropriate to the objective of this project, ie, reducing the negative impacts that the combined system has on the Tamar Estuary. This section documents the preliminary assessment of potential mitigation options identified in this meeting. The following options were documented:

- development requirements — long-term benefit
- WSUD to reduce stormwater volumes in peak flow
- household level options, ie, storage tanks per residence
- disconnection of illegal connections to stormwater, eg Trevallyn, Kings Meadows
- water storage and harvesting to support irrigation schemes
- screening at CSOs (linked to disinfection)
- increased screening capacity at treatment plants at old outfall
- system operation overall — automation to maximise existing network
- separating separated sub-catchments, eg West Launceston and Kings Meadows
- operational improvements:
    - existing rising main
    - pump station
    - maximise existing capacity
    - weir levels
    - maximise Margaret Street operation
- storage within existing system
- first-flush capture like Margaret Street
- prevention of first flush — reducing peak, eg WSUD or series of pipes throughout system
- additional pipelines — move to treatment
- renewal strategy for existing infrastructure
- full separation — including on-property separation

- increase size of pipes or require separation during infrastructure work — detention infrastructure increased
- detention
- preliminary treatment at pump stations and at overflow
- disinfection at discharge:
    - chlorination
    - ozofractionation
- upgraded pipes and pumps to send more effluent to Ti Tree Bend
- additional rising main to Ti Tree Bend and additional pumps
- downstream discharge — flushes quicker when further down the river (past Hillwood)
- make gravity CSOs redundant
- larger releases down South Esk — dilution
- consolidated discharge points
- system monitoring to maximise asset life
- stormwater ejectors at Esplanade — consolidate with one larger pump station
- community information — monitoring and notification of quality

The options relevant to the Margaret Street, St John Street and Forster Street catchments were then grouped into the following categories (Table 7).

Table 7 Treatment option high-level description

Treatment option	High-level description
1. Legislation, regulation and policy improvement	Changes to the legislative and regulatory environment to incentivise continuous improvement of the combined system
2. Community information and education	Ongoing monitoring of river health to facilitate continuous system improvement, education streams and warnings in the event of an overflow
3. Operational improvements and system optimisation	Reviews of existing operational environment of the combined system to ensure existing infrastructure is operating efficiently and effectively (ie, Margaret Street Detention Basin and weir levels at CSO locations)
4. Green infrastructure (primarily WSUD treatments)	Development of framework required to transition from “traditional” drainage systems to WSUD drainage systems including detention, wetlands, ponds, bio-filtration systems and infiltration systems to decrease run-off frequency, volume and peak flow. Green infrastructure would also be considered for the immediate mitigation options
5. Screening, preliminary treatment and/or disinfection at CSO locations	Installation of screening and chemical treatment facilities at the three key CSO locations
6. Offline storage	Underground storage tanks located at the key CSO locations
7. Live storage	Storage within the existing system, requiring baffles, weirs, actuators at the three key CSO locations
8. Separation	Full separation of the combined system and construction of a separated sewer and stormwater network
9. Diversion of separated sewage catchments	Diversion of the West Launceston and South Launceston trunk sewerage mains directly to the Ti Tree Bend STP
10. Diversion of separated stormwater catchments	Construction of required stormwater drainage components to enable direct discharge to the Estuary at Margaret Street
11. System upgrade, ie, additional combined rising main to Ti Tree Bend and reconfiguration of network components	Increase of the pump rate to Ti Tree Bend for the key CSO locations
12. Consolidation and movement of discharges further downstream	Pumping of combined discharge further downstream to where the Estuary widens and dilution is increased

These options were subjected to preliminary investigation and a multi-criteria selection process to determine which options would be investigated further and/or modelled and costed to estimate the potential benefits of the projects. Scoring for the multi-criteria analysis ranged from five (high) to one (low). Please refer to Table 8 for the results of the multi-criteria analysis.

Table 8 Multi-criteria analysis results

Treatment option	Preliminary costing	Short term effectiveness (weighting 30%)	Long-term effectiveness of treatment (weighting 20%)	Feasibility of treatment option (30%)	Intangible benefits other than pathogen reduction in Zone 1 (weighting 20%)	Weighted score /100
1. Legislation, regulation and policy improvement	$1M	2	4	3	1	62.5
2. Community information and education	$500K	2	2	4	4	75.0
3. Operational improvements and system optimisation	$200K	2	2	4	1	60.0
4. Green Infrastructure (primarily Water Sensitive Urban Design (WSUD) treatments)	$100K	2	3	3	4	72.5
5. Screening, preliminary treatment and/or disinfection at CSO locations	$40M	3	3	1	1	50.0
6. Offline storage	$30M	3	3	4	1	72.5
7. Live storage	$6M	2	2	5	1	67.5
8. Separation	$500M	2	5	1	1	52.5
9. Diversion of separated sewage catchments	$30M	4	4	3	1	77.5
10. Diversion of separated stormwater catchments	$15M–$30M	3	3	1	1	50.0
11. System upgrade, ie, additional combined rising main to Ti Tree Bend and reconfiguration of network components	$30M	3	3	4	3	82.5
12. Consolidation and movement of discharges further downstream	$50M	2	2	2	1	45.0

Due to the multi-criteria analysis process above and the results of preliminary investigations, options 10 and 12 were not evaluated any further.

Option 5 was not eliminated from this preliminary assessment as the Combined System Overflow Working Group agreed that this option warranted further investigation due to the group's limited knowledge of this treatment option, ie, the group was not comfortable dismissing this option without seeking external resources with significant experience in preliminary treatment of CSOs.

Option 2, community information and education, will be further explored by the Catchment Action Working Group.

The remaining options are explored further in the following sections.

5.4 Legislation, regulation and policy improvement

The EPA regulates discharge from the Ti Tree Bend STP (and all other STPs) to the Tamar Estuary, through conditions within the Environmental Protection Notice (EPN) for the treatment plant. Penalties apply for discharges that do not meet the effluent quality and quantity specified in the EPN. However, overflows from Launceston's combined sewage and stormwater system are not subject to the conditions contained within the Ti Tree Bend STP's EPN.

DPIPWE's *Sewage Pumping Station Environmental Guidelines 1999*[34] recommend that every effort should be made to minimise the impact of CSOs, however the guidelines have no legal force. It would appear that the CSOs are outside the statutory framework, other than *s23A General Environmental Duty of EMPCA 1994*[35]. Currently there are no regulatory drivers to mitigate combined sewage and stormwater system overflows to the Estuary.

In order to decrease contaminants entering Launceston's waterways, it is critical that legislation, regulations and policy be reviewed. Best practice throughout the western world regulates combined system overflows with conditions such as:

- elimination of CSOs during dry weather
- pollution prevention programs to reduce contaminants in CSOs
- public notification to ensure that the public receives adequate notification of CSO occurrences and impacts, and the location of CSO outfalls
- minimisation or elimination of solid and floatable materials' discharge to the receiving environment from CSOs
- proper operation and regular maintenance programs for the sewer system and CSO outfalls
- maximum use of the collection system for storage
- maximised flow to treatment plants
- accurate and timely reporting of all CSO events, including date, time, location, and quality and volume of the effluent discharged, including discharge from gravity overflows
- review and modification of pre-treatment requirements to ensure that CSO impacts are minimised
- ambient monitoring to effectively characterise CSO impacts and the efficacy of CSO controls

New policy is required regarding stormwater management to ensure that water-sensitive urban design (WSUD) principles are implemented for developments that are:

- new buildings
- extensions to existing buildings where the extensions are 50m^2 or greater, or create substantial new areas of impervious surfaces
- major site redevelopments
- subdivision of land

WSUD policy must be underpinned by objectives, guidelines and targets for urban development. Example objectives include:

- To promote the use of WSUD, including stormwater reuse.
- To mitigate the detrimental effect on downstream waterways with best practice stormwater management through WSUD for new development.
- To minimise peak stormwater flows and stormwater pollutants to improve the health of water bodies, including creeks, rivers and the Tamar Estuary.
- To support the sustainable use of water resources by encouraging best practice in the use and management of water, and to promote safe, sustainable use of rainwater and recycled stormwater.
- To reintegrate urban water into the landscape for a range of benefits including microclimate cooling, local habitat and provision of attractive spaces for community use and wellbeing.

In order to ensure the success of the WSUD policy, education and training must be developed for the general community and construction industry. Compliance monitoring of the installation and operation of WSUD devices is considered critical for success.

Currently, separation of assets occurs on private property and in roads undergoing major reconstruction if the work requires the disturbance of these underground assets, and it is sensible, feasible and economically viable to do so. While wholesale separation of the combined system is not supported, separation of parts of the system could be progressed in some areas of Launceston. Separation should be considered in areas where the stormwater can be collected, treated and more readily discharged to the waterways; for example parts of Newstead, East Launceston and West Launceston. The decision to separate stormwater from sewer must be on a case-by-case basis, and not implemented as a blanket rule.

[34] DPIPWE *Sewage Pumping Station Environmental Guidelines 1999*

[35] s23A General Environmental Duty of EMPCA 1994

It is apparent that there are gaps in the legislation, regulation and policy surrounding the ongoing use, operation and replacement of the Launceston's combined system. Ongoing work to resolve the legislative issue needs to be a priority.

In order to achieve substantial improvements in recreational water quality in the Estuary it is recommended that:

- Launceston's combined system is managed as a complete system that includes Ti Tree Bend, the pipe network, pump stations and overflow outfalls (including any future infrastructure); and
- clear and consistent objectives and targets are established for WSUD from a regional perspective.

5.5 Operational improvements

The intent of this work stream was to understand the existing operation of the combined system at both the whole of system level but also at individual asset or installation level. The work stream required the assessment of the performance of the existing system and identification of potential minor capital or operational changes to reduce the frequency and impact of CSO discharges. This stream of work is strongly aligned to TasWater's corporate objective of no dry weather overflows.

The work stream broadly considered four major improvement areas, as follows:

- alteration to existing CSOs — Changes to weir operating heights, network configuration settings, pump arrangements.
- network storage investigation — Scope to make use of live or "in-network" storage during wet weather events.
- operational changes (below ground) — Increased preventive maintenance in known problem areas to reduce the build-up of silt and grit in pipe assets and ensure that all available system network capacity is used. Making use of predictive weather data to implement a range of operating protocols to either reduce the frequency of discharge or to reduce the characteristic pollutant strength of an overflow event.
- Operational changes (above ground) — Changes to maintenance regimes for street sweeping and cleaning of side entry pits. There appears to be significant solids loading of the network occurring due to inadequate maintenance of stormwater assets.

The improvement areas are discussed in further detail in the following sections.

5.5.1 Alterations to existing CSOs

CSO events within the network can arise in a number of ways. The overflows can be through pumped discharge to the Estuary and via a gravity discharge either directly to the Estuary, or through diversion into a separated stormwater asset within the city. A review of the existing pump-station operating levels, diversion weirs within the network, hydraulic modelling outputs and discussions with operations staff have flagged that there is some potential to reduce the frequency of overflow from the system through some minor operational changes to either pump stations or network overflow locations. Some of the actions identified for further investigation and possible implementation are described below.

Pump stations (sewer)

- Hope Street SPS — The station currently has two methods of overflow. One is from a dedicated stormwater pump and the second is via a gravity overflow direct to the estuary. It is suggested that the operating points for the stormwater pump be investigated to see if they could be raised and at the same time consider the implication of using the gravity overflow more frequently. This potential improvement would need to be considered against the risk of increased localised flooding.
- Forster Street SPS — Discussion with TasWater staff indicated that the sewer and stormwater pumps at the station may not be operating at an effective duty point due to the pumps operating at 43Hz rather than the recommended 45Hz.
- Esplanade Ejector Stations — There are potential issues with the tide flaps at the Willis Street and Shields Street pump stations. The data suggests a link between high-tide events and overflow frequency.
- New Margaret Street SPS — The operation of the low and high flow stormwater pumps (start/stop levels) should be investigated through SCADA and hydraulic modelling to determine if it is possible to raise the levels to prevent small overflow events by increasing the use of network storage.

Pump stations (stormwater)

- Racecourse Crescent SWPS — The station seems to operate on most days. An investigation is needed to determine if the discharge is due to groundwater infiltration, cross connection with the sewer network or backflow issues due to insufficient capacity in the Boland Street sub-catchment.

- Lower Charles Street SWPS — The station has similar operational concerns to those flagged above for Racecourse Crescent SWPS and needs further investigation.

- Lytton Street SWPS — Similar issues to both Racecourse Crescent and Lower Charles Street.

Gravity network

The highest priority area identified for the gravity network is the Morshead Street Diversion. This network structure allows for interconnection of the Hoblers Bridge separated system to the Ti Tree Bend combined system. The diversion is operated through a connecting pipe between the two systems in the vicinity of Morshead Street that directs flow by opening and closing penstocks in the connecting manholes. During normal operations all flows are directed to the Ti Tree Bend STP for treatment as it has a higher level of treatment performance and a more favourable outfall discharge location than the Hoblers Bridge STP. The diversion is currently manually operated. Operation of the diversion generally only changes as a response to treatment plant or network maintenance. Alteration of the operation as a response to wet weather events is infrequent. There is scope to automate the operation of the penstocks so that the diversion can be remotely operated during wet weather periods. The benefit to this approach would be the diversion of separated sewage flows to the Hoblers Bridge STP for treatment as opposed to the current operating regime where, during wet weather, CSO discharges occur from the gravity overflows in the East Launceston and Newstead area, or through the Esplanade ejector stations. This improvement could be achieved through the installation of hydraulic or pneumatic actuators on the existing penstocks and the installation of supporting control equipment that would operate the penstocks, depending on the level of the Willis Street ejector station and flow rate into Hoblers Bridge.

Similar opportunities were identified in other catchments as well but in particular the Esplanade (St John Street) catchment appears to offer the most potential. System improvements could be realised through modification to overflow weir heights and upgrade of some of the diversion locations. This work needs further investigation to understand the increase in weir height achievable that will not significantly increase the risk of localised flooding or backing up of flows into private property.

It was also noted that there is currently limited understanding of the frequency and volume of discharge from the gravity overflows within the network. It is suggested that the hydraulic modelling results be used as a guide for the installation of monitoring equipment on the more frequent or high volume discharge locations, to validate the model results and as a guide to prioritising improvement works.

5.5.2 Network storage

Any discussion of combined system operational improvements should include consideration of "storage" within the existing network pipes, detention basins and pump wells. Pump station wells by definition will always have some storage capability. The pipe network has only limited static storage during wet periods. Static storage is not available in the pipe network in the hilly terrain rising from central Launceston. As the pipes fill under normal flow conditions they will always overflow to the surface, weir etc at the lowest point. Therefore the storage capacity is only potentially available in the flatter areas. Utilising the in-line storage capability is not without risk as it relies on knowing where the lowest points in the system are. In the older parts of the city these may be in basements of buildings.

Using the *City Rising Main Planned & Unplanned Shutdown Manual* (City of Launceston 2009) as a reference, areas within the combined system that do offer potential for storage are shown in Table 9.

Table 9 Potential for network storage

Sub-catchment	Potential pipe network storage volume (ML)
Margaret Street — Margaret Street Detention Basin to New + Old Margaret Street Pump Stations	2.8
The Esplanade — St Johns Street Pump Station through to Willis Street Pump Station	2.3
Forster Street — Inveresk to Invermay	2.5

The very flat Inveresk to Invermay area that drains to Forster Street Pump Station offers good potential for in-system storage. The available network storage volumes are quite small and therefore the potential is only realised for very small rain events (< 1mm).

The undercover Margaret Street Detention Basin, with its outlet valve closed, offers perhaps the greatest potential storage with a nominal capacity of 7ML. Under the current method of operation the undercover storage outlet remains open most of the time. Automating the valve on the outlet presents an opportunity to use the significant undercover storage volume for all rain events rather than just the larger events it captures currently.

There is also potential to better use the storage available in all pump-station wet wells. To realise this potential all pump stations would need to be interconnected to a smart operating system whereby all pump-station wet wells, starting from the highest points in the catchment, could be pumped down to low water level in advance of predicted rain (use BOM digital forecasts). Operating the pump stations this way would push the concentrated sewage flow through the network and on to Ti Tree Bend for full treatment in advance of the pending stormwater flow.

Time constraints and complexity preclude modelling the expected level of improvement for this proposed method of operation at this stage. As this sewage would have to be pumped to Ti Tree Bend Sewage Treatment Plant at one time or another there should be no overall difference in electricity costs for this method of operation.

5.5.3 Operational changes (above ground)

Figure 22 Typical litter in Launceston's gutters and streets

Litter, both natural and introduced, collects in our streets and roadside gutters as shown in Figure 22. Litter can be cans and bottles, paper, leaves, sticks and grit from the road surface. The combined drainage area of Launceston contains 148 hectares of roads and footpaths and 3100 gully pits. Due to the cross fall built into our roads and footpaths the wind, traffic and rain causes the litter to be swept to the roadsides and gutters where it tends to gather at the gully pit grates or in the sumps of the pits below. If left, the litter passes into the roadside drainage system and on to pump stations before reaching, at worst, a river outfall or, at best in the case of the combined system, Ti Tree Bend STP. A good side effect of a combined system is that a lot of the litter entering the network does get treated however it is at a cost. The grit and litter can erode the bottom of pipes, block grates and screens causing local flooding, wear out pump impellors, take up volume in the pipe thereby reducing storage volume and flow capacity, and add to the grit removal volumes at treatment points.

The street-cleaning regime can greatly reduce the amount of litter entering the combined drainage network. The regime should include regular sweeping of the roadsides and gutters, clearing the pit grates and removing the build-up of material in the sumps of the roadside pits.

During the investigations for this project it became evident that the roadside pits, and some of the larger pipes with flat gradients, were collecting excessive amounts of grit creating adverse effects to the local as well as wider environment. As a result the City of Launceston's current street- and pit-cleaning schedules are being reviewed for the central business area and wider combined drainage area. Similarly TasWater is reviewing its pipe-cleaning schedules. Both parties should continue to liaise regarding their maintenance schedules because, if grit continues to build up in pipes, is it due to poor construction-site practices or impending failure (sink holes) of pipes?

The improved street, pit and pipe-cleaning regime has not been costed. Similarly it was difficult in the time available to model improvement in flows, discharges and ultimate effects on the Estuary. However, it is generally accepted that keeping litter from reaching the rivers must improve the Estuary overall.

5.5.4 Operational changes (below ground)

The operation of gravity conveyance systems results in the accumulation and deposition of solids during low flow periods. Solids accumulation can compromise the hydraulic capacity of pipe assets and effectively raise the operating level of a system. In a combined system this increases the risk of overflow events during wet weather periods. TasWater has a program of sewer cleaning for critical network infrastructure to address this risk. Sewers flagged as high priority for cleaning include the Esplanade trunk sewer from St John Street through to Willis Street, the Margaret Street trunk sewer from the New Margaret Street SPS to Margaret Street Detention Basin and the inlet main leading into the Forster Street SPS.

Some of these works have commenced with the cleaning of the Forster Street inlet sewer, cleaning of the Esplanade trunk sewer between St John Street and Shields Street and with preparatory works in place to clean the Margaret Street trunk sewer back to the Brisbane Street intersection.

TasWater is working through CCTV analysis and hydraulic modelling to understand sections of the combined system that are likely to experience issues with solids deposition.

Other potential operational changes to reduce or limit the impact of CSO events could include predictive weather monitoring to guide system operations. In other combined systems around the world operating levels within the system are controlled through real-time weather monitoring so that the maximum network capacity is available when rainfall is forecast. This approach helps to reduce the volume of overflow generated, as well as ensuring that the sanitary sewage component of an overflow is minimised. Some combined systems elsewhere in the world also use a "water-charging" process whereby, after prolonged dry periods, water is artificially introduced into the system to charge the pipes and pass deposited solids forward for treatment. This process does not reduce the frequency of overflow but significantly reduces the pollutant load associated with the overflow event.

5.6 Green infrastructure

Green infrastructure uses natural processes such as infiltration to reduce, slow down and clean run-off using structures such as green roofs, bioswales, rain gardens, constructed wetlands and permeable pavement. Green infrastructure promotes infiltration, evapotranspiration and water reuse. Grey, or hard, infrastructure is the traditional means of engineering using concrete pipes and centralised treatment to remove stormwater as quickly as possible from population centres.

As the City of Launceston has grown and expanded, the nature and volume of wastewater and stormwater has changed. Increased urban population density and service area result in higher municipal wastewater and stormwater flows (Tao et al. 2014)[36], with densely developed inner urban areas such as the Launceston central business district almost completely impervious. Hard engineering solutions for a sewered and drained city created a network of pipes and gutters to collect and remove stormwater as quickly as possible from the city. With increasing impervious areas, this can lead to combined sewer overflows, flooding, and polluted run-off (Tao et al. 2014). Climate change is likely to further amplify the issues due to increased frequency of heavy rainfall events (Grose et al. 2015). The focus on water in urban environments has transitioned through several states – from securing a water supply to becoming a sewered city, a drained city and now a water-sensitive city (Chini et al. 2017)[37]. The current shift to WSUD is important for urban planning and policy, particularly considering the extensive impervious areas associated with cities and creating persistent stormwater concerns (Chini et al. 2017). The perceived value of 'natural' urban waterways is increased, requiring management approaches different from the more traditional engineering solutions (Soars & Miller 2013)[38].

[36] Tao, W., Bays, J.S., Meyer, D., Smardon, R.C. & Levy, Z.F. Constructed Wetlands for Treatment of Combined Sewer Overflow in the US: A Review of Design Challenges and Application Status. *Water* 2014, 6, 3362-3385

[37] Chini, C.M., Canning, J.F., Schreiber, K.L., Peschel, J.M. & Stillwell, A.S. The Green Experiment: Cities, Green Stormwater Infrastructure, and Sustainability. *Sustainability* 2017, 9, 105

[38] Soars, J., & Miller, F. 2013. Changing water values on urban waterway naturalization: findings from a Sydney case study. In SOAC 2013: *State of Australian Cities National Conference : Conference Proceedings and Powerpoint Presentations* pp. 1-12 Sydney: State of Australian Cities Research Network

A transition from a hard infrastructure (grey) stormwater system to an integrated green–grey system is required to move towards the goal of urban stormwater sustainability. Numerous studies have demonstrated that expanding sewer services via green infrastructure provides: environmental benefits (water quality and quantity, air quality); social benefits (more green spaces promote a sense of community, public health, mental health and a sense of community, and reduce urban heat-island effects); and increased property values. This approach can also be lower cost than comparable hard infrastructure solutions (Chini et al. 2017). There is a large range of choice for green infrastructure that requires case-by-case evaluation.

International experience has identified the importance of a coordinated approach that combines traditional infrastructure solutions with green infrastructure and community education initiatives.

Green infrastructure provides opportunities to reduce pollutant loads when managing stormwater run-off from low intensity rainfall events and "first flush" storm events. First flush describes the pollutants (eg, sediments) that have accumulated on impervious surfaces which are transported to the stormwater network at the beginning of a rainfall event (DoE 2006). This results in high pollution concentrations at the start of the run-off hydrograph, reducing to lower levels as urban streetscapes are washed clean. In particular, rains following long dry periods create high pollutant loads during run-off, as large volumes of pollutants (litter, sediment, hydrocarbons, leaves etc.) that have accumulated on impervious surfaces are washed into the drainage system, polluting receiving water bodies (DoE 2006). Conventional hard infrastructure stormwater conveyance systems do not sufficiently address the impact of changes to hydrology and water quality for the receiving environment (Younos 2011)[39] Monitoring data collected by the City of Launceston indicate that stormwater flows contain high pathogen loads, which are discharged directly to urban waterways in areas with a separated sewerage system (Refer to Appendix F for further information). To achieve water quality suitable for recreational activities in Zone 1 of the estuary will require measures to capture pollutants from stormwater in both the combined catchment and the separated sewer catchments. The need for green infrastructure to mitigate water quality and hydrology impacts needs to be underpinned by policy and regulations to ensure these treatments are installed and maintained.

Green infrastructure options are numerous and include constructed wetlands, floating wetlands, rain gardens, vegetated swale drains, rainwater tanks and detention tanks, infiltration trenches, permeable pavements, street trees, and green roofs and walls. They can be installed as few medium- to large-scale public assets, or as numerous small-scale private assets.

Considerable research demonstrates that constructed wetlands can deliver multiple integrated objectives, including reduced flood risk, improved stormwater quality, access to passive recreation opportunities and habitat for a range of flora and fauna. Constructed wetlands have the capacity to reduce total coliforms by more than 50 per cent, and as much as 99 per cent reduction can be achieved with some systems (Karim et al. 2008)[40]. Die-off rates for *Escherichia coli* and *Salmonella typhimurium* are observed to be higher in wetlands containing aquatic plants. Competition for nutrients and predation are thought to be important drivers of bacteria removal from wastewater in constructed wetlands.

There are several local examples of newly constructed wetlands in northern Tasmania. A constructed wetland to manage stormwater flows from a residential subdivision is currently under construction on Sheepwash Creek in Perth, Tasmania. An overflow weir allows higher flows to bypass the wetland treatment train to prevent flooding. A hardstand and concrete-lined sediment basin have been installed at the top of the treatment train for easier cleaning and maintenance of the system, and to prevent rapid sedimentation of the constructed wetland. Similarly, the Burnie City Council has recently completed a leachate treatment wetland for a municipal landfill. Occupying 2.6ha, the wetland has the capacity to treat up to 0.6ML per day of landfill leachate, removing high nitrogen (ammonia) and metals concentrations to acceptable discharge limits at a capital cost of $2M. The site has been in operation for several months, with pollutant concentrations in the effluent below the discharge limits set by the EPA.

In Wellington, New Zealand, extensive treatment wetlands have been constructed in the waterfront precinct, which provide water treatment, habitat and a pleasing aesthetic for the area (Figure 23).

[39] Younos, T. 2011, Paradigm shift: Holistic approach for water management in urban environments, *Frontiers of Earth Science*, vol. 5, no. 4, pp. 421-427

[40] Karim, M.R., Glenn, E.P. & Gerba, C.P. 2008, The effect of wetland vegetation on the survival of *Escherichia coli*, *Salmonella typhimurium*, bacteriophage MS-2 and polio virus, *Journal of Water and Health*, vol. 6, no. 2, pp. 167-175

Figure 23 Constructed wetland in downtown Wellington, New Zealand

Green infrastructure options for Launceston

There are several sites within central Launceston that are potentially suitable for wetland development for treating combined system wastewater that exceeds the capacity of the treatment plants. Potential sites include repurposing the silt ponds at Ti Tree Bend, or constructing wetlands in the land adjacent to the Eastern Outfall on the North Esk Trail. The existing silt ponds at Ti Tree Bend provide a promising option. As discussed in Section 5.9, it is proposed to increase flow from the Margaret Street and Forster Street pump stations, which would require the addition of storage at Ti Tree Bend. First- flush flow, containing the highest sewage concentration, would be delivered to the Ti Tree Bend STP, but flows greater than the capacity of the STP would be diverted to storage or a wetland (Figure 24). Overflow water discharged to a wetland would make its way through a treatment train before being discharged to the Tamar Estuary, and would not need to be pumped to the treatment plant.

Figure 24 Potential wetland site at existing Ti Tree Bend silt ponds

Private installation of rainwater tanks for harvesting stormwater should be encouraged in the Launceston region and new developments should require rainwater tanks by default. Consideration should be given to a rebate scheme such as the Living Victoria Water Rebate Program, which offered incentives for purchase and installation of rainwater tanks. The installation of a 2000L rainwater tank at every domestic residence within the combined sewerage area would have the capacity to capture 9.5ML of stormwater in a 10mm rain event, reducing the stormwater flow by approximately 10 per cent. The inclusion of rainwater tanks will not provide tangible benefits in the reduction of flooding, however the reduced frequency of run-off will lead to decreased frequency of CSOs. Rainwater tanks have the additional benefits of capturing sediments, thus reducing sediment loads to the local waterways and providing some water security during times of low rainfall. This additional water security can be particularly beneficial for keeping gardens alive during water restrictions. Overflow from rainwater tanks needs to be plumbed into the stormwater network, and there must be no possibility of cross connection with the mains water supply.

Permeable pavements typically consist of a permeable surface layer overlaying an aggregate storage layer (crushed stone or gravel). Water in the storage layer then infiltrates to the underlying soil, or can be discharged to a piped drainage system. Permeable pavements can reduce (or even eliminate) peak discharges, delay peak run-off, increase groundwater recharge and improve stormwater quality by removing sediments and pollutants during infiltration. Permeable paving is typically greater than conventional pavements; however substantial savings can be made when factoring in downstream stormwater management (DPLG 2010[41]).

Rain gardens are planted depressions that allow rainwater run-off from impervious urban areas to infiltrate underlying soil, recharge groundwater and reduce peak flows from a site. The rain-garden concept can be applied to small domestic gardens or large commercial or municipal spaces and is easily integrated into the landscape to achieve attractive low-maintenance stormwater solutions. Rain gardens are typically planted with native species, and have ecological benefits in addition to stormwater-flow mitigation and water quality benefits. Generally, the size of the rain garden should be approximately two per cent of the run-off area. Overflow from the rain gardens needs to be plumbed into the stormwater network. A program to support residential-scale WSUD features such as rain-garden construction could provide substantial benefits for the Launceston community.

5.7 Separation

5.7.1 Description

In summary, separation refers to the concept of a completely separated sewer and stormwater networks. As described in Section 2, significant portions of the Launceston municipality including the CBD are serviced by a combined sewage and stormwater system that provides both the sewerage and stormwater requirements. Successful separation eliminates CSOs and can optimise STP performance as the rate of flow through the plant remains stable – providing there is not substantial infiltration and inflow during wet weather, and that separation is complete – ie, all stormwater removed from the sewerage system and all sewage removed from the stormwater system. Full separation of the combined system requires the pipe network in all public land to be separated (which would cost the community significantly) as well as separation on private land (separation to the boundary of private assets) for which individual landowners may bear the financial burden. Public mains through private property would also require separation. Full separation of the combined system would be tremendously disruptive to the Launceston community, as new pipes would need to be laid within almost the entire road network and approximately half of the backyards in the combined drainage area. In some cases, particularly within the CBD, full separation of the pipe network within the road reserve, under buildings, and from the buildings, would be very difficult to achieve. Incomplete sewer separation would result in poor outcomes: sending stormwater to the sewer network which could cause sewer overflows or disruption to the treatment process at the STP; or worse, sending untreated sewage to the stormwater network to be discharged directly to waterways.

The following section details the costs and benefits associated with full separation of the system including the construction of a separated new sewer system and the required separation on private property.

5.7.2 Proposed facilities

The proposed facilities would include the necessary connections, pipelines, manholes and pump stations required to provide the current combined drainage area with a separated sewer network.

[41] Department of Planning and Local Government, 2010. *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region.* Government of South Australia, Adelaide

5.7.3 Concept and operational costs

The following costs were prepared assuming a separated sewerage system which was developed for the TasWater valuation of the Sewerage and Stormwater System Components of the Launceston Combined Drainage System project[42]. This assumed that a new separate sewer network "paralleling" the existing combined drainage pipelines (which would become the stormwater network) would be installed. Sewage pump stations would be located adjacent to the existing combined system pump stations. It is more logical to assume the construction of a new sewerage system rather than a stormwater system due to the comparatively small flows of a sewerage system, ie, the resultant infrastructure of a sewerage system will be smaller and cheaper to construct and operate.

The estimated cost to construct and "complete" the described separated sewerage system is estimated at approximately $435M, with an NPV of -$485M.

The operational and maintenance costs associated with a newly separated sewerage system would include both scheduled and reactive maintenance works, network renewal/upgrade costs and monitoring costs.

5.7.4 Benefit to Estuary

In theory, the full separation of the combined network will result in the elimination of sewage discharge to the Estuary (ie, 100 per cent reduction in sewage discharge to the Estuary at all locations). However, removing the sewage from the combined system will not remove all the pollution from the catchment to the rivers and estuary as there is a significant pollution load in stormwater — particularly in the first flush of stormwater after dry periods, when significant pollution from oil and grease, sediment, dog and animal faeces, papers, cans, etc. is "washed" from roads and surrounding surfaces into the stormwater-pipe network. Ideally this should be treated as it is a significant pollution load. A well-performing combined system would "catch" this stormwater first flush and transport it to the STP for treatment. This would not happen in a conventional separated sewerage system.

5.8 West Launceston diversion

5.8.1 Description

As described in Section 2.4, 3371 of the total 10,590 sewage ETs originate in sub-catchments with separated stormwater and sewer systems within the New + Old Margaret Street catchments. The separated ETs in the West Launceston and Trevallyn areas could be readily diverted directly to the Ti Tree Bend STP.

Under DWF conditions, these sewage flows are directed to Ti Tree Bend, however under Wet Weather Flow (WWF) conditions, the Margaret Street Pump Stations can discharge direct to the Estuary. The intention of this project would be to reduce the sewage component of the discharge to the Estuary from the Margaret Street Pump Stations.

5.8.2 Proposed facilities

To facilitate this mitigation option, upgrade works will be required to the sewer mains between West Launceston and the Ti Tree Bend STP (Figure 25). In summary, the works required include:

- diversion of the West Launceston trunk sewer across the South Esk River
- installation of a new transfer main between West Tamar Road and Ti Tree Bend STP including connection of West Tamar No. 1 Pump Station and crossing of the Tamar Estuary
- connection works at Ti Tree Bend

5.8.3 Concept and operational costs

The estimated cost to construct the West Launceston and Trevallyn Sewage Catchment Diversion is approximately $4.6M, with an NPV of –$5.6M.

5.8.4 Benefit to Estuary

Based on the design events presented in Section 4, this mitigation option is estimated to reduce sewage loading to the Estuary by approximately 19 per cent.

---

[42] TasWater 2014 *Valuation of the Sewerage and Stormwater System - Components of the Launceston Combined system - Assessment Report*

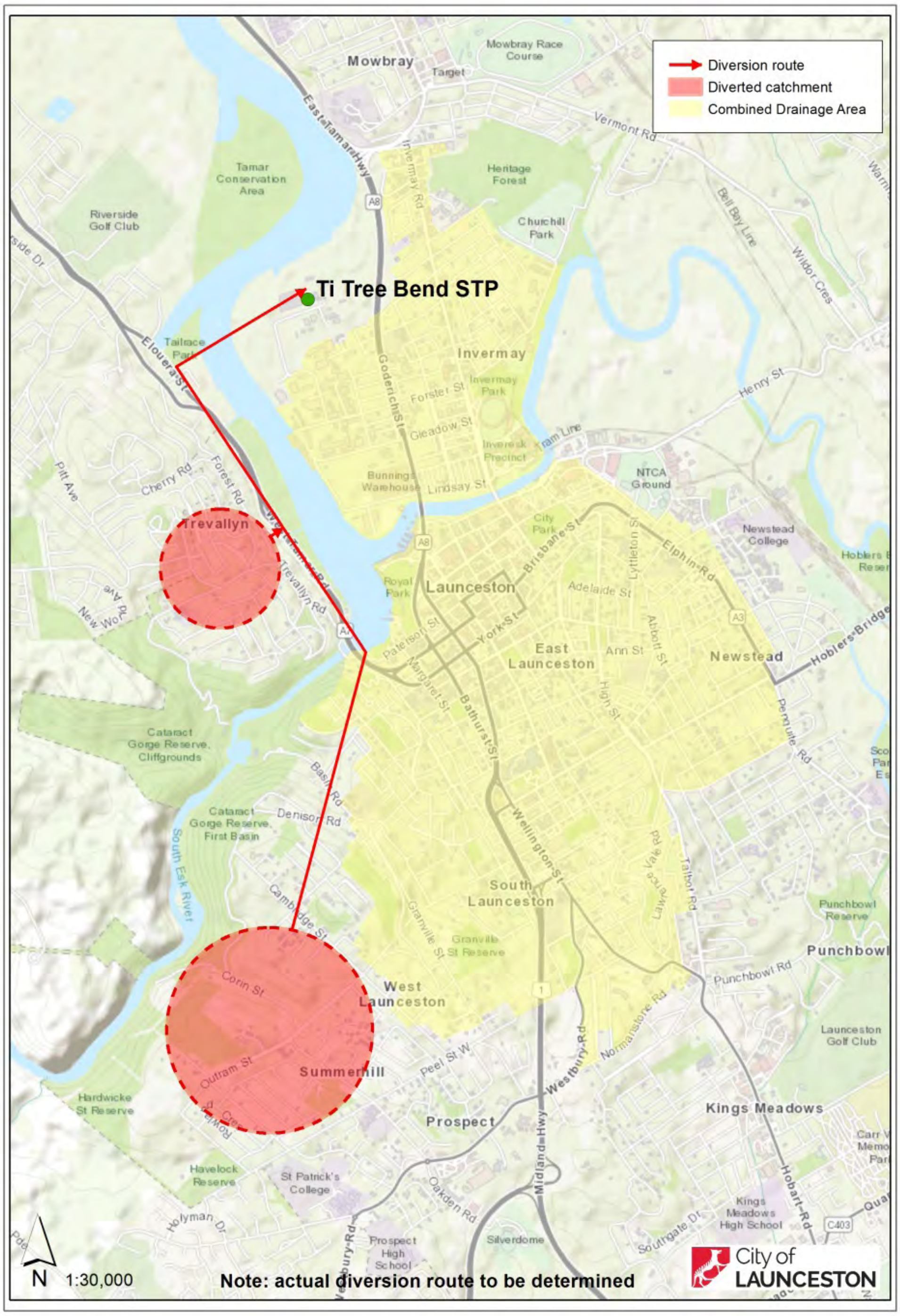


Figure 25 West Launceston diversion

5.9 New combined rising main

5.9.1 Description

This concept is discussed in the October 2001 GHD report *Decommissioning of the Old Margaret Street Pump Station*[43]. The works include the decommissioning of the Old Margaret Street Pump Station and diverting these flows to the New Margaret Street Pump Station (NMSPS) and increasing the combined low (sewage) flows to the STP from approximately 400L/s to 800L/s (nominally). To accommodate the additional flows, it is proposed that a new rising main be constructed to connect the upgraded NMSPS to Ti Tree Bend.

Other than reducing the sewage loading discharged to the Estuary from the Margaret Street site, additional benefits of constructing a rising main between NMSPS and Ti Tree Bend include the following:

- reduced flow in the City Rising Main enabling greater flows to be discharged from St John Street SPS and the Forster Street SPS
- opportunity for a significant area of habitat rehabilitation at Ti Tree Bend
- screening of all flows prior to discharge at the Margaret Street site (currently CSO from Old Margaret Street Pump Station are not screened)
- alternative discharge route (system redundancy) to the STP in the event that the City Rising Main is "out of service"

5.9.2 Proposed facilities

To achieve the full benefit of this increased flow it will be necessary to upgrade the Ti Tree Bend STP so that this additional volume (and the associated pathogens) is not "overflowed" to the Tamar River after the inlet works at the Ti Tree Bend STP during high inflow periods. It is proposed that the land adjacent to Ti Tree Bend (owned by the City of Launceston, currently known as the "silt ponds") be converted to a wetland system with additional buffer undercover storage.

The land available at the silt ponds would enable the construction of a 10-hectare wetland. It is likely that the wetland would still require undercover storage to mitigate the odour.

In summary, the project will include:

- works upstream of New + Old Margaret Street pump stations to divert flows to NMSPS (making OMSPS redundant)
- installation of new high head sewage pumps to increase the total sewage pump capacity to (nominally) 800L/s
- installation of rising main works to connect NMSPS to both the proposed storage facility and Ti Tree Bend STP
- reconfiguration of St John Street SPS including the required rising main upgrade from the pump station to the City Rising Main (junction in the vicinity of the Charles Street Bridge) to increase the pump rate to Ti Tree Bend to approximately 500–600L/s
- reconfiguration of Forster Street to increase the pump rate to Ti Tree Bend to approximately 500–600L/s
- works to a storage and wetland at Ti Tree Bend as described above

The proposed layouts are shown in Figure 26 and Figure 27.

5.9.3 Concept and operational costs

The estimated cost to construct this project is approximately $26.8M, with an NPV of -$34.9M.

[43] GHD October 2001 *Decommissioning of the Old Margaret Street Pump Station*

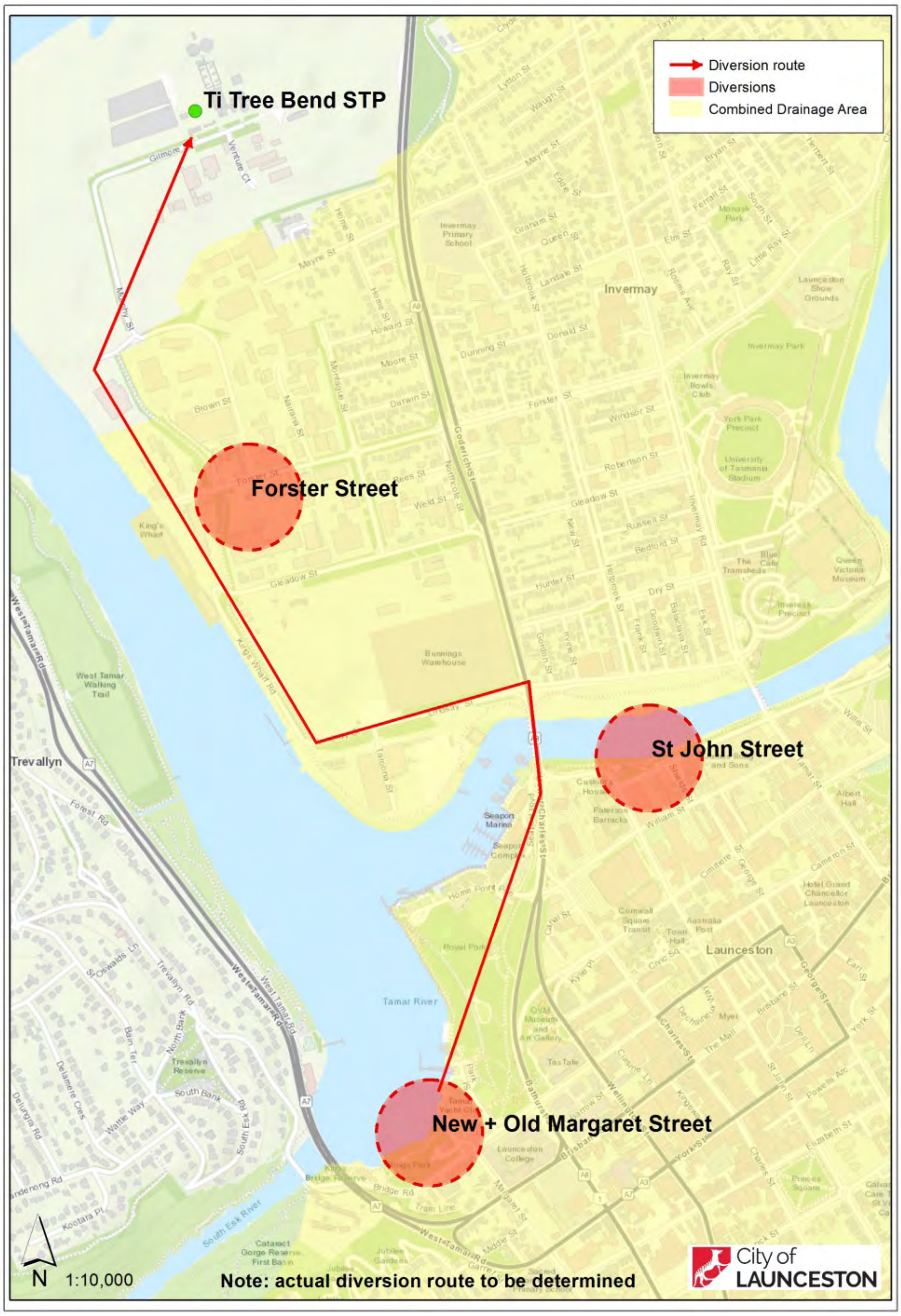


Figure 26 New rising main

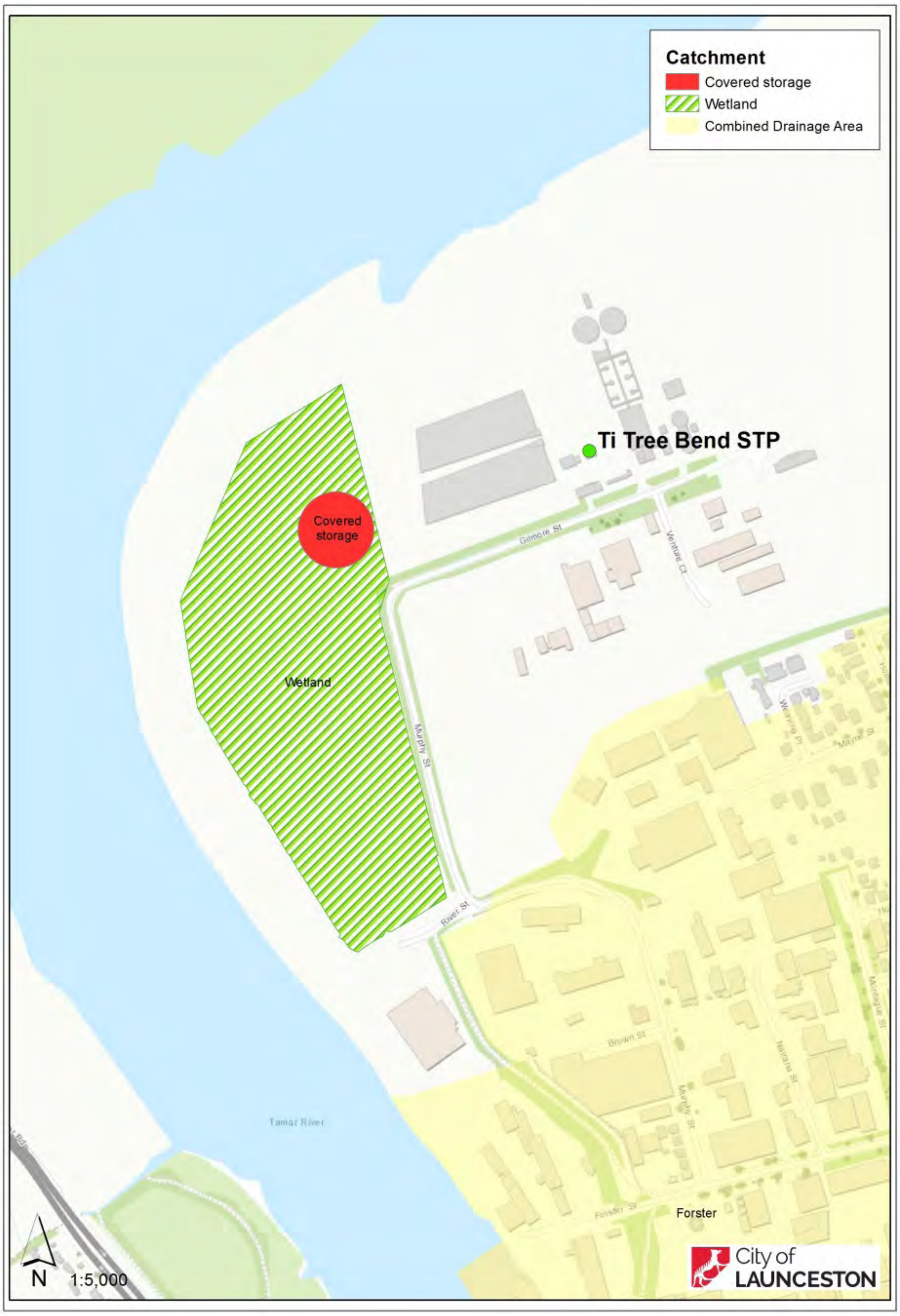


Figure 27 Ti Tree Bend storage facility

5.9.4 Benefit to Estuary

The benefit to the Estuary of this project is estimated by reduction in sewage discharged into the Estuary. This assumes that all additional flows will receive effective treatment at Ti Tree Bend to remove pathogens. Treatment at Ti Tree Bend STP was not modelled by the CSO Working Group. It is considered by the Catchment Action Working Group.

The intent of a constructed wetland is to make use of the natural wetland functions and processes to treat the combined system effluent. Wetland vegetation traps sediments and the biological processes within them remove pollutants. Typically, wetlands remove the majority of sediments, and significantly reduce the nutrients and heavy metals (varies dependent on speciation, particle-size distribution and detention time) (DPLG 2010). Wetlands are also known to efficiently reduce human pathogens in wastewater. In addition to water treatment, wetlands provide habitat, passive recreation opportunities and improved visual amenity.

Based on the design events presented in Section 4, this mitigation option is estimated to reduce sewage loading to the Estuary by approximately 28 per cent.

5.10 South Launceston diversion

5.10.1 Description

As described in Section 2.4, 3101 of the total 8257 sewage ETs originate in catchments with separated stormwater and sewer systems. The separated 3101 ETs in the Kings Meadows/Newstead and Broadland Drive areas could be diverted directly to the Ti Tree Bend STP.

Under DWF conditions, these sewage flows are directed to Ti Tree Bend, however under WWF conditions, a series of stormwater overflow pump stations (at Shields, Tamar and Willis Streets) lift (sewage contaminated) stormwater over the levee banks into the North Esk River to minimise the risk of flooding to the lower level areas of Launceston. The intention of this project would be to reduce the sewage component of the discharge to the Estuary from the pump stations located at Shields Street, Tamar Street and Willis Street.

5.10.2 Proposed facilities

In order to facilitate this mitigation option, a variety of works will be required to upgrade the sewer system between Hoblers Bridge Road and the Ti Tree Bend STP. In summary, the works required include:

- diversion of the South Launceston Trunk Sewer to a new pumping facility in the vicinity of Black Bridge and Boland Street
- diversion of the Boland Street SPS rising main to the new pumping facility
- installation of a new transfer main between the proposed pumping facility and Ti Tree Bend STP
- connection works at Ti Tree Bend

The construction of the rising main to facilitate this diversion will enable the connection of the separated sewer catchments located in the Inveresk precinct. With significant development imminent due to the relocation of the University of Tasmania's Launceston campus, the potential to convey sewage flows from the precinct directly to Ti Tree Bend will reduce the sewage loading at Forster Street and, therefore, the volume of sewage ultimately discharged to the Estuary during WWF conditions.

This alternative is shown in Figure 28.

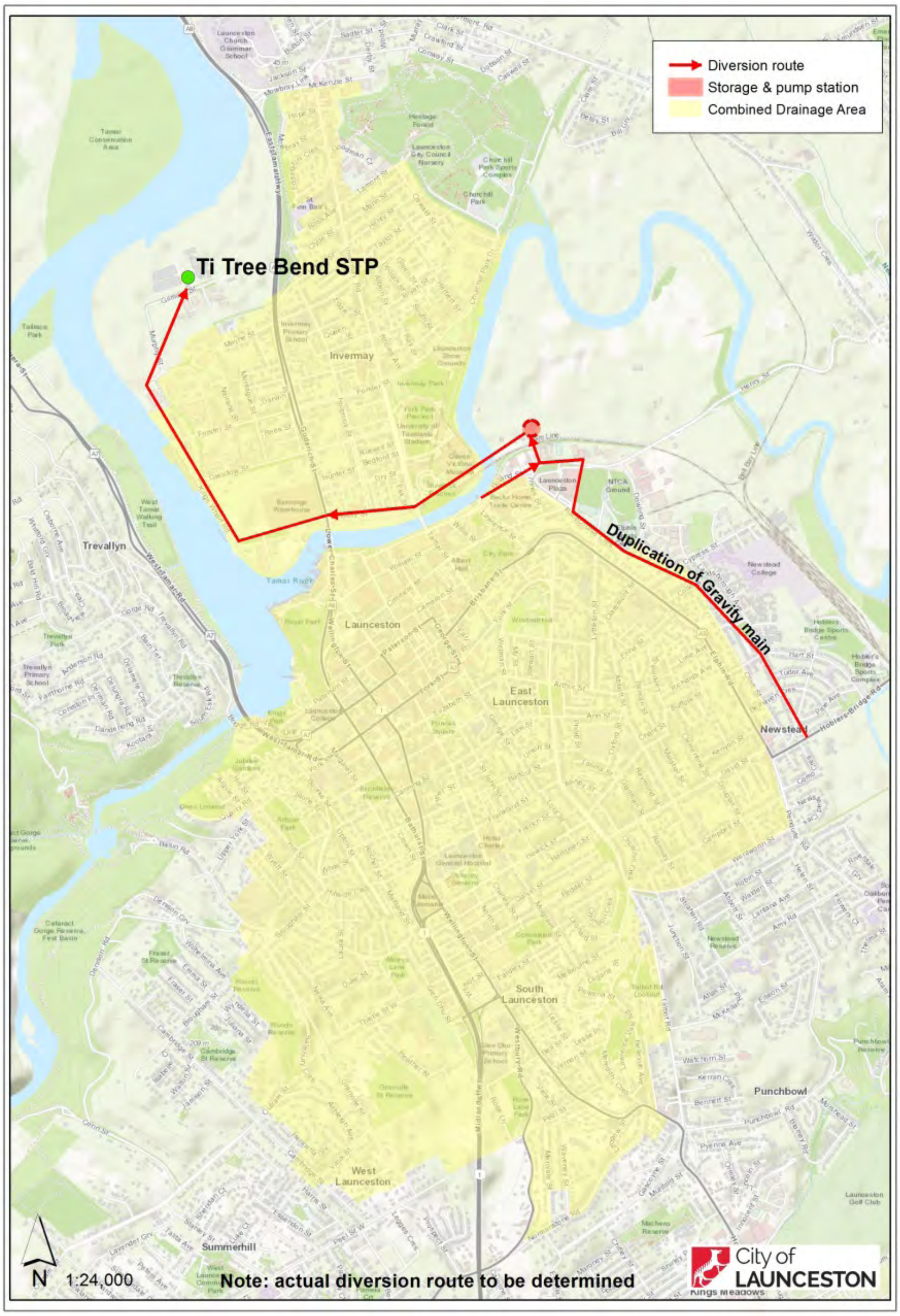


Figure 28 South Launceston diversion

5.10.3 Concept and operational costs

The estimated cost to construct this project approximately $18.1M, with an NPV of –$22.4M.

5.10.4 Benefit to Estuary

Based on the design events presented in Section 4, this mitigation option is estimated to reduce sewage loading to the Estuary by approximately 13 per cent.

Please note the benefits presented do not include any potential decrease in sewage loading discharged to the Estuary due to the connection of the Inveresk precinct directly to Ti Tree Bend.

The disruption for the public caused by the construction of this project would be more significant than other options presented in this section.

5.11 Offline storages

5.11.1 Description

This section provides an overview of proposed storage facilities designed to reduce the frequency and sewage contamination discharged to the Estuary at the following locations:

- New Margaret Street Pump Station
- Forster Street Pump Station
- Esplanade (including the CSO pump stations located at Shields Street, Tamar Street and Willis Street)

The proposed storage facilities have been sized with three considerations in mind:

- decrease the frequency with which overflows occur at each site
- capture the more contaminated “first flush” of the combined system
- construction constraints such as availability of land

5.11.2 Proposed facilities and operational costs

The proposed facilities will include:

- storages at each of the locations
- connection works to the relevant pump station
- pumping requirements to empty the storages once dry weather flow conditions have returned to the system

The following provide indicative storage sizes and locations at each location:

- New Margaret Street: 4.2ML underground storage located in Kings Park adjacent to existing NMSPS
- Forster Street: 2.5ML underground storage located on vacant land adjacent to Forster Street pump station
- Esplanade: 3ML underground storage located in the vicinity of Black Bridge and Boland Street

5.11.3 Concept and operational costs

New Margaret Street: $10.0M, with an NPV of –$11.4M

Forster Street: $8.4M, with an NPV of –$9.7M

Esplanade: $6.7M, with an NPV of –$7.6M

5.11.4 Benefit to Estuary

Based on the design events presented in Section 4, the proposed 4.2ML storage located at New Margaret Street is estimated to reduce sewage loading to the Estuary by approximately 21 per cent.

Similarly, the proposed 2.5ML storage at the Forster Street Pump Station is estimated to reduce sewage loading to the Estuary by approximately 6 per cent.

Finally, the proposed 3ML storage designed to service the St John Street catchment is estimated to reduce sewage loading to the Estuary by approximately 9 per cent.

It should be noted that the benefits of these storages is based upon the storage being empty before each rain event, ie, between each rain event, there is enough time for the volume within the storage to be bled back into the system and be treated at the Ti Tree Bend STP.

5.12 Treatment of combined sewerage overflows to Estuary

5.12.1 Description

This section details the high-level process undertaken to assess the feasibility of treatment options intended to decrease the pathogen load at the following CSO sites:

- Margaret Street Pump Station
- Esplanade Pump Stations
- Forster Street Pump Station

Treatment of the CSO at the locations stated above would probably involve a combination of the following:

- screening and sedimentation to remove litter and course sediments
- chemical treatment of CSO flows including appropriate contact time
- holding time to negate any potential effects of discharging the treated CSO to the Estuary (ie, chemical dissipation)

The primary constraints to consider when assessing the feasibility of this option are the availability of land required and the amenity of the CSO locations in question.

5.12.2 Proposed facilities and operational costs

The proposed facilities would include:

- screens and sedimentation tanks or channels
- chemical dispersion facilities
- tanks for both chemical contact time and dissipation

Given the likely locations of these facilities they would need to be either underground or obscured from view. A vast amount of land would be required to achieve adequate sedimentation, contact time and dissipation for effective disinfection or treatment of the CSO at Margaret Street, St John Street and Forster Street. Due to these restricting factors, disinfection and treatment of CSO at the discharge locations is dismissed from further investigation.

6 Solution evaluation

6.1 Criteria and evaluation methodology

This section outlines the proposed mitigation options for prioritisation. The prioritisation includes consideration of the return on investment as described in Section 5. The percentage reductions presented in this section are based on the volumetric reduction of sewage discharged to the Estuary based on the design WWF events. For tabled results please refer to Appendix C: Tabulated cumulative model results.

Figure 29 displays the estimated reduction in sewage loading to the Estuary for the proposed mitigation options. The linear trend-line provides an indication of projects that deliver above- average returns for investment (projects above the line) and those projects that deliver less than average (projects below the line).

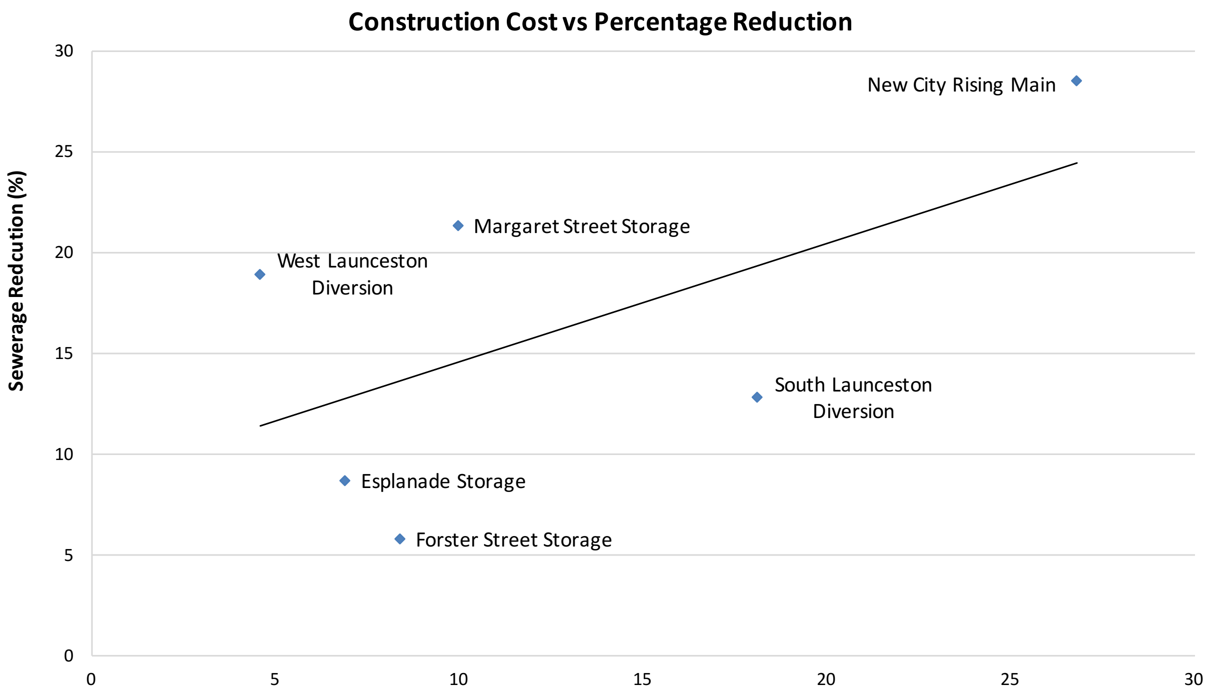


Figure 29 Construction cost vs percentage reduction

It should be noted that the relative benefits are presented as mutually exclusive projects for this process. In reality, this is not the case. Many of the proposed mitigation options will have a flow-on effect to subsequent mitigation options. For example, the West Launceston diversion will decrease the sewage content of the CSO at Margaret Street. Therefore this will decrease the relative effectiveness of the storage facility proposed for Margaret Street in that the sewage concentration and therefore sewage volume held within the storage will decrease. This section details the proposed mitigation options to be carried forward into an investment strategy and displays sewage reductions to the Estuary cumulatively.

6.2 Preferred solution

The following section details the recommended priorities for the proposed mitigation options in order of priority.

6.2.1 Regulation and policy reform; adoption of green infrastructure stormwater treatment; and operational improvements

Legislation, regulation and policy reform; adoption of green infrastructure stormwater treatment; and operational improvements should be undertaken as described in Section 5. These options do not require significant investment and can be started immediately.

Changes to the legislative and regulatory environment should be made to incentivise works within the combined system to incrementally reduce the environmental harm caused by CSO discharges to the Estuary. Given an appropriate regulatory environment; appropriate goals, objectives and strategies could be identified for the combined system. It is recommended that the policy and infrastructure recommendations documented in Section 5 be adopted.

It is also recommended that Councils develop and adopt a framework to enable the implementation and regulation of green infrastructure and move away from "traditional" drainage systems.

6.2.2 Hard infrastructure mitigation options

This section recommends the identified infrastructure projects that should be undertaken and provides the reasoning for project selection. The infrastructure options listed above are prioritised according to the effectiveness of the option in reducing the sewage loading ultimately received by the Estuary.

From Figure 31 it is clear that three projects provide above-average return on investment. These are:

- West Launceston Diversion (Section 5.8)
- New Combined Rising Main (Section 5.9)
- Offline storage located at New Margaret Street SPS (Section 5.11)

The quantified cumulative benefits of these projects, based on the modelling as described in Sections 4 and 5, are estimated at a reduction in sewage discharged to the estuary of 53 per cent.

The South Launceston Diversion would provide significant reductions in the sewage discharged to the Estuary, however the detail of this project is less understood and therefore the associated risks of this project are greater than Options 1 to 3 presented above. This option is currently being considered by TasWater under the current LSIP program. With the repurposing of Hoblers Bridge STP to a pump station, a less disruptive route for the proposed main is available. Therefore, if funding for this project is made available, it is better considered as part of the LSIP program.

Figure 30 displays the cumulative reductions in sewage discharged to the Estuary based on the proposed packages of works.

Table 10 Project costings and cumulative sewage reductions

Option No.	Project	Individual project construction costing ($M)	Cumulative construction costing ($M)	Cumulative sewage reductions (%)
1	West Launceston Diversion	4.6	4.6	19
2	(1) + New Combined Rising Main	26.8	31.4	44
3	(2) + The offline storage located at New Margaret Street SPS	10.0	41.4	53
4	(3) + South Launceston Diversion in conjunction with the Esplanade offline storage	24.8	66.2	66
5	(4) + The offline storage located at Forster Street SPS	8.4	74.6	68

To put the proposed mitigation options in perspective, Figure 30 also displays separation (Section 5.7) as a stand-alone option. It is clear that the proposed mitigation options provide significant value.

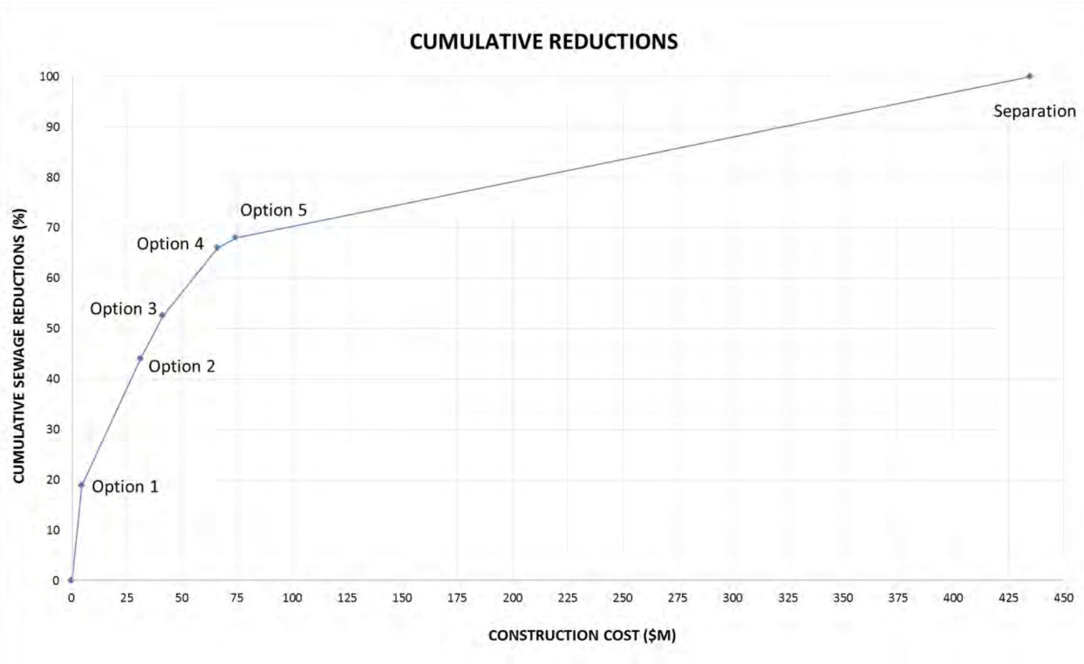


Figure 30 Cumulative sewage reductions

6.3 Additional analysis of preferred solution regarding CSO volume, frequency and quality

This section assumes the adoption of the five major infrastructure projects as specified in Section 6.2.2.

Figure 31 displays the modelled sewage component of the total CSO discharged to the Estuary for the design rainfall events based on the mitigation Options 1 to 5 in Section 6.2.2. For comparison, the current system performance as outlined in Section 4.2 is also displayed (dashed).

The focus of this report has been the three key locations that contribute the more significant sewage loading to the Estuary, namely Margaret Street, Forster Street and Esplanade. No works are formally proposed for the remaining sites, therefore the frequency with which the combined system (treated as a whole) overflows to the Estuary is unchanged. However, from the three key locations specified above, the modelling indicates that the likelihood of sewage-contaminated CSO will decrease by approximately 50 per cent.

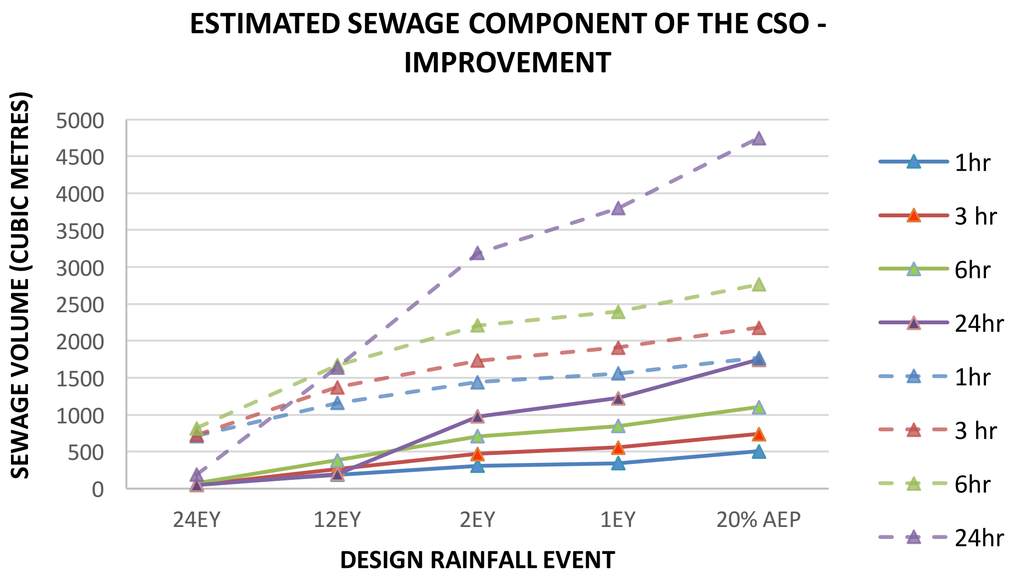


Figure 31 Estimated sewage component of the CSO — Improvement

At the time of writing this report, the pump records for the New Margaret Street Pump Station indicate that a CSO to the Estuary from this location occurred on approximately 50 days from 1 January 2017 to 10 October 2017. Based on theoretical pump rates, 60 per cent of these overflows were of magnitude 5ML or less (please note, these overflow volumes do not include volume of discharge from the Old Margaret Street Pump Station). With the proposed 4.2ML holding tank and increased pump rate to Ti Tree Bend, it is likely the frequency of CSO at this location will more than halve.

Furthermore, the modelling showed a more significant percentage decrease in the sewage loading to the Estuary in the more frequent events. The reduction of sewage loading discharged to the Estuary by events of magnitude 12EY or less totalled approximately 85 per cent.

The intent of this report was to investigate and propose regulatory, policy and operational reform, and hard infrastructure mitigation options to reduce the pathogen load discharged to the Estuary. Due to limited Estuary modelling capabilities, this investigation does not include consideration of the negative effects the sewage loading has on the Estuary. This will be considered by additional works undertaken by the Tamar Estuary Management Taskforce. Any investment strategy should be based on Estuary health. This report documents options to decrease pathogens caused by CSOs. The water quality effects that the estimated sewage loading has on the Estuary will be better understood when considered at catchment level, ie, as part of the River Health Action Plan.

7 Investment strategy

The investment strategy should be primarily based on Estuary health and the expectations of the community. This section outlines an investment strategy to deliver the proposed regulatory, policy and operational reform, and hard infrastructure mitigation options.

Changes to the regulatory, policy and operational environment of the combined system should be considered “business as usual”, with the relevant authorities committing to continuous improvement of the overall management of the system and corresponding catchments.

The hard infrastructure investment should be undertaken as presented in Section 6.2.2. It should be noted that the estimates for the LSIP works (West Launceston and South Launceston Diversions) have been taken directly from the LSIP report. These estimates have been undertaken on the preliminary design of the pipelines and pump stations for the transfer systems, and include allowances for design, approvals and construction. The construction cost estimates have been done by John Holland within a ±20% limit of accuracy.

Estimates for non-LSIP options have been prepared based on conceptual designs, using similar construction rates used for LSIP. Estimates include an allowance of 20 per cent (of construction cost) for engineering/approvals, and a 30 per cent construction contingency.

The diversion of the two separated catchments of West Launceston and South Launceston should be considered as part of the current LSIP strategy. However it should be recognised that LSIP is a long-term strategy designed to rationalise treatment plants and decrease nutrient loads discharged to the Estuary. The reduction of sewage-associated pathogens entering the Estuary due to the combined system is not identified as an objective. The timing and implementation of these projects should consider the LSIP program.

The proposed storages at Margaret Street and Forster Street – in conjunction with the proposed reconfiguration at the relevant pump stations, new rising main to Ti Tree Bend and a large storage facility or wetland located at Ti Tree Bend – can be considered separate stand-alone projects.

The investment strategy needs to consider the likelihood of implementation of the proposed LSIP program referenced throughout this report. Implementation of the full LSIP strategy will provide significant water quality benefits for the Estuary. However, if the strategy is subject to change or delay, these benefits may be reduced or delayed.

Table 11 Financial summary

Option No.	Project	Individual project construction costing ($M)	Cumulative construction costing ($M)
1	West Launceston Diversion	4.6	4.6
2	(1) + New Combined Rising Main	26.8	31.4
3	(2) + The offline storage located at New Margaret Street SPS	10.0	41.4
4	(3) + South Launceston Diversion in conjunction with the Esplanade offline storage	24.8	66.2
5	(4) + The offline storage located at Forster Street SPS	8.4	74.6
Full separation[44]	Development of a full separated sewer and stormwater system in the combined area	435	

Hydraulic modelling undertaken to quantify the potential reduction in sewage volume discharged to the Estuary during wet weather events indicates that an average decrease of approximately 68 per cent could be achieved over a range of design events.

The effects of the potential investment options for reducing CSOs were analysed using an improved version of the TEER CAPER DSS. In order to be used for this analysis significant changes have been made to the DSS to allow results from the CoL hydraulic model to be incorporated and to better represent connections between the combined system and Ti Tree Bend STP. This analysis first looked at the benefits of individual projects before developing a recommended pathway of preferred options.

The final options (Table 11) which have been assessed using the CoL hydraulic model and which are analysed in this report are:

- West Launceston Diversion – takes the separated sewage from West Launceston and Trevallyn and diverts this directly to Ti Tree Bend STP along the West Tamar highway and directly across the Tamar Estuary via a new main reducing the load on New Margaret St
- New combined rising main – diverts flows to New Margaret St with decommissioning of Old Margaret St, installation of new sewage pumps to increase sewage pump capacity, installation of new rising main works to connect New Margaret St to a storage at Ti Tree Bend and to the Ti Tree Bend STP, reconfiguration of Forster St and St John SPS to increase pump rate to Ti Tree Bend and construction of a storage or wetland at Ti Tree Bend
- New Margaret St storage – 4.2ML storage in Kings Park adjacent to New Margaret St Pump Station
- South Launceston Diversion – takes the separated sewage from South Launceston including Kings Meadows/Newstead and Boland St direct to Ti Tree Bend away from the Forster St Pump Station
- Esplanade storage – 3 ML storage located in the vicinity of Black Bridge/Boland St
- Forster St storage – 2.5ML underground storage adjacent to Forster St Pump Station

[44] Note that full separation is not considered to be a feasible option due to the enormous disruption it would cause to residents and business in the combined system area. This option has been included for comparison with feasible alternatives to demonstrate their effectiveness and costs relative to this frequently cited option. Costs attached to this option may be significantly underestimated given the many unknowns involved in a project of this scale and type.

A preferred pathway of investment has been developed from the analysis which maximises benefits with minimal costs and disruption.

The potential for avoided CSOs to put additional pressures on treatment at Ti Tree Bend has also been explored, together with the potential benefits of an additional $10 million investment in upgraded nutrient treatment capacity at Ti Tree Bend.

Figure 32 shows the impact of the preferred CSO Investment Options in conjunction with a treatment upgrade at Ti Tree Bend on Greater TEER catchment total loads. Note that loads and concentrations of TSS and Enterococci are assumed to be unaffected by this upgrade. This figure shows that with this upgrade included Greater TEER catchment nutrient loads can be expected to decrease by 3 to 4 per cent. Investment in the combined system can be expected to lead to large decreases in Enterococci loads. The curve shows decreasing returns to scale of the investment, such that the initial investment in Option 1 (West Launceston diversion) achieves approximately 20 per cent of the decrease in Enterococci loads from full separation at 1 per cent of the cost. Option 5 achieves roughly 85 per cent of the full benefit at 17 per cent of the total cost, and with significantly less disruption to the residents and businesses in the combined system area.

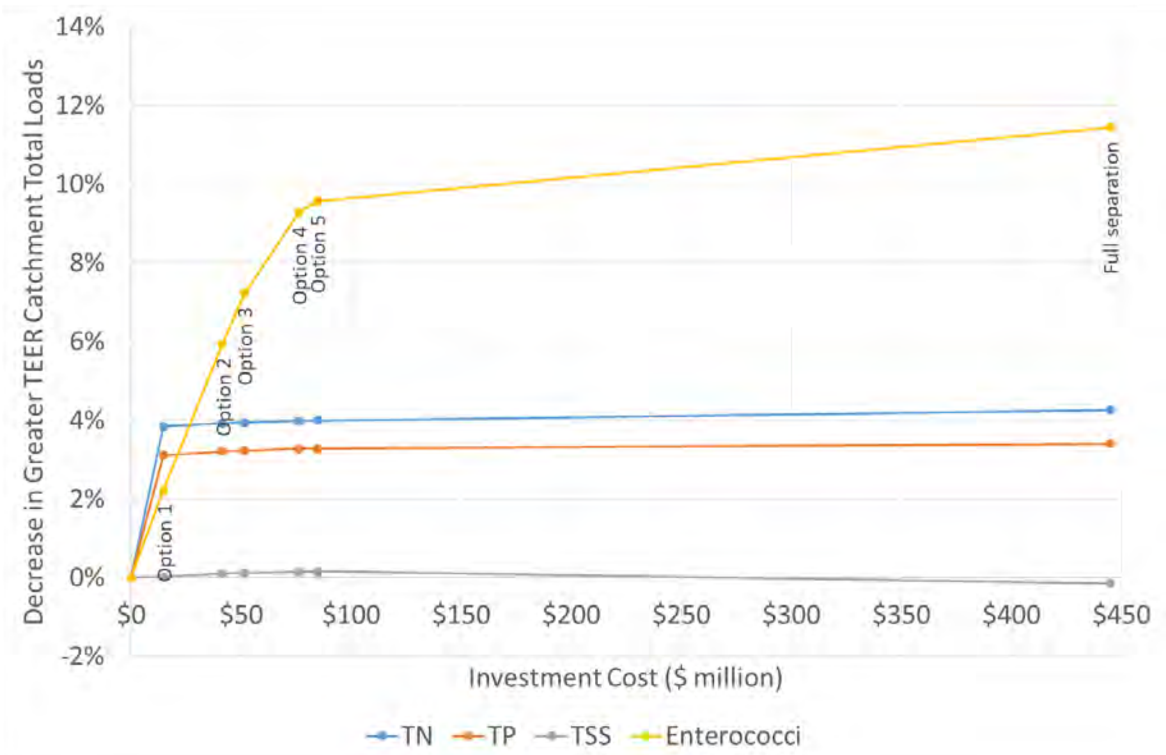


Figure 32 Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Figure 33 shows the impacts of these Investment Options with the treatment upgrade at Ti Tree Bend STP on Tamar Estuary Zone 1 concentrations. CSOs are the largest contributor to Tamar Estuary Zone 1 concentrations. This pathway of preferred investment in reducing CSOs can be expected to have very large and significant benefits in terms of reduced Enterococci concentrations in the upper estuary. As shown in this figure, Enterococci concentrations can be expected to decrease by nearly 10 per cent. Investment in Option 5 can be expected to decrease Enterococci concentrations by 37 per cent, which can be expected to have very significant benefits for recreational users of the upper estuary.

Figure 33 also shows substantial benefits of the treatment upgrade in terms of decreased nutrient concentrations. It is estimated that TP concentrations would decrease by 18 per cent and TN by 26 per cent. This investment option allows the benefits of reduced CSOs in terms of Enterococci to be retained while substantially decreasing nutrient concentrations, avoiding the potential decline that could be expected without such an upgrade.

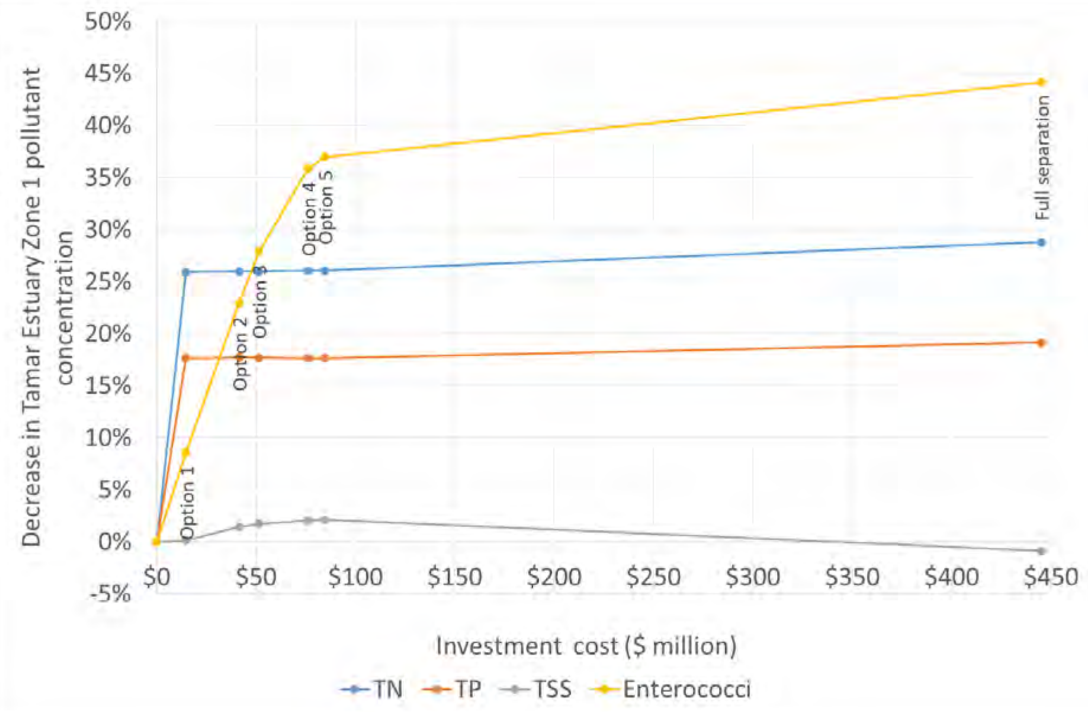


Figure 33 Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Based on the analysis in this report:

- There is a clear pathway of investments in reduced CSOs that has the potential to provide large improvements in Enterococci (and other pathogen) concentrations in Zone 1. These investments could be undertaken using a staged approach, progressively capturing the benefits of full investment. Decreasing returns to the scale of investment mean that this approach captures most of the benefits in the early stages of the investment pathway. Investment in Option 5 is expected to lead to a 37 per cent decrease in Tamar Estuary Zone 1 Enterococci concentrations for a total cost of roughly $75 million. This represents 85 per cent of the total benefit that could be achieved by fully separating sewage and stormwater in the combined system at 17 per cent of the cost. Full separation is considered to be infeasible given the enormous disruption it would cause over many years to businesses and residents in the combined system. These results demonstrate that this option is not needed to achieve very large decreases in pathogen concentrations in the upper estuary.

- Increased influent volumes to Ti Tree Bend STP from avoided CSOs have the potential to increase nutrient concentrations in the upper estuary. Very little data is available to accurately estimate this impact but significant trends in treatment effectiveness with increased influent volume are observed in the data that is available. Ti Tree Bend was not designed to effectively reduce nutrient concentrations. It is recommended that nutrient treatment upgrades at Ti Tree Bend are considered as part of the investment pathway to reduce CSOs. TasWater already has some preliminary investigations of upgrade options which could be further developed in the design phase of any investment in CSOs. The analysis here shows this type of upgrade in conjunction with the CSO investment options could lead to significant water quality benefits in the upper estuary with concentrations of TN and TP decreasing by 26 per cent and 18 per cent respectively.

- More data on influent and effluent volumes and pollutant concentrations at Ti Tree Bend would significantly reduce the uncertainty of estimates of the impacts of increased influent volumes on treatment effectiveness. TasWater should continue to add to their understanding through continuation and refinement of their monitoring program.

The implementation of the proposed mitigation options and the required investment strategy should be primarily based on Estuary health and the expectations of the community. Options should be considered in conjunction with the proposed mitigation options as presented by the Catchment Action Working Group. Proposed operational improvements and changes to the legislative and regulatory environment should be undertaken for best practice management of the combined system.

In conclusion, significant and cost effective improvements to both recreational and ecological water quality can be made in the kanamaluka/ Tamar Estuary by implementing a staged program of works in combination with policy change rather than embarking on the disruptive and expensive full separation of Launceston's combined system.

8 Abbreviations and glossary

Abbreviations

1D	One dimensional
2D	Two dimensional
ADWF	Average dry weather flow
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
BBS	Brick barrel sewer
BOD	Biochemical oxygen demand
BOM	Bureau of Meteorology
CAPER DSS	NRM North's Tamar Catchment Water Quality Model
CBD	Central business district
CCTV	Closed circuit television
CDS	Combined drainage system
CoL	City of Launceston
CSO	Combined system overflow
Cumecs	Cubic metre per second
CWA	Clean Water Act (USA)
°C	Degrees Celsius
DEPHA	Department of Environment, Parks, Heritage and the Arts
DN	Diamètre Nominal (Nominal Diameter)
DPIW	Department of Primary Industries and Water
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DWF	Dry weather flow
ET	Equivalent tenement (a measure of sewage)
EPA	Environmental Protection Agency (USA)
EY	Exceedance per year
GIS	Geographical information system
InfoWorks ICM	Corporate software package for hydraulic and hydrological modelling
IDEAL	Intermittent decanted extended aeration lagoon
IFD	Intensity frequency duration
KBA	Key biodiversity area
L	Litre
LCC	Launceston City Council
LCSS	Launceston combined sewerage system
L/s	Litres per second
LSIP	Launceston Sewerage Improvement Program
m	metre
mm	millimetre
M	Million
ML	Mega litre (1,000,000 litres)
ML/d	Mega litre per day
MSPS	Margaret Street Pump Station
NNP	New Northern STP
NPDES	National Pollutant Discharge Elimination System (USA)
NPV	Net present value
NMSPS	New Margaret Street Pump Station
NRM North	Natural Resource Management Northern Tasmania
OMSPS	Old Margaret Street Pump Station
PGP	Pressure gravity pipeline
PL	Pollutant load
PS	Pump station
RC	Reinforced concrete
SPS	Sewage pump station
SJSPS	St John Street Pump Station
STP	Sewage treatment plant
SW	Stormwater
SWPS	Stormwater pump station

TEER	Tamar Estuary and Esk Rivers program
TEMT	Tamar Estuary Management Taskforce
UTAS	University of Tasmania
WWF	Wet weather flow
WQ	Water quality
WQIP	Water quality improvement program
WSUD	Water-sensitive urban design

Glossary of terms

Term	Abbreviation	Definition
Annual exceedance probability	AEP	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year
Combined sewerage system	CSS	Sewer network that collects rainwater run-off, sanitary sewage and industrial wastewater into one pipe for delivery to a treatment plant
Combined system overflow	CSO	Discharge of untreated stormwater and wastewater directly to the receiving environment when the volume of water in the combined sewer system exceeds capacity of the network (eg, during heavy rainfall events)
Concentration		The quantifiable amount of a chemical in water or sediment
Cumecs		A measure of flow; cubic metre per second
Disinfection		The removal, deactivation or killing of pathogenic microorganisms. Disinfection treatment methods include chlorination, chlorine dioxide, chloramines, ozone and ultraviolet light
Diversion		The interception of separated sewage prior to discharge into the combined sewerage system for direct delivery to a treatment plant
Dry weather flow	DWF	The flow carried by a sewerage system during dry weather. It consists of flows generated by properties connected to a sewerage system excluding the effect of inflow/infiltration resulting from rain events
Escherichia coli	*E. coli*	A bacterium commonly found in the intestines of humans and other animals, some strains of which can cause severe food poisoning
Effluent		Treated or untreated wastewater flowing out of a treatment plant or sewerage system
Ejector pump		A pump to lift sewage above the grade of the sewer main
Enterococci		The enterococcus group is a subgroup of faecal streptococci. The Enterococci portion of the faecal streptococcus group is a valuable bacterial indicator for determining the extent of faecal contamination of recreational waters
Exceedances per year	EY	Events with an Annual Exceedance Probability (AEP) more frequent than 50%, the number of times a given condition is exceeded in any year
Infiltration		The ingress of groundwater to a sewerage system
Inflow		The entry of water into the sewer resulting from rainfall events
Partial separation		Separation or removal of the currently separated sewers' sub-catchments from the combined drainage system. Also referred to as 'diversion'
Pathogen		Microorganisms that can cause disease in humans and other animals
Pluviograph		An automated rain gauge instrument for measuring and graphing the amount of water that has fallen against real time
Primary treatment		The process that removes a substantial amount of suspended matter from wastewater but little or no colloidal and dissolved matter

Term	Abbreviation	Definition
Receiving environment		The environment upon which a proposed activity may have effect (eg, a waterway downstream of a discharge location)
Rising main		A sewer requiring sewage pumping stations to provide the energy to discharge sewage at a higher level. Rising mains are under pressure and therefore require more controls and design requirements to reduce flows from a burst pressure main. Also referred to as pressure main
SCADA	SCADA	Supervisory Control and Data Acquisition: refers to a computer system that monitors and controls a process eg pump stations, treatment plant network
Screening		The removal of objects such as rags, paper, plastics and metals to prevent damage and clogging of downstream equipment, piping and appurtenances or discharge to the environment
Secondary treatment		The process that removes or reduces suspended and dissolved solids, and colloidal matter from wastewater
Separated sewerage system		Sewer network that collects only sanitary sewage and industrial wastewater for delivery to a treatment plant
Sewage		The used water from domestic, commercial and industrial sanitary appliances containing dissolved and suspended matter
Sewage pump		A pump used to move sewage (or a combination of sewage and stormwater) through a sewer system
Sewer		An underground conduit (pipe) for carrying wastewater
Sewer overflow		The discharge of effluent from a sewerage system to the environment
Sewerage		A system of pipes, maintenance holes, pumps, treatment facilities and other infrastructure for handling sewage
Stormwater pump		A pump used to move stormwater through a stormwater system
Stormwater separation		The separation of the stormwater-pipe network from the sewerage
Tertiary treatment		Advanced wastewater treatment process, following secondary treatment, which produces high-quality water. It includes removal of nutrients and practically all suspended and organic matter from wastewater
Trunk main		A very large diameter sewer that carries large flows directly to treatment plants or major pump stations
Wet weather flow	WWF	The flow carried by a sewerage system during wet weather. It consists of the sanitary (sewage) flow and the flows resulting from inflow/infiltration
Water-sensitive urban design	WSUD	A design approach that integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal

9 References

AMC Search 2015. *Tracer analysis of sediment redistribution of Tamar Estuary for Launceston Flood Authority.* AMC Search, Launceston

Aquenal & DEPHA 2008. *State of the Tamar Estuary.* DEPHA Tasmania

Aquenal 2001. *Exotic marine pests survey of the Port of Launceston, Tasmania.* Prepared for the Port of Launceston Pty Ltd to meet the requirements of the AQIs Decision support system (DSS) for ballast water management

Attard, M., Thompson, M., Kelly, R. & Locatelli, A. 2012. *Tamar Estuary ecosystem health assessment program monitoring report 2012.* Prepared for NRM North

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Birdlife Australia http://www.birdlife.org.au/projects/KBA

Blake, G and Cannell, R. 2000. *Foreshore and vegetation management and analysis.* In: Watchorn, L., Tamar Estuary and Foreshore Management Plan, Tamar Estuary 2020

Cardno 2017 *Hydrology Parameter Investigation Launceston Stormwater Modelling CG150576 Report R01*, Cardno, Victoria.

Department of Health and Human Services, *Public Health Act 1997, Recreational Water Quality Guidelines 2007*

DPIWE 2005. *Calystegia sepium* factsheet http://www.threatenedspecieslink.tas.gov.au/Pages/Calystegia-sepium.aspx

DPIPWE 2009. Tasmanian Acid Sulfate Soil Management Guidelines. Sustainable Land Use Section, Land Conservations Branch, DPIPWE, Hobart

Department of Environment and Swan River Trust 2006. Retrofitting, Stormwater Management Manual for Western Australia, Department of Environment and Swan River Trust, Perth, Western Australia.

Edgar, G. J., Barrett, N. S. & Graddon, D. J. 1999. *A Classification of Tasmanian Estuaries and Assessment of their Conservation Significance using Ecological and Physical Attributes, Population and Land Use.* Marine Research Laboratories – Tasmanian Aquaculture and Fisheries Institute, University of Tasmania

Foster D., Nittim, R. & Walker, J. 1986. *Tamar River Siltation Study Technical Report No. 85/07.* University of New South Wales Water Research Laboratory

GHD *TasWater's Report #12 Preliminary Design Report.* February 2016

Grose, M. et al. 2015. *Southern Slopes Cluster Report*, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia

Gunns Ltd 2006. *Bell Bay Pulp Mill — Draft Integrated Impact Statement.* Gunns Limited Mill Operations

Haslett, Simon, Professor of Physical Geography at the University of Wales and author of Coastal Systems (2016, University of Wales Press), YouTube clips:How mudflats form in an estuary: https://www.youtube.com/watch?v=J5C3JRWrQWo; How vegetation builds up the mudflats: https://www.youtube.com/watch?v=wrRRgRXA-yI

Hedge, P. 2002. *Strategy for the management of rice grass (Spartina anglica) in Tasmania, Australia (2nd edition).* Australian Rice Grass Advisory Group, Tasmania.

Karim, M. R., Glenn, E. P. & Gerba, C. P. 2008. The Effect Of Wetland Vegetation On The Survival Of *Escherichia Coli*, *Salmonella Typhimurium*, Bacteriophage MS-2 and Polio Virus, *Journal of Water and Health*, vol. 6, no. 2, pp. 167-175.

Lucas, F. S., Therial, C., Gonçalves, A., Servais, P., Rocher, V. & Mouchel, J. 2014. Variation Of Raw Wastewater Microbiological Quality In Dry And Wet Weather Conditions, *Environmental science and pollution research international*, vol. 21, no. 8, pp. 5318–28.

Newall, P., Tiller, D. & Lloyd, L.N. 2012. *Technical Report For Freshwater Monitoring Framework & Report Card For The Tamar Estuary and Esk Rivers Program.* Report to NRM North. Lloyd Environmental Pty Ltd, Victoria

NVA 2017. https://www.naturalvaluesatlas.tas.gov.au

PWS 2017. http://www.parks.tas.gov.au/indeX.aspX?base=4127 5/9/17

Rowland, C. 2001. *Tamar Region Natural Resource Management strategy. 2nd edition.* Department of Primary Industries, Water and Environment, Hobart

Soars, J. & Miller, F. 2013. *Changing water values in urban waterway naturalisation: findings from a Sydney case study.* In SOAC 2013: *State of Australian Cities National Conference: Confoerence Proceeding and Powerpoint Presentations* pp. 1-12 Sydney: State of Australian Cities Research Network

SFM Environmental Solutions 2008. *Tamar Estuary Management Plan: A Management Plan for the Natural Values of the Tamar Estuary.*

TasWater Drawing Nos. TWA-16-0411 Sheets 1 and 2 TIBS – Ti Tree Sewerage System Schematic Overall Plan 20 August 2012

TEER (Tamar Estuary and Esk Rivers) website http://www.nrmnorth.org.au/teer

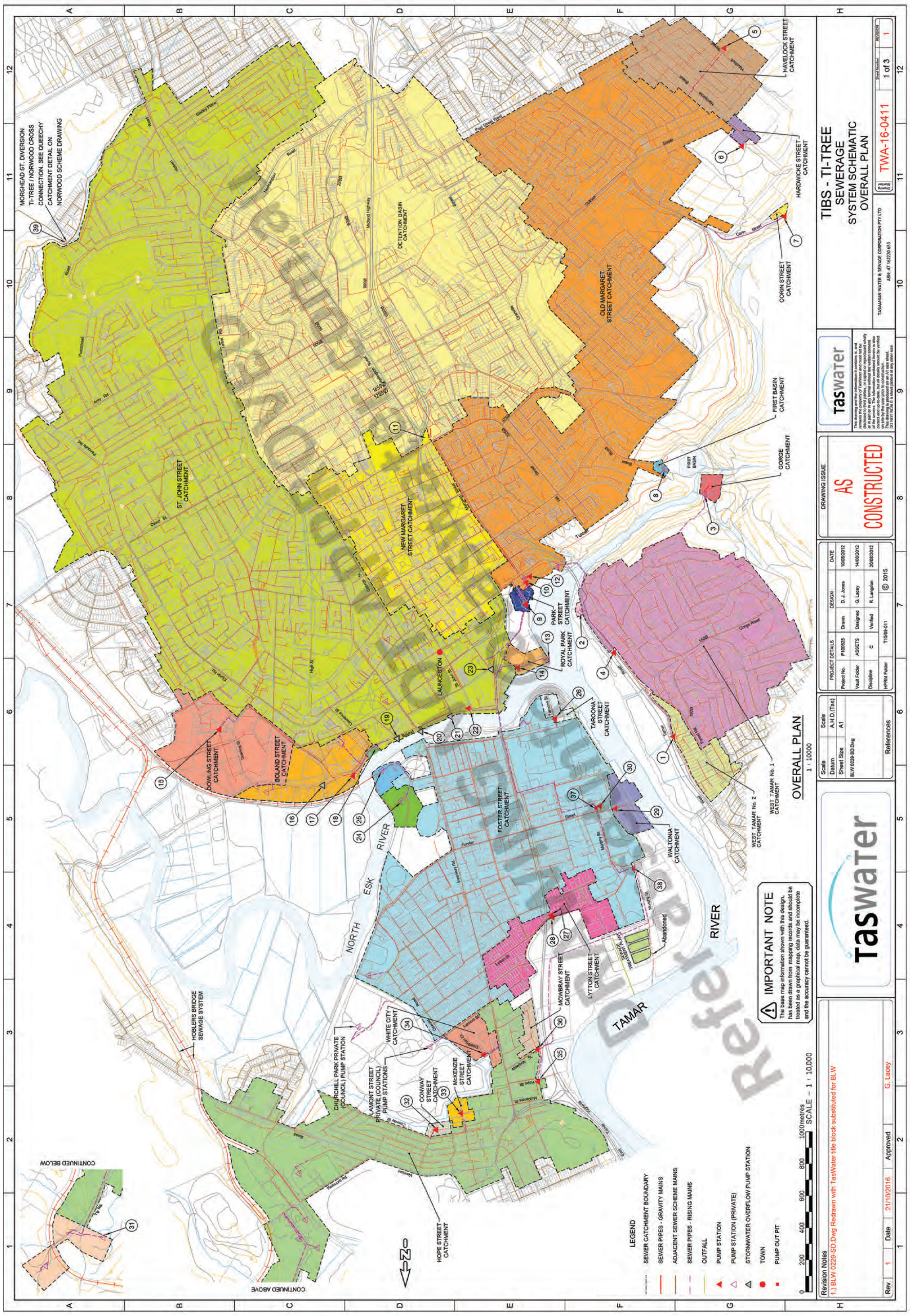
Tamar Estuary and Esk Rivers Program 2015. *Tamar Estuary and Esk Rivers Catchments Water Quality Improvement Plan.* NRM North, Tasmania Urban Drainage Act 2013

Water and Sewerage Industry Act 2008

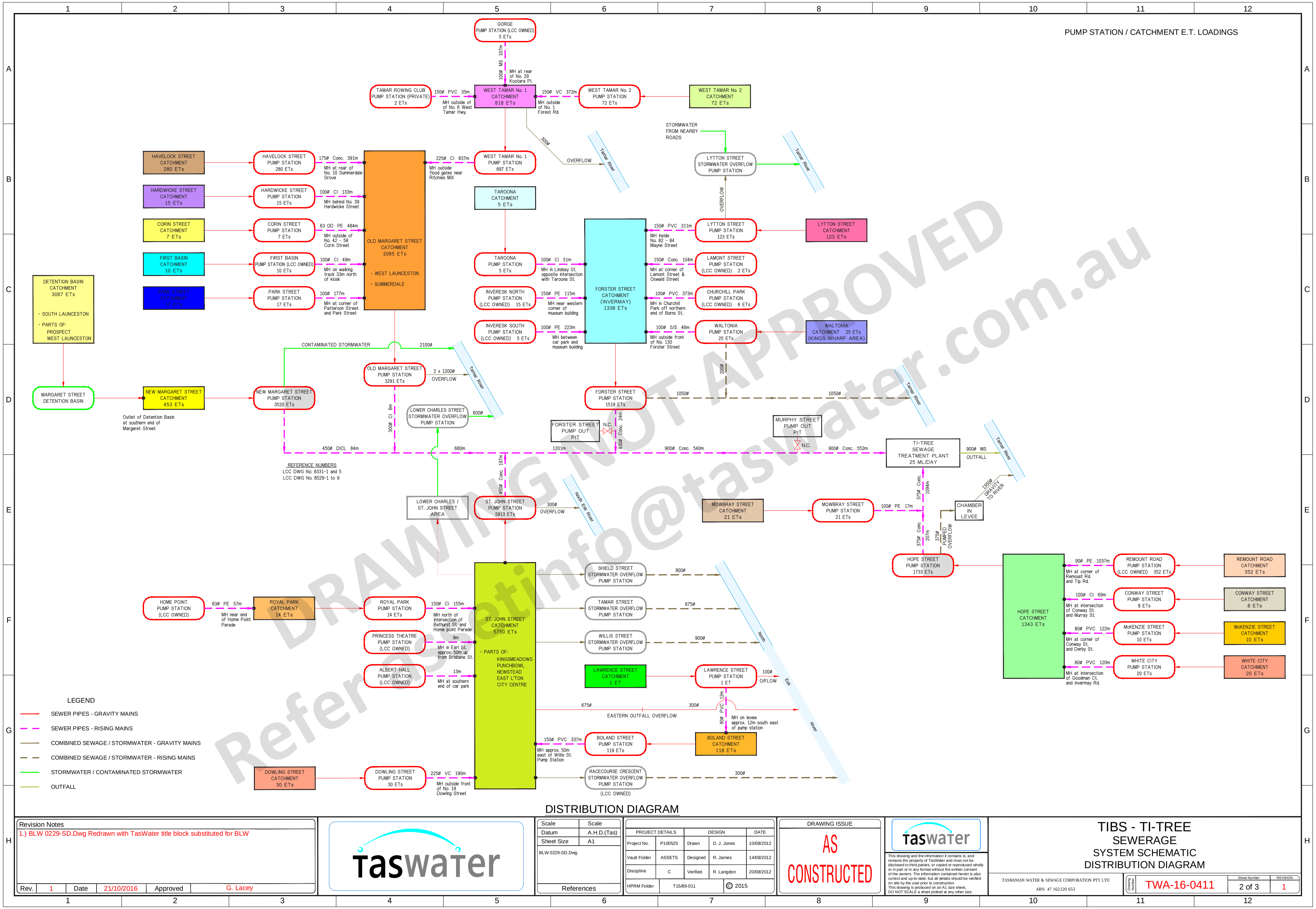
Younos, T. 2011, Paradigm shift: Holistic Approach For Water Management In Urban Environments, *Frontiers of Earth Science*, vol. 5, no. 4, pp. 421–427.

Appendix A

Plans



Plan 1: TIBS – Ti Tree sewerage system schematic overall plan – TWA-16-041



Plan 2: TIBS – Ti Tree sewerage system schematic distribution diagram – TWA-16-0411

Appendix B: Model validation

Combined system – Risk management plan

Combined system model

Executive Summary

This document presents a summary and gap analysis of the information supplied to the City of Launceston by TasWater to support the generation of a combined-system risk- management plan. Of primary interest is the review, update and validation process of the existing InfoWorks TasWater combined system model.

The model validation process included:

- simulation of a 72-hour dry weather flow (DWF) including diurnal variation to provide initial conditions for the sewerage/combined networks and altering of the 1D network where surcharge or ponding occurred in the network and/or at surface level under DWF conditions
- interrogation of the pump station rising main configuration and altering of the rising main configuration where inconsistencies occurred
- interrogation of the pump operation and configuration (switch on level, duty/stand-by arrangements and pump make and associated head/ discharge curves) and alteration of this where inconsistencies occurred
- verification of CSO's (gravity linkages between the sewerage and stormwater networks) modelling configuration
- selection and generation of the validation rainfall event which occurred on 18 March 2016
- simulation of the event and comparison between observed SCADA recordings and modelled system outputs

The base model is to be used as a comparison tool to assess proposed mitigation options for the development of the Combined System Risk Management Plan. The improved correlation between modelled and recorded (SCADA) flows within the combined rising main and combined pump operation detailed in this report, provides assurance that the model is fit for purpose due to the validation process undertaken.

1 Introduction

The Smart Cities Plan: Launceston City Deal, signed on 20 April 2017, stipulates the formation of a Tamar Estuary Management Taskforce (TEMT) to facilitate a coordinated and evidence-based approach to address the health of the Tamar River. TEMT will oversee the development of a River Health Action Plan by the end of 2017. The River Health Action Plan will:

- Recommend priority government investments and policy actions
- Include preferred options for mitigating the effect on the Tamar Estuary of the combined sewerage and stormwater system
- Enable long-term oversight of the health of the Tamar Estuary and its catchments
- Identify measurable targets
- Build on the work of the Tamar Estuary and Esk Rivers (TEER) Partnership led by NRM North, including the 2015 Water Quality Improvement Plan

While the scope of the River Health Action Plan is at a catchment level, a key direction is noted in mitigating the effect on the Tamar Estuary of the combined sewerage and stormwater system.

A validated combined system model is required in order to estimate the effect on the Tamar of the combined sewerage and stormwater system and the benefits of any proposed mitigation projects.

This document provides context and an overview of key previous studies on the combined system and documents the model validation process undertaken.

At the inception of this project TasWater provided the City of Launceston with a number of documents and data to support this process. These included:

- Launceston CDS Investigation Interim Options and Strategy Report (Beca)
- Launceston's Combined Sewerage System — Investigation and Strategy Development (Cameron Jessup dissertation)
- Location details of combined system overflows:
    - Launceston Sewerage System Schematics
    - Hoblers Bridge
    - Newnham
    - Norwood
    - Prospect
    - Riverside
    - Ti Tree
- Launceston Sewerage Improvement Program (LSIP), Report #12 Preliminary Design Report
- TasWater Sewer Modelling Guidelines
- Combined System Pump Station Schematics
- The existing 1D InfoWorks ICM Combined System Model
- Rainfall and SCADA data for specified rainfall periods

2 Literature and data review

Recognising the extensive body of works about the operation of the combined-system-associated risk-management strategies that have been undertaken in the past, the intent of this section is to summarise the significant information that contributes to the context for development of the Combined System Risk Management Plan and the modelling component of this project.

2.1 Launceston CDS investigation interim options and strategy report

In August 2015, TasWater engaged Beca to prepare the Launceston Combined Drainage System Strategy — Options Identification and Assessment. The purpose of this project was to develop a long-term strategy based on an understanding of the frequency, extent and environmental impact of Combined Sewer Overflow (CSO) events on the receiving environment.

The current performance of the combined system was quantified using a network model. Although there are some concerns about the accuracy and currency of the model that has been used to produce the results, the results are representative of the situation "on the ground" as observed by TasWater and other stakeholders.

The model results indicated that:

- CSOs spill on a frequent basis with 10 CSOs that spill weekly or more frequently, and some that spill daily.
- The four largest spilling CSOs contribute almost 80% of the spills to the river.
- A mass balance of volume and mass load on an annual basis indicates that 99% of the volume comes from the river with CSOs contributing only 0.1% (STP and stormwater providing the remaining flows). Contribution of biochemical oxygen demand (BOD) from CSOs makes up 3% of the pollutant load in the river.
- Analysis of an extreme event from March 2011 indicates that under wet weather conditions BOD contributions to total BOD in the river could approach 30%.

Potential solutions have been developed as follows:

- screening of overflows at the most frequent CSOs. If implemented, these would screen between 94% and 99.6% of overflows at a cost of between approximately $16M and $24M (+/– 30%, a range of $12M to $31M)
- containment of overflows at the four largest spilling CSO sites. This will result in the construction of three retention tanks, storing between 79% and 88% of the CSO spill volume, at a cost of between $108M and $121M (+/– 30%, a range of $75M to $160M)
- conveyance of overflows at the four largest spilling CSO sites to storage at the Ti Tree Bend STP, resulting in a similar impact to the containment at overflow option, at a cost of between $153M and $167M (+/– 30%, a range of $107M to $217M)
- partial separation to reduce the volume of CSO spills by 22%, along with the associated reduction in pollutant load. Costing has been provided by TasWater as part of LSIP, and is approximately $200M
- full separation to reduce the volume of CSO spills by 65%, with a cost of $440M (+/– 30%, a range of $300M to $560M)

2.2 Launceston's combined sewerage system — Investigation and strategy development — Cameron Jessup dissertation

The Jessup study compared a performance analysis of the existing Launceston combined sewerage system and the theoretical performance of a separated network.

In order to quantify the performance of Launceston's combined system, daily rainfall totals were compared with CSO pump function during these periods. CSO discharge duration, volume and probability of discharge based on catchment rainfall were interrogated. A summary of the CSO (pumped only) discharge locations is contained in Figure 34 below.

	No. Overflows/Discharges		Overflow Volume (ML)		90% likelihood of ejection rainfall
	2013	2014	2013	2014	
Willis St SWPS	173	232	728.9	556.9	2-3 mm
Shields St SWPS	131	77	275.7	155.7	4-5 mm
Tamar St SWPS	N/A	88	N/A	83.2	3-4 mm
Lower Charles St SWPS*	270	253	46	28.3	2-3 mm
Racecourse Cres SWPS**	341	285	220.5	89	1-2 mm
New Margaret St SPS	84	61	1,312.9	714.4	3-4 mm
Forster St SPS'	45	54	391.7	243.8	3-4 mm
Hope St SPS''	61	48	73.3	34.7	5-6 mm
Waltonia SWPS*	365	354	41.7	14.9	0-1 mm
Lytton St SWPS*	216	212	98.7	60.2	2-3 mm

*Pump station is a separated stormwater pump station

**Pump station is a separated stormwater pump station owned by LCC

'Pump station data not available before July 2013

''Pump station data not available before April 2013

Figure 34: Pump station overflow/discharge to river — Summary

The results of the performance comparison — combined system versus theoretical separated system are displayed below in Figure 35.

	Combined	Separated	% Improvement
Flows (ML)	12116.15	12116.15	N/A
TN (tonnes)	198.79	112.21	44%
TP (tonnes)	50.88	29.24	43%
SS (tonnes)	444.44	465.94	-5%
Enterococci (cfu)	1.636E+15	1.523E+15	6%
Cr (kg)	14.74	55.72	-278%
Cu (kg)	77.12	197.01	-155%
Pb (kg)	43.16	42.59	34%
Zn (kg)	884.42	731.69	17%

Figure 35: Performance Comparison — Combined System vs Theoretical Separated System

In summary, this study indicates that the benefits associated with a separated sewage and stormwater system are reduced due to the benefits of treating stormwater in the combined system.

It should be noted that the pollutant loading rate for pumped CSO discharges was based on average available sampling data (three rainfall events at three CSO locations). From the report delivered, it is not possible to determine at what point of the rainfall these samples were taken. Recognising that the concentration of sewage and stormwater pollutants within the combined flow discharged to the river will be greater towards the beginning of the rain event, the report recommends continuous monitoring of CSOs.

In addition to continuous monitoring, the study also recommends a number of mitigation strategies to reduce the negative effects of the LCSS on the receiving Tamar Estuary waters. These include:

- Implement tide flap maintenance and inspection program.
- Improve capture of low intensity and low total rainfalls storm flows.
- Screen high priority CSO discharges.
- Target separation in high risk areas.

2.3 Launceston Sewerage Improvement Program (LSIP) — TasWater — GHD

TasWater has engaged GHD Pty Ltd (GHD) to undertake preliminary design of the proposed network transfer system from the Greater Launceston STPs to the New Northern STP (NNP) located at Ti Tree Bend Launceston. There are two sides to the network: the Eastern Component comprising the network from Norwood, Hoblers Bridge and Newnham STPs, and the western component comprising the network from Prospect Vale, Riverside and Legana STPs. Figure 36 presents a schematic of the intended linkages from the current STP sites to the NNP. The work also involves redirection of flows from separated catchments that currently discharge to Ti Tree Bend STP, to the NNP.

Figure 36: Schematic of the linkages from the current STP sites to the NNP

Figure 37 provides an overview of the intended sewer treatment plant rationalisation scheme and sewer transfer pump-station requirements.

Term	Icon	Site Name
CRM		City Rising Main
HB	HB	Hoblers Bridge STP/Future STPS
LG	LG	Legana STP/Future STPS
NN	NN	Newnham STP/Future STPS
NNP	NNP	Proposed New Northern Plant (STP)
NR	NR	Norwood STP/Future STPS
PV	PV	Prospect Vale STP/Future STPS
QPS		Queechy Pump Station
RV	RV	Riverside STP/Future STPS
TTB	TTB	Existing Ti Tree Bend STP
WTPS1	WT PS	West Tamar Pump Station #1
WTPS2		West Tamar Pump Station #2

Figure 37: LSIP site details

Although this report does not consider the impacts of the combined sewage and stormwater system on the Tamar Estuary, it does provide significant context regarding TasWater sewerage strategy for the Greater Launceston region.

2.4 The existing 1D InfoWorks ICM Combined System Model

The existing 1D InfoWorks ICM Combined System Model was supplied to Council for the purpose of this study in June 2017. The 1D model comprises a number of 1D elements (pipes, nodes, weirs, pumps) to model the transfer of flows generated from differing sources (base flow, rainfall events and associated run-off and sewer loading).

The model stormwater/combined catchment is distinct to the combined system however does include inputs from sewerage systems outside the commonly known combined system. This reflects the operating nature and loading conditions for the system.

The model presented was stable and functional upon delivery. Dry Weather Flow (DWF) and two recorded rainfall events were simulated to confirm stability and functionality of the model.

The review of the model included assessing the feasibility of including a 2D surface to the hydraulic model. Given the DWF runtimes and the size and nature of the hydraulic model it was decided that using a connected 2D surface was not practical. The review did confirm that some key overland flow paths are included in the model as 1D elements which improves the 1D functionality of the model.

With validation it was determined that the model would be fit for purpose for development of the Combined System Risk Management Plan. Note that without suitable calibration data the system's hydrology could not be confirmed. Rather a validation process was undertaken to ensure that the modelled results were within the order of magnitude expected during a rainfall event. Any risk-mitigation strategies modelled in order to estimate potential benefits will be presented as a potential percentage of benefits gained based upon the differing pre- and post-mitigation model outputs.

TasWater provided SCADA recordings for two rainfall events that occurred in 2016. This information included:

- pump operation (time/date detail, start, stop and well level)
- rising main flows at:
  - Combined Rising Main (Old + New Margaret Street Pump Station)
  - St John Street Rising Main
  - Combined Rising Main (Ti Tree Bend)

This information complemented existing rainfall data sourced by the City of Launceston. This information was used to validate the Combined System Model (detailed in Appendix B Section 4).

3 Model validation process

The SCADA provided by TasWater for two rainfall events in 2016 has enabled the validation of the combined system model. Selection of appropriate rainfall events was based on the following criteria:

- significant dry period observed prior to rain event (a minimum of four days)
- significant rainfall depth observed (a minimum of 30mm over a 24 hour period, approximately a 1EY 24 hour event)
- complimentary pump station SCADA available for validation

The data provided by TasWater included:

- pump operation (time/date detail, start, stop and well level); and
- rising main flows at:
    - Combined Rising Main (Old + New Margaret Street Pump Station)
    - St John Street Rising Main; and
    - Combined Rising Main (Ti Tree Bend)

It should be noted that one event was chosen for this process due to time restrictions, general completeness of SCADA records and suitability of the rainfall event.

The validation process included:

- simulation of a 72-hour DWF including diurnal variation to provide initial conditions for the sewerage/combined networks and altering of the 1D network where surcharge or ponding occurred in the network and/or at surface level under DWF conditions
- interrogation of the combined pump station rising main configuration and altering of the rising main configuration where inconsistencies occurred
- interrogation of the combined pump operation and configuration (switch on level, duty/stand-by arrangements and pump make and associated head/discharge curves) and alteration of this where inconsistencies occurred
- verification of CSOs (gravity linkages between the sewerage and stormwater networks) modelling configuration
- selection and generation of the validation rainfall event which occurred on 18 March 2016
- simulation of the event and comparison between observed SCADA recordings and modelled system outputs

Please note all changes made within the InfoWorks ICM combined system model as part of this process have been flagged under LCC.

From 4am to 7pm on 18 March 2016, 32.6mm of rain was recorded at the Kings Meadows pluviograph rain gauge. This equates to approximately a 1EY 24-hour rainfall event. This rainfall event was simulated using the updated InfoWorks ICM combined system model. The combined City Rising Main recorded SCADA data was then compared with the modelling outputs at three locations to begin validation of the model. Refer to Figure 38 to Figure 40 for detail.

The figures show good correlation at all three sites, however the modelled New + Old Margaret Street rising main flows tend to be underestimated when compared to the recorded SCADA.

3.1 Rising main and sewer pump configuration

Combined rising main flows were available for the validation process at three locations:

- New + Old Margaret Street Rising Main
- St John Street Rising Main
- Combined Rising Main at Ti Tree Bend

Adjustment was made to the combined system model to ensure a more refined relationship between the observed SCADA flows and the modelled. The changes included changes to the rising main and pump station configurations. These included:

- connection of the New + Old Margaret Street Rising main to the City Rising Main which resulted in additional losses within the modelled rising main and better reflected observed SCADA from the event
- pump operation (flow rate) at St John Street to better reflect observed SCADA
- pump operation at Forster Street to better reflect pump configuration

Please refer to Figure 38, Figure 39 and Figure 40 for detail.

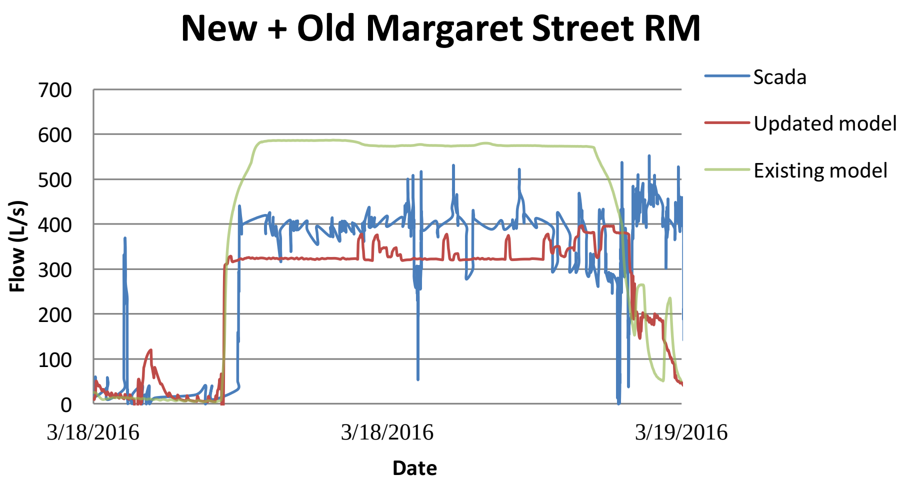


Figure 38: New + Old Margaret St RM

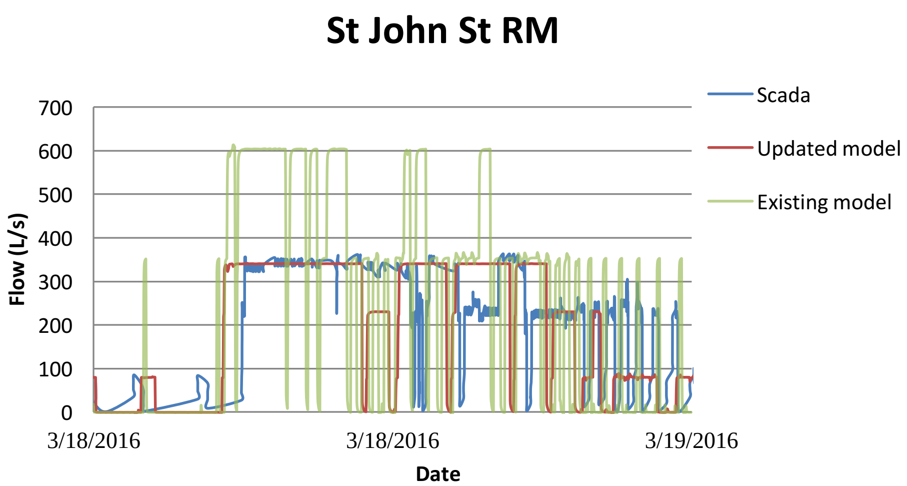


Figure 39: St John St RM

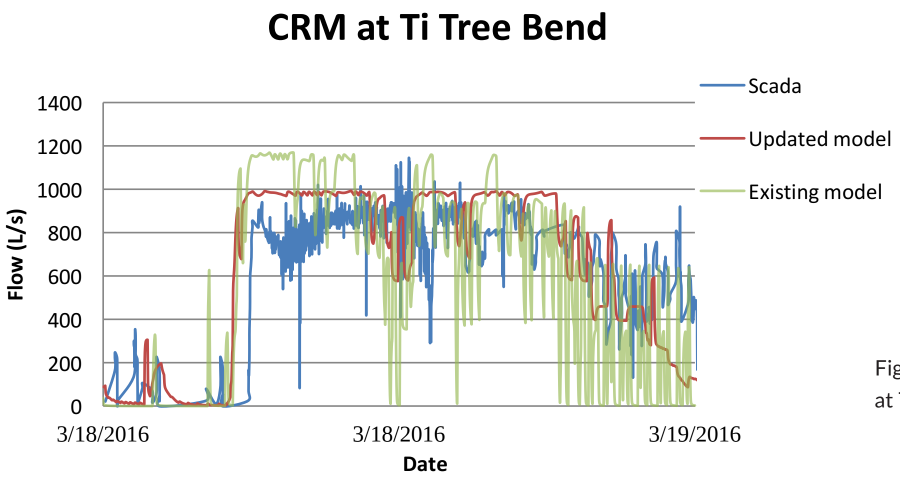


Figure 40: CRM at Ti Tree Bend

3.2 Model hydrology

In addition to the refinements made to the rising main and sewer pump configurations, alterations to the model hydrology were also made. It should be noted that no changes were made to the sewerage flows, base flow or infiltration rates.

Alterations made to the stormwater hydrology included:

- stormwater run-off surface definition (percentage of road, roof and ground) assigned to sub-catchments to better reflect current City of Launceston understanding and associated values. Changes made within the Margaret Street, West Launceston and Esplanade catchments
- stormwater pervious area hydrology parameters (Horton initial 30mm/hr, Horton limiting 2mm/hr and Horton decay 2/hr) as per City of Launceston – Hydrology Parameter Investigation undertaken for the generation of stormwater flood studies
- stormwater impervious area fixed run-off coefficient to a standard 0.90

The model was then run for the March 2016 event and a comparison made between the observed SCADA, the existing model outputs and the updated model outputs. The results of this comparison are displayed in Table 12, Table 13 and Table 14.

Table 12: New Margaret Street combined discharge to Estuary

New Margaret Street Pump Station to Estuary									
	SCADA			Existing Combined System Model			Updated Combined System Model		
Pump	Start	Stop	Run time hours	Start	Stop	Run time hours	Start	Stop	Run time hours
1	NA	NA	0	NA	NA	0	NA	NA	0
2	7:00 AM	2:30 PM	2.99	NA	NA	0	NA	NA	0
3	6:38 AM	7:23 PM	5.71	6:35 AM	9:48 AM	0.21	6:01 AM	4:12 PM	4.87
4	6:42 AM	7:23 PM	3.58	6:23 AM	10:27 AM	2.45	6:16 AM	3:55 PM	2.08
5	7:03 AM	10:38 AM	0.07	NA	NA	0	6:21 AM	6:42 AM	0.25
6	NA	NA	0	NA	NA	0	NA	NA	0
	Total (high flow)		12.35	Total (high flow)		2.66	Total (high flow)		7.20
7	6:34 AM	8:12 PM	11.60	5:51 AM	6:01 PM	7.43	5:24 AM	7:52 PM	13.7
8	6:34 AM	8:12 PM	12.26	5:28 AM	8:07 PM	13.45	5:18 AM	9:26 PM	15.7
	Total (low flow)		23.86	Total (low flow)		20.88	Total (low flow)		29.4

Table 13: Forster Street combined rising main to Estuary

Forster Street Pump Station to Estuary									
	SCADA			Existing Combined System Model			Updated Combined System Model		
Pump	Start	Stop	Run time hours	Start	Stop	Run time hours	Start	Stop	Run time hours
4	6:44 AM	6:26 PM	4.08	6:45 AM	7:28 AM	0.57	6:33 AM	10:20 AM	2.25
5	7:00 AM	8:15 PM	5.86	6:01 AM	5:10 PM	5.2	5:37 AM	5:52 PM	7.03
6	6:17 AM	5:29 PM	5.65	NA	NA	0	NA	NA	0
7	7:00 AM	5:08 PM	6.56	6:22 AM	10:29 AM	3.18	6:04 AM	4:16 PM	4.56
	Total		22.15	Total		8.95	Total		13.84

Table 14: Esplanade stormwater pump stations

Esplanade Pump Stations to Estuary									
Esplanade	SCADA			Existing Combined System Model			Updated Combined System Model		
Pump	Start	Stop	Run time (hours)	Start	Stop	Run time (hours)	Start	Stop	Run time (hours)
Willis St high flow	6:09 AM	7:18 PM	7.07	5:23 AM	5:58 PM	3.51	5:19 AM	6:08 PM	5.48
Tamar St pump 1	6:07 AM	7:26 PM	3.10	5:46 AM	3:28 PM	0.27	5:36 AM	1:03 PM	0.48
Tamar St pump 2	6:07 AM	8:17 PM	2.10	5:25 AM	6:16 PM	3.53	5:21 AM	7:08 PM	4.47
Shields St	6:16 AM	4:44 PM	1.80	6:08 AM	3:28 PM	0.18	5:47 AM	3:45 PM	0.87

4 Gap analysis

This section documents the uncertainties and assumptions regarding the combined-system model-validation process. Noted that due to the nature of this project, full calibration of the combined system model is not possible; rather a validation process was undertaken and documented in the previous section of this appendix to determine the suitability of the model for this process. This section details where information was not available to support this process.

While all sites show an improvement in correlation to observed SCADA as displayed in Appendix B Section 3, due to the significant number of uncertainties remaining in the system, the City of Launceston is reluctant to "tweak" the system hydrology any further. Uncertainties/assumptions include:

- The modelled rainfalls are evenly distributed across the entire catchment, however in reality rainfall within Launceston is highly variable.
- Large catchments (made up of individual sub-catchments) are assigned constant rates of impervious and pervious areas.
- Horton hydrological parameters are based upon Hydrology Parameter Investigation undertaken by City of Launceston and Cardno (2017)[45].
- 1D configuration (particularly asset information including invert levels, pipe sizing material etc.) and associated hydraulic losses.
- Pump discharge rates to estuary are based on theoretical pump curves.

Sewerage flows within the model are assigned per capita at 180l/day/person. Capita numbers are defined within the sub-catchments and the associated sewerage flow distribution is defined by diurnal curves for both commercial and residential areas. The diurnal pattern adopted is in line with TasWater modelling guidelines literature. The flow per capita is in line with TasWater ET statements and TasWater modelling guiding literature. It should be noted however that the monitoring and subsequent calibration of DWFs has not occurred and diurnal curves are assumed.

The first pass validation included running the DWF over a 72-hour period. The primary purpose of this assessment was to identify any sections of the existing model where the network surcharged under DWF conditions. This identified a range of problems within the sewer network which were appropriately amended. This 72-DWF run also provides the initial state for the network when simulating wet weather flow (WWF).

Stormwater is routed to the 1D network when rainfall is applied. The sub-catchments and associated run-off surfaces are assigned values to determine the catchment response. In a similar manner, base flow and infiltration is calculated for both dry weather and rainfall events. Stormwater is generated via rainfall run-off catchments which are subdivided using land-use characteristics such as pervious areas, roof area and impervious surfaces. The rainfall run-off module uses the Wallingford routing model which is an accepted rainfall run-off generation method. Stormwater generation is defined as a separate sub-catchment layer. From review of the rainfall run-off sub-catchments the definition of the surfaces appears reasonable. Some areas required adjustments to the impervious fraction assigned to the sub-catchments and to the pervious run-off parameters. It should be noted that flow monitoring of WWFs has not been undertaken and, therefore, full model calibration cannot be undertaken.

The 1D network is comprised of links (pipes) and nodes (manholes, weirs, pumps and outfalls). Th information contained in these elements dictates how the flow generated from the sub-catchments is passed through the system. The GIS information collected to determine the physical attributes of the network is stored by both TasWater and the City of Launceston and is of varied accuracy. The validation process of the combined system model resulted in minor changes to the 1D network to fix minor issues associated with flow conveyance, and to ensure rising mains and pump operation reflected the SCADA information provided for the two rainfall events that occurred in 2016.

[45] Cardno 2017 Hydrology Parameter Investigation Launceston Stormwater Modelling CG150576 Report R01

5 Conclusion and recommendations

The base model is to be used as a comparison tool to assess proposed mitigation options for the development of the Combined System Risk Management Plan. The improved correlation between modelled and recorded (SCADA) flows within the combined rising main and combined pump operation detailed in this report, provides assurance that the model is fit for purpose due to the validation process undertaken.

Recommendations to further validate the model are:

- Continue to refine the model as the project progresses in the event that inconsistencies or instabilities are observed.
- Undertake further validation for a significant short duration event if suitable SCADA can be sourced.
- Implement continuous flow sampling of combined discharge to the estuary to determine content due to the varied nature of discharge pollutant/pathogen levels (generally speaking more concentrated at the beginning of a rain event).
- Conduct additional flow monitoring to enable critique of the model hydrology and hydraulics.

Appendix C: Location, frequency and magnitude of CSOs

Combined system – Risk management plan

Combined system model

Location, frequency and magnitude of combined system overflows

Executive Summary

In order to identify those Combined Sewer Overflows (CSOs) that spill most frequently and contribute the more significant sewerage loading to the Estuary, a selection of design rainfall events were simulated within the InfoWorks Combined System Model.

The results of the simulated events indicate that 95 per cent of sewage discharged to the Estuary originates in the catchments associated with the:

- New Margaret Street facility including:
  - New Margaret St Combined Rising Main (CRM)
  - Margaret St Brick Barrel
  - Old Margaret St PS Overflow
- Forster St CRM
- The Esplanade-based combined pump stations including:
  - Willis St Combined PS
  - Tamar St Combined PS
  - Shields St Combined PS

It is recommended that these catchments and facilities become the focus for mitigation.

Furthermore, in the development of mitigation options, the mitigation design criteria must be considered and agreed by the Tamar Estuary Management Taskforce and relevant associated technical parties. These criteria or design parameters may include:

- spill frequency (design rainfall events to be considered)
- concentration of sewage within spills (maximum concentration limits)
- total volume of sewage discharged to the Estuary for select design events
- percentage reduction in sewage discharge to the Estuary based on pre- and post-mitigation works

1 Introduction

The Smart Cities Plan: Launceston City Deal signed on 20 April 2017, stipulates the formation of a Tamar Estuary Management Taskforce (TEMT) to facilitate a coordinated and evidence-based approach to address the health of the Tamar River. TEMT will oversee the development of a River Health Action Plan by the end of 2017. The River Health Action Plan will:

- Recommend priority government investments and policy actions.
- Include preferred options for mitigating the effect on the Tamar Estuary of the combined sewerage and stormwater system.
- Enable long-term oversight of the health of the Tamar Estuary and its catchments.
- Identify measurable targets.
- Build on the work of the Tamar Estuary and Esk Rivers (TEER) Partnership led by NRM North, including the 2015 Water Quality Improvement Plan.

While the scope of the River Health Action Plan is at a catchment level, a key direction is noted in mitigating the effect on the Tamar Estuary of the combined sewerage and stormwater system. A validated combined system model will be used in order to quantify proposed mitigation options. For detail regarding the validation process please refer to the model validation report in Appendix B.

The intent of this document is to detail the procedure undertaken to:

- Select the design rainfall patterns.
- Estimate the concentration of sewage within the combined system discharge to the estuary for a range of design rainfall events to define a base case.
- Identify those discharges to the estuary that spill most frequently and contribute the more significant sewer loading to the estuary and therefore will become the focus of prioritised mitigation options.

This report should be read in conjunction with the City of Launceston model validation 2017 report in Appendix B.

2 Design rainfall patterns

The rainfall patterns selected for the interrogation of the combined system discharges are derived from 2016 release of Australian Rainfall and Runoff (ARR 2016). To determine those CSOs that spill most frequently and contribute significant sewage loading to the Estuary, a range of Intensity Frequency Duration (IFD) design rainfall events were selected. Please refer to Table 15 for the selected events and corresponding rainfall depths.

Table 15: Design rainfall depths (mm)

	Exceedance per year (EY)			
Duration	12EY	4EY	2EY	1EY
60 minutes	6.24	7.99	10.0	12.3
3 hours	10.0	12.7	15.8	19
24 hours	19.3	25.2	31.8	38.7

In addition to the selected IFDs, temporal patterns are required to describe how the rainfall is distributed throughout the rain event, ie, the rainfall intensity is not constant for the entire duration. The rainfall is divided into equal time-increments with varied intensities over each increment. For the purpose of identifying which CSOs spill most frequently, and to estimate the concentration of sewage within the discharge, temporal patterns that most linearly distribute the rainfall were selected. Evenly distributed rainfall was selected so as not to skew the loading results to the Estuary. Figure 41 displays the linear nature of rainfall distribution for the three durations selected.

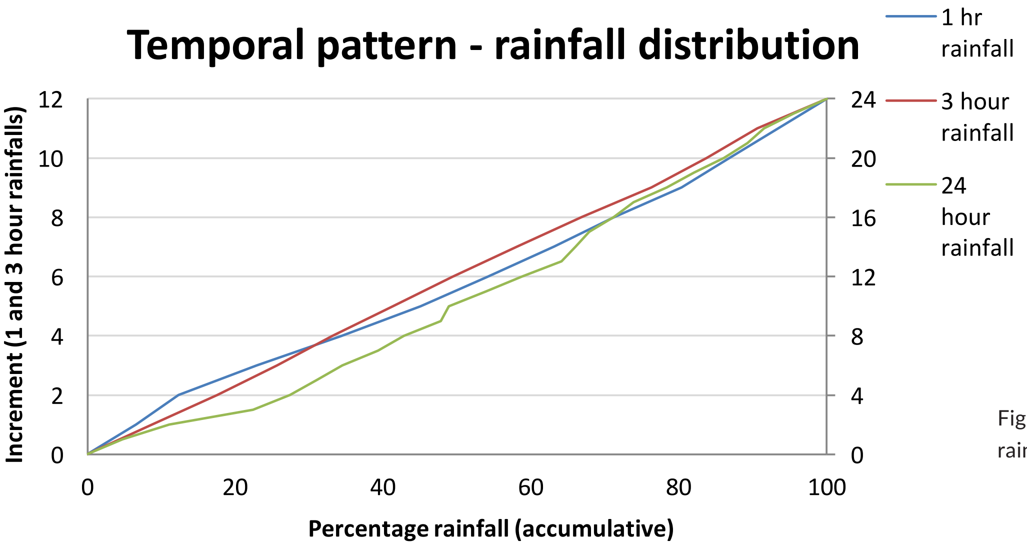


Figure 41: Temporal pattern — rainfall distribution

The corresponding design rainfall events were then generated within InfoWorks to enable simulation. Due to the effect of sewerage diurnal curves, sewerage loading within the combined system varies throughout the day.

For this reason, the one- and three-hour design rainfalls are applied at noon which represents an average loading time within the system. The 24-hour rainfall is applied at midnight and simulated over the course of the day.

3 Sewer concentration within discharge to Estuary

To effectively quantify the benefits of any proposed mitigation option designed to reduce the negative effects of combined system discharge to the estuary it is important to estimate the content of the discharge, ie, the concentration of sewage within total discharge will vary at each discharge point. InfoWorks has built-in water quality functionality which enables a trace pollutant load (PL) to be assigned to flows.

In order to trace sewage flows in the combined system, a PL was assigned to the raw sewage flows (ie, those flows not related to infiltration or rainfall events). It is important to note that this PL enables the estimation of the concentration of sewage within combined flows; it does not represent any "real" pollutant load. The PL selected was 1000mg/L as concentrations within simulated flows in InfoWorks are displayed in kg/m^3, therefore the concentration should not exceed $1kg/m^3$. An indicative plot of the DWF simulation is displayed below in Figure 42. The figure displays the effect of applying diurnal variability to the sewage flows and the concentration of sewage within this dedicated sewer main trending towards one as the system is loaded.

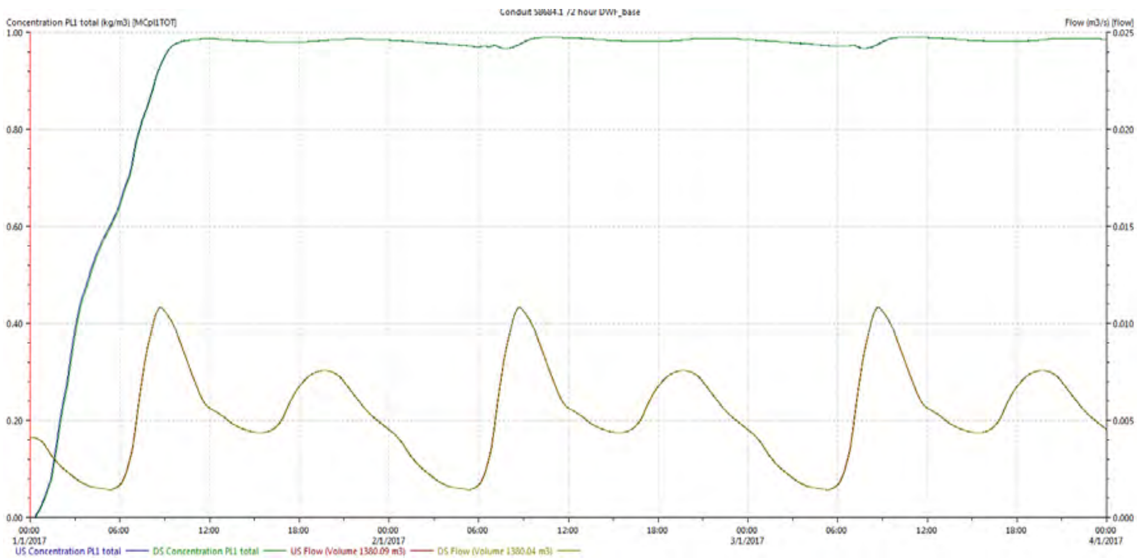


Figure 42: Diurnal variability and sewerage concentration (PL)

When rainfall is applied, the concentration of sewage within the combined network reduces as the stormwater dilutes the flow. Figure 43 displays this relationship within a combined rising main whereas Figure 44 displays the relationship within a combined gravity main.

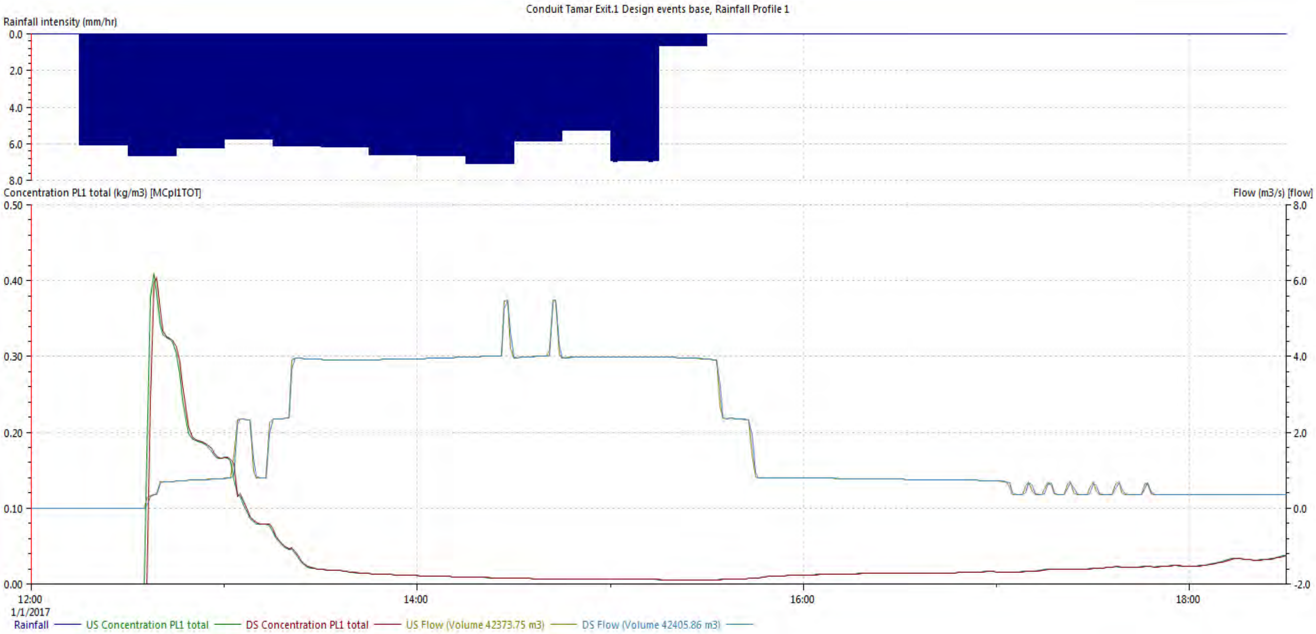


Figure 43: Sewage concentration within a combined rising main to estuary

From Figure 43, it can be seen that when flow within the pipe is zero, the corresponding concentration is also zero. As the combined flow increases due to rainfall, combined pumps operate and discharge to the estuary. Figure 43 displays the “first flush” relationship where higher concentrations of sewerage are present at the front end of the rainfall event.

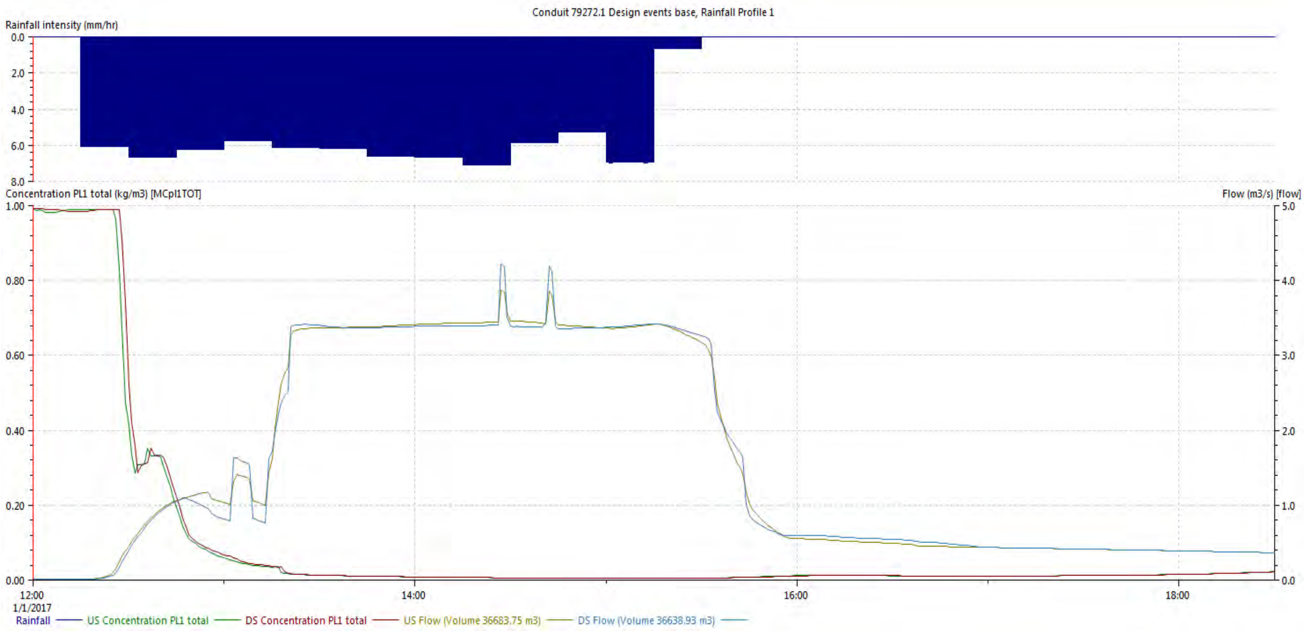


Figure 44: Sewage concentration within a combined gravity main

From Figure 44 it can be seen that when rainfall and subsequent run-off is added to the system, the concentration of sewage within the main decreases as the volume of combined flow increases.

By tracing sewage flows within the combined system, it is possible to identify those discharges to the estuary that spill most frequently and contribute the majority of sewer loading to the estuary and therefore will become the primary focus of prioritised mitigation options. This is further detailed in Appendix D Section 4.

4 Discharge to the Estuary

4.1 Preliminary results

Discharge to the Estuary from the combined system occurs via three distinct methods:

- overflow or bypass from the sewage treatment plant (STP) at Ti Tree Bend
- pumped to the Estuary via combined rising mains
- gravity overflows that link the sewer or combined network to the separated stormwater system

This section does not attempt to quantify the overflow or bypass from the sewage treatment plant (STP) at Ti Tree Bend.

In order to identify those discharges to the estuary that spill most frequently and contribute the more significant sewer loading to the estuary, the design rainfalls as described in Appendix C Section 2 were simulated within the InfoWorks combined system model. A 72- hour dry weather flow simulation (ie, only sewer loading) was used to provide the initial conditions within the network. A mass flow calculation of combined flows to the Estuary was then undertaken to quantify the volume of sewage discharge to the Estuary from each discharge point. The results of this analysis are presented in Table 16, Table 17 and Table 18.

Table 16: 1-hour duration — total sewerage mass flow to Estuary (m^3)

Common name	12EY	4EY	2EY	1EY
New Margaret St CRM	704.4	726.1	747.2	759.7
Forster St CRM	272.6	304.3	323.9	353.3
Old Margaret St PS Overflow	41.2	206.3	247.0	276.7
Margaret St Brick Barrel	290.6	286.3	279.1	268.4
Lytton St SWPS	62.9	161.2	222.9	263.9
Willis St Combined PS	116.8	116.4	109.7	116.4
Tamar St Combined PS	58.0	60.5	65.1	63.5
Shields St Combined PS	15.7	23.6	29.5	39.2
Eastern Outfall	18.1	25.8	33.4	38.9
Hoblers Bridge SW Discharge (South)	36.8	38.7	38.6	36.6
Hoblers Bridge SW Discharge (North)	11.8	13.4	14.7	15.7
Hope St Combined PS	7.6	9.8	11.2	11.5
McKenzie St SW Discharge	0.0	2.2	2.9	3.5
Churchill Pk SW Discharge	0.0	0.0	0.0	1.1

Table 17: 3-hour duration — total sewerage mass flow to Estuary (m^3)

Common name	12EY	4EY	2EY	1EY
New Margaret St CRM	760.0	809.0	846.7	853.3
Margaret St Brick Barrel	360.4	391.0	397.1	380.5
Forster St CRM	233.1	290.0	326.6	354.1
Lytton St SWPS	223.3	269.7	289.7	292.4
Old Margaret St PS Overflow	0.0	7.9	196.6	269.0
Willis St Combined PS	216.4	229.9	257.6	259.4
Tamar St Combined PS	88.5	96.4	101.3	104.1
Hoblers Bridge SW Discharge (South)	36.8	36.3	35.5	41.6
Eastern Outfall	0.5	11.4	25.2	33.7
Shields St Combined PS	5.8	15.2	27.4	33.1
Hope St Combined PS	9.2	15.5	18.5	20.6
Hoblers Bridge SW Discharge (North)	15.4	17.1	18.3	19.0
McKenzie St SW Discharge	0.0	0.0	0.0	4.1

Table 18: 24-hour duration — total sewerage mass flow to Estuary (m^3)

Common name	12EY	4EY	2EY	1EY
New Margaret St CRM	1728.1	1805.2	1731.0	1752.4
Margaret St Brick Barrel	218.7	688.3	1061.8	1189.4
Willis St Combined PS	273.5	489.2	703.8	842.6
Forster St CRM	8.0	20.8	165.3	358.7
Lytton St SWPS	318.1	335.0	338.2	346.8
Tamar St Combined PS	257.8	307.2	330.0	343.4
Hoblers Bridge SW Discharge (South)	41.3	40.6	40.1	39.7
Hoblers Bridge SW Discharge (North)	0.0	0.0	5.3	22.4
Hope St Combined PS	0.0	0.0	0.8	2.2
Shields St Combined PS	0.0	0.0	0.8	1.3

Of those CSOs that spilled during the simulation of the design rainfall events, the percentage contribution of sewerage discharge to the Estuary is contained in Table 19.

Table 19: Design event simulated sewerage discharge (m^3)

Common name	Percentage of total sewerage discharge (%)
New Margaret St CRM	39.9
Margaret St Brick Barrel	17.5
Willis St Combined PS	11.3
Lytton St SWPS	9.4
Forster St CRM	9.1
Tamar St Combined PS	5.7
Old Margaret St PS Overflow	3.8
Hoblers Bridge SW Discharge (South)	1.4
Shields St Combined PS	0.6
Eastern Outfall	0.6
Hoblers Bridge SW Discharge (North)	0.5
Hope St Combined PS	0.3
McKenzie St SW Discharge	0.0
Churchill Pk SW Discharge	0.0
TOTAL	100.0

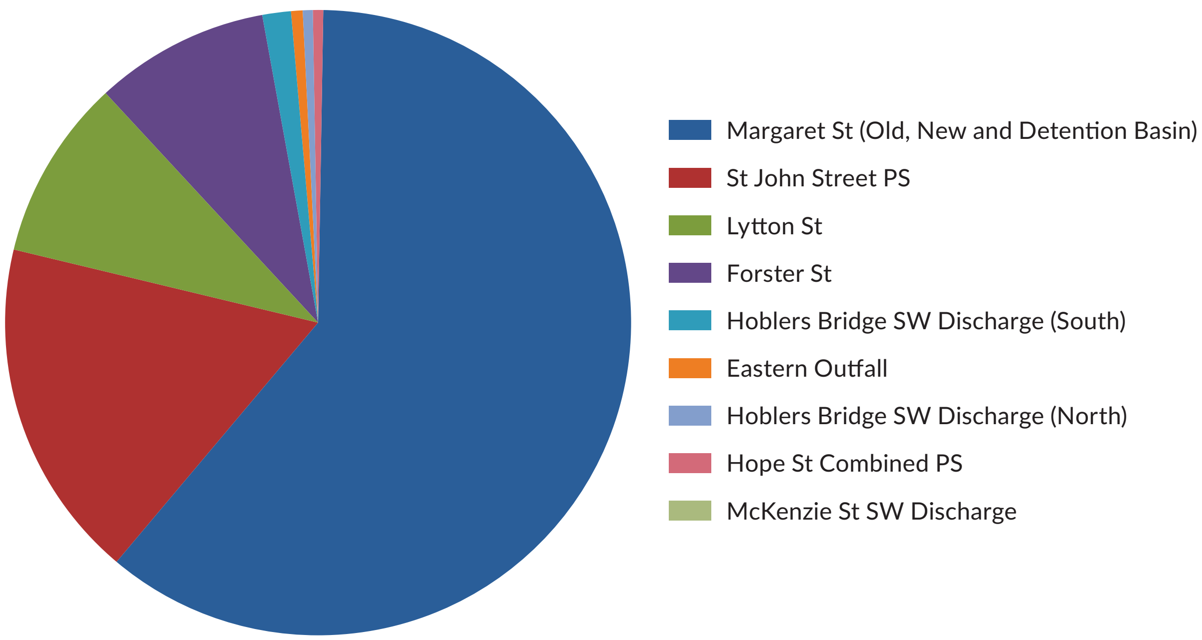


Figure 45: Sewerage discharge

The results tabulated above indicate that 97.3 per cent of sewage discharged to the Estuary originates in the catchments associated with the:

- New Margaret Street facility including:
    - New Margaret St Combined Rising Main (CRM)
    - Margaret St Brick Barrel
    - Old Margaret St PS Overflow
- Forster St CRM
- The Esplanade-based combined pump stations including:
    - Willis St Combined PS
    - Tamar St Combined PS
    - Shields St Combined PS
- Lytton St SWPS*

*At the time of writing this report, the operating (switch on level) of the Lytton St SPS was found to be incorrect causing sewage to spill prematurely to the separated stormwater system.

The results presented in Appendix C Section 4.2 are based on the final base case results.

4.2 Final base case results

This section summarises the final base case results from the modelling process. In thorough negotiation with the Technical Review Committee, the design events were refined to include the following durations: 1-hour, 3-hour, 6-hour and 24-hour with the following recurrence intervals: 24EY, 12EY, 2EY, 1EY and the 20% AEP. Please note, the 24EY is estimated. The same modelling process was undertaken as described in Appendix C Sections 2 and 3.

The CSO locations were collated and summated into five distinct locations:

- Mowbray North
- Forster Street:
- Margaret Street
- Esplanade
- Hoblers Bridge Road

Figure 46: CSO locations

In summary, of the CSOs listed in Appendix C Section 4.2, the modelling shows that three locations contribute a very significant portion (95%) of sewage loading to the Estuary. Table 20 shows the modelling results for the design events listed including sewage discharge and combined discharge.

Table 20: Base case results

TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	476	127	0	75
1hr 12EY	62	711	186	9	192
1hr 2EY	77	925	190	15	233
1hr 1EY	87	982	214	16	258
1hr 20%	106	1089	257	18	303
Total Combined (m^3)					
1hr 24EY	2258	4792	1968	160	722
1hr 12EY	6311	12,684	5175	534	3166
1hr 2EY	11,804	23,173	8880	1103	6078
1hr 1EY	15,196	29,608	11,382	1471	7879
1hr 20%	23,481	45,701	17,366	2366	11,840
Percentage (%)					
1hr 24EY	1.6	9.9	6.5	0.0	10.4
1hr 12EY	1.0	5.6	3.6	1.7	6.1
1hr 2EY	0.7	4.0	2.1	1.4	3.8
1hr 1EY	0.6	3.3	1.9	1.1	3.3
1hr 20%	0.4	2.4	1.5	0.8	2.6

TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
3hr 24EY	37	457	188	0	45
3hr 12EY	48	793	339	12	183
3hr 2EY	80	966	394	26	267
3hr 1EY	96	1068	417	30	298
3hr 20%	131	1246	448	34	321
Total Combined (m^3)					
3hr 24EY	3838	8489	3395	235	841
3hr 12EY	8715	22,635	10,225	788	5117
3hr 2EY	16,751	39,451	16,240	1734	10,092
3hr 1EY	21,595	48,649	19,567	2205	12,798
3hr 20%	34,018	77,257	27,850	3498	18,601
Percentage (%)					
3hr 24EY	1.0	5.4	5.5	0.0	5.3
3hr 12EY	0.5	3.5	3.3	1.5	3.6
3hr 2EY	0.5	2.4	2.4	1.5	2.7
3hr 1EY	0.4	2.2	2.1	1.3	2.3
3hr 20%	0.4	1.6	1.6	1.0	1.7

TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
6hr 24EY	36.8	505.2	264.1	0.0	8.3
6hr 12EY	49	953	435	3	230
6hr 2EY	76	1160	578	38	358
6hr 1EY	97	1246	602	48	402
6hr 20%	147	1496	623	60	440
Total Combined (m^3)					
6hr 24 EY	5432	11,817	4378	308	151
6hr 12EY	11,798	30,935	12,240	738	5967
6hr 2EY	2,0804	55,093	23,851	2076	13,184
6hr 1EY	26,754	67,553	28,777	2753	16,924
6hr 20%	43,018	112,963	40,249	4546	25,802
Percentage (%)					
6hr 24 EY	0.68	4.27	6.03	0.00	5.54
6hr 12EY	0.42	3.08	3.55	0.46	3.86
6hr 2EY	0.36	2.11	2.42	1.84	2.71
6hr 1EY	0.36	1.84	2.09	1.73	2.38
6hr 20%	0.34	1.32	1.55	1.33	1.71

TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
24hr 24EY	48	110	31	0	0
24hr 12EY	49	1020	536	0	34
24hr 2EY	62	1861	1028	4	233
24hr 1EY	77	2101	1183	10	427
24hr 20%	109	2458	1381	32	765
Total Combined (m^3)					
24hr 24EY	8124	2921	2084	437	0
24hr 12EY	16,849	31,564	11,499	1000	772
24hr 2EY	28,539	70,182	27,595	1780	6208
24hr 1EY	35,408	90,866	36,422	2332	12,098
24hr 20%	51,490	139,151	57,063	3812	26,770
Percentage (%)					
24hr 24EY	0.6	3.8	1.5	0.0	0.0
24hr 12EY	0.3	3.2	4.7	0.0	4.4
24hr 2EY	0.2	2.7	3.7	0.2	3.7
24hr 1EY	0.2	2.3	3.2	0.4	3.5
24hr 20%	0.2	1.8	2.4	0.8	2.9

This is further summarised in Figure 47.

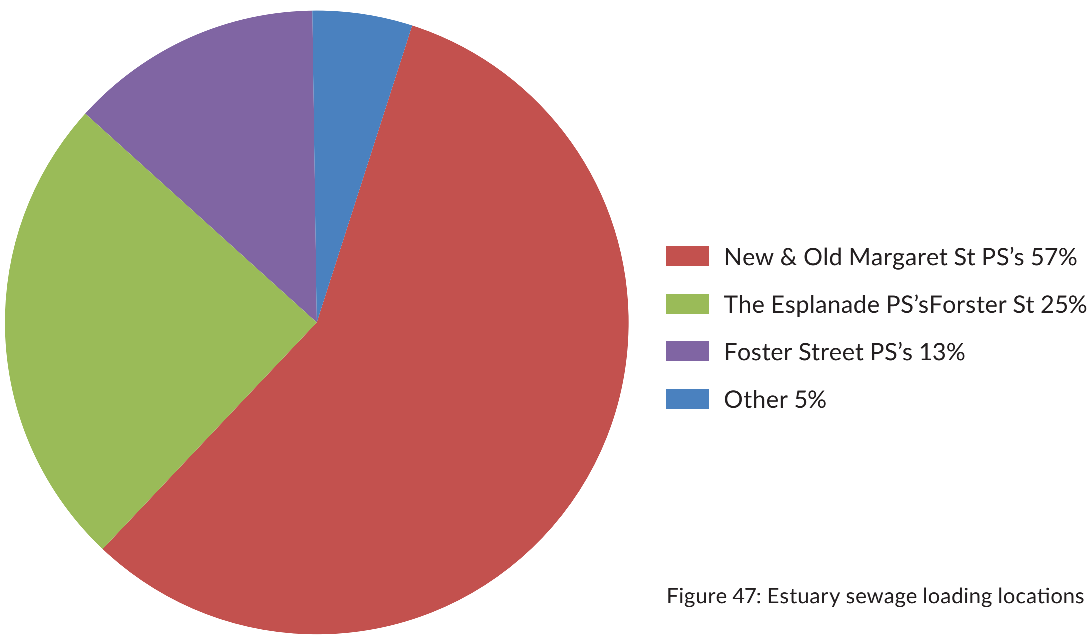


Figure 47: Estuary sewage loading locations

5 Conclusion and recommendation

In line with the scope of this project, it is recommended that the catchments associated with the following facilities become the focus for mitigation:

- New Margaret Street facility including:
    - New Margaret St Combined Rising Main (CRM)
    - Margaret St Brick Barrel
    - Old Margaret St PS Overflow
- Forster St SPS
- Esplanade-based combined pump stations including:
    - Willis St Combined PS
    - Tamar St Combined PS
    - Shields St Combined PS

Furthermore, in developing mitigation options, the mitigation design criteria must be considered and agreed by the Tamar Estuary Management Taskforce and relevant associated technical parties. These criteria or design parameters may include:

- spill frequency (design rainfall events to be considered)
- concentration of sewage within spills (maximum concentration limits)
- total volume of sewage discharged to the Estuary for select design events
- percentage reduction in sewage discharge to the Estuary based on pre- and post-mitigation works

A. Tabulated cumulative model results

Option 1					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	356	127	0	75
1hr 12EY	62	496	186	9	192
1hr 2EY	77	604	190	15	233
1hr 1EY	87	629	214	16	258
1hr 20%	106	690	257	18	303
Total Combined (m^3)					
1hr 24EY	2258	3861	1968	160	722
1hr 12EY	6311	11318	5175	534	3166
1hr 2EY	11,804	21,695	8880	1103	6078
1hr 1EY	15,196	28,010	11,382	1471	7879
1hr 20%	23,481	43,572	17,366	2366	11,840
Percentage (%)					
1hr 24EY	1.6	9.2	6.5	0.0	10.4
1hr 12EY	1.0	4.4	3.6	1.7	6.1
1hr 2EY	0.7	2.8	2.1	1.4	3.8
1hr 1EY	0.6	2.2	1.9	1.1	3.3
1hr 20%	0.4	1.6	1.5	0.8	2.6
Total Sewage (m^3)					
3hr 24EY	37	326	188	0	45
3hr 12EY	48	543	339	12	183
3hr 2EY	80	655	394	26	267
3hr 1EY	96	700	417	30	298
3hr 20%	131	810	448	34	321
Total Combined (m^3)					
3hr 24EY	3838	7076	3395	235	841
3hr 12EY	8715	20,531	10,225	788	5117
3hr 2EY	16,751	37,037	16,240	1734	10,092

Option 1					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
3hr 1EY	21,595	45,887	19,567	2205	12,798
3hr 20%	34018	74078	27850	3498	18601
Percentage (%)					
3hr 24EY	1.0	4.6	5.5	0.0	5.3
3hr 12EY	0.5	2.6	3.3	1.5	3.6
3hr 2EY	0.5	1.8	2.4	1.5	2.7
3hr 1EY	0.4	1.5	2.1	1.3	2.3
3hr 20%	0.4	1.1	1.6	1.0	1.7
Total Sewage (m^3)					
6hr 24EY	36.8	376.0	264.1	0.0	8.3
6hr 12EY	49	654	435	3	230
6hr 2EY	76	792	578	38	358
6hr 1EY	97	837	602	48	402
6hr 20%	147	972	623	60	440
Total Combined (m^3)					
6hr 24 EY	5432	9664	4378	308	151
6hr 12EY	11,798	27,818	12,240	738	5967
6hr 2EY	20,804	51,155	23,851	2076	13,184
6hr 1EY	26,754	63,523	28,777	2753	16,924
6hr 20%	43,018	107,877	40,249	4546	25,802
Percentage (%)					
6hr 24 EY	0.68	3.89	6.03	0.00	5.54
6hr 12EY	0.42	2.35	3.55	0.46	3.86
6hr 2EY	0.36	1.55	2.42	1.84	2.71
6hr 1EY	0.36	1.32	2.09	1.73	2.38
6hr 20%	0.34	0.90	1.55	1.33	1.71

Option 1					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
24hr 24EY	48	72	31	0	0
24hr 12EY	49	704	536	0	34
24hr 2EY	62	1227	1028	4	233
24hr 1EY	77	1382	1183	10	427
24hr 20%	109	1616	1381	32	765
Total Combined (m^3)					
24hr 24EY	8124	2015	2084	437	0
24hr 12EY	16,849	24,397	11,499	1000	772
24hr 2EY	28,539	60,771	27,595	1780	6208
24hr 1EY	35,408	80,600	36,422	2332	12,098
24hr 20%	51,490	127,063	57,063	3812	26,770
Percentage (%)					
24hr 24EY	0.6	3.6	1.5	0.0	0.0
24hr 12EY	0.3	2.9	4.7	0.0	4.4
24hr 2EY	0.2	2.0	3.7	0.2	3.7
24hr 1EY	0.2	1.7	3.2	0.4	3.5
24hr 20%	0.2	1.3	2.4	0.8	2.9

Option 2					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	76	126	0	0
1hr 12EY	62	291	185	9	51
1hr 2EY	77	400	193	15	104
1hr 1EY	87	427	213	16	118
1hr 20%	106	517	257	18	155

Option 2					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Combined (m^3)					
1hr 24EY	2258	1034	1919	160	0
1hr 12EY	6311	7636	5042	534	1387
1hr 2EY	11,804	17,700	8743	1103	3834
1hr 1EY	15,196	23,636	11,110	1471	5353
1hr 20%	23,481	39,362	16,714	2366	8781
Percentage (%)					
1hr 24EY	1.6	7.3	6.6	0.0	0.0
1hr 12EY	1.0	3.8	3.7	1.7	3.7
1hr 2EY	0.7	2.3	2.2	1.4	2.7
1hr 1EY	0.6	1.8	1.9	1.1	2.2
1hr 20%	0.4	1.3	1.5	0.8	1.8
Total Sewage (m^3)					
3hr 24EY	37	59	191	0	0
3hr 12EY	48	260	304	12	42
3hr 2EY	80	431	376	26	103
3hr 1EY	96	497	403	30	126
3hr 20%	131	622	435	34	167
Total Combined (m^3)					
3hr 24EY	3838	2607	3427	235	0
3hr 12EY	8715	14,612	8794	788	1858
3hr 2EY	16,751	30,863	15,217	1734	6020
3hr 1EY	21,595	39,948	18,695	2205	8436
3hr 20%	34,018	67,955	27,128	3498	13,785
Percentage (%)					
3hr 24EY	1.0	2.3	5.6	0.0	0.0
3hr 12EY	0.5	1.8	3.5	1.5	2.3
3hr 2EY	0.5	1.4	2.5	1.5	1.7
3hr 1EY	0.4	1.2	2.2	1.3	1.5
3hr 20%	0.4	0.9	1.6	1.0	1.2

Option 2					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m³)					
6hr 24EY	37	62	254	0	0
6hr 12EY	49	308	482	3	10
6hr 2EY	76	527	548	38	133
6hr 1EY	97	605	577	48	182
6hr 20%	147	771	606	60	246
Total Combined (m³)					
6hr 24 EY	5432	2710	4193	308	0
6hr 12EY	11,798	19,068	13,321	738	390
6hr 2EY	20,804	42,201	22,013	2076	6358
6hr 1EY	26,754	54,497	27,042	2753	9946
6hr 20%	43,018	98,981	37,707	4546	18,379
Percentage (%)					
6hr 24 EY	0.68	2.28	6.06	0.00	0.0
6hr 12EY	0.42	1.62	3.62	0.46	2.5
6hr 2EY	0.36	1.25	2.49	1.84	2.1
6hr 1EY	0.36	1.11	2.13	1.73	1.8
6hr 20%	0.34	0.78	1.61	1.33	1.3
Total Sewage (m³)					
24hr 24EY	48	0	31	0	0
24hr 12EY	49	103	541	0	0
24hr 2EY	62	604	1027	4	14
24hr 1EY	77	783	1201	10	33
24hr 20%	109	1092	1384	32	107
Total Combined (m³)					
24hr 24EY	8124	0	2087	437	0
24hr 12EY	16,849	4969	11,481	1000	0
24hr 2EY	28,539	35,911	27,289	1780	609
24hr 1EY	35,408	54,904	36,460	2332	1667

Option 2					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
24hr 20%	51,490	100,555	56,002	3812	5963
Percentage (%)					
24hr 24EY	0.6	0.0	1.5	0.0	0.0
24hr 12EY	0.3	2.1	4.7	0.0	0.0
24hr 2EY	0.2	1.7	3.8	0.2	2.4
24hr 1EY	0.2	1.4	3.3	0.4	2.0
24hr 20%	0.2	1.1	2.5	0.8	1.8

Option 3					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	0	126	0	0
1hr 12EY	62	59	185	9	51
1hr 2EY	77	140	193	15	104
1hr 1EY	87	157	213	16	118
1hr 20%	106	252	257	18	155
Total Combined (m^3)					
1hr 24EY	2258	0	1919	160	0
1hr 12EY	6311	3436	5042	534	1387
1hr 2EY	11,804	13,500	8743	1103	3834
1hr 1EY	15,196	19,436	11,110	1471	5353
1hr 20%	23,481	35,162	16,714	2366	8781
Percentage (%)					
1hr 24EY	1.6	0.0	6.6	0.0	0.0
1hr 12EY	1.0	1.7	3.7	1.7	3.7
1hr 2EY	0.7	1.0	2.2	1.4	2.7
1hr 1EY	0.6	0.8	1.9	1.1	2.2
1hr 20%	0.4	0.7	1.5	0.8	1.8

Option 3					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
3hr 24EY	37	0	191	0	0
3hr 12EY	48	110	304	12	42
3hr 2EY	80	215	376	26	103
3hr 1EY	96	260	403	30	126
3hr 20%	131	368	435	34	167
Total Combined (m^3)					
3hr 24EY	3838	0	3427	235	0
3hr 12EY	8715	10,412	8794	788	1858
3hr 2EY	16,751	26,663	15,217	1734	6020
3hr 1EY	21,595	35,748	18,695	2205	8436
3hr 20%	34,018	63,755	27,128	3498	13,785
Percentage (%)					
3hr 24EY	1.0	0.0	5.6	0.0	0.0
3hr 12EY	0.5	1.1	3.5	1.5	2.3
3hr 2EY	0.5	0.8	2.5	1.5	1.7
3hr 1EY	0.4	0.7	2.2	1.3	1.5
3hr 20%	0.4	0.6	1.6	1.0	1.2
Total Sewage (m^3)					
6hr 24EY	37	0	254	0	0
6hr 12EY	49	180	482	3	10
6hr 2EY	76	327	548	38	133
6hr 1EY	97	383	577	48	182
6hr 20%	147	526	606	60	246
Total Combined (m^3)					
6hr 24 EY	5432	0	4193	308	0
6hr 12EY	11,798	14,868	13,321	738	390
6hr 2EY	20,804	38,001	22,013	2076	6358
6hr 1EY	26,754	50,297	27,042	2753	9946

Option 3					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
6hr 20%	43,018	94,781	37,707	4546	18,379
Percentage (%)					
6hr 24 EY	0.68	0.0	6.06	0.00	0.0
6hr 12EY	0.42	1.21	3.62	0.46	2.5
6hr 2EY	0.36	0.86	2.49	1.84	2.1
6hr 1EY	0.36	0.76	2.13	1.73	1.8
6hr 20%	0.34	0.56	1.61	1.33	1.3
Total Sewage (m^3)					
24hr 24EY	48	0	31	0	0
24hr 12EY	49	43	541	0	0
24hr 2EY	62	535	1027	4	14
24hr 1EY	77	702	1201	10	33
24hr 20%	109	977	1384	32	107
Total Combined (m^3)					
24hr 24EY	8124	0	2087	437	0
24hr 12EY	16,849	769	11,481	1000	0
24hr 2EY	28,539	31,711	27,289	1780	609
24hr 1EY	35,408	50,704	36,460	2332	1667
24hr 20%	51,490	96,355	56,002	3812	5963
Percentage (%)					
24hr 24EY	0.6	0.0	1.5	0.0	0.0
24hr 12EY	0.3	5.6	4.7	0.0	0.0
24hr 2EY	0.2	1.7	3.8	0.2	2.4
24hr 1EY	0.2	1.4	3.3	0.4	2.0
24hr 20%	0.2	1.0	2.5	0.8	1.8

Option 4					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	0	126	0	0
1hr 12EY	62	59	185	9	0
1hr 2EY	77	140	193	15	15
1hr 1EY	87	157	213	16	18
1hr 20%	106	252	257	18	54
Total Combined (m^3)					
1hr 24EY	2258	0	1919	160	0
1hr 12EY	6311	3436	5042	534	0
1hr 2EY	11,804	13,500	8743	1103	1334
1hr 1EY	15,196	19,436	11,110	1471	2853
1hr 20%	23,481	35,162	16,714	2366	6281
Percentage (%)					
1hr 24EY	1.6	0.0	6.6	0.0	0.0
1hr 12EY	1.0	1.7	3.7	1.7	0.0
1hr 2EY	0.7	1.0	2.2	1.4	1.1
1hr 1EY	0.6	0.8	1.9	1.1	0.6
1hr 20%	0.4	0.7	1.5	0.8	0.9
Total Sewage (m^3)					
3hr 24EY	37	0	191	0	0
3hr 12EY	48	110	304	12	0
3hr 2EY	80	215	376	26	44
3hr 1EY	96	260	403	30	61
3hr 20%	131	368	435	34	85
Total Combined (m^3)					
3hr 24EY	3838	0	3427	235	0
3hr 12EY	8715	10,412	8794	788	0
3hr 2EY	16,751	26,663	15,217	1734	3520
3hr 1EY	21,595	35,748	18,695	2205	5936
3hr 20%	34,018	63,755	27,128	3498	11,285

Option 4					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Percentage (%)					
3hr 24EY	1.0	0.0	5.6	0.0	0.0
3hr 12EY	0.5	1.1	3.5	1.5	0.0
3hr 2EY	0.5	0.8	2.5	1.5	1.2
3hr 1EY	0.4	0.7	2.2	1.3	1.0
3hr 20%	0.4	0.6	1.6	1.0	0.8
Total Sewage (m^3)					
6hr 24EY	37	0	254	0	0
6hr 12EY	49	180	482	3	0
6hr 2EY	76	327	548	38	75
6hr 1EY	97	383	577	48	119
6hr 20%	147	526	606	60	170
Total Combined (m^3)					
6hr 24 EY	5432	0	4193	308	0
6hr 12EY	11,798	14,868	13,321	738	0
6hr 2EY	20,804	38,001	22,013	2076	3858
6hr 1EY	26,754	50,297	27,042	2753	7446
6hr 20%	43,018	94,781	37,707	4546	15,879
Percentage (%)					
6hr 24 EY	0.68	0.0	6.06	0.00	0.0
6hr 12EY	0.42	1.21	3.62	0.46	0.0
6hr 2EY	0.36	0.86	2.49	1.84	1.94
6hr 1EY	0.36	0.76	2.13	1.73	1.59
6hr 20%	0.34	0.56	1.61	1.33	1.07
Total Sewage (m^3)					
24hr 24EY	48	0	31	0	0
24hr 12EY	49	43	541	0	0
24hr 2EY	62	535	1027	4	0
24hr 1EY	77	702	1201	10	0
24hr 20%	109	977	1384	32	66

Option 4					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Combined (m^3)					
24hr 24EY	8124	0	2087	437	0
24hr 12EY	16,849	769	11,481	1000	0
24hr 2EY	28,539	31,711	27,289	1780	0
24hr 1EY	35,408	50,704	36,460	2332	0
24hr 20%	51,490	96,355	56,002	3812	3463
Percentage (%)					
24hr 24EY	0.6	0.0	1.5	0.0	0.0
24hr 12EY	0.3	5.6	4.7	0.0	0.0
24hr 2EY	0.2	1.7	3.8	0.2	0.0
24hr 1EY	0.2	1.4	3.3	0.4	0.0
24hr 20%	0.2	1.0	2.5	0.8	1.9

Option 5					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
1hr 24EY	37	0	17	0	0
1hr 12EY	62	59	56	9	0
1hr 2EY	77	140	60	15	15
1hr 1EY	87	157	68	16	18
1hr 20%	106	252	73	18	54
Total Combined (m^3)					
1hr 24EY	2258	0	300	160	0
1hr 12EY	6311	3436	1874	534	0
1hr 2EY	11,804	13,500	5053	1103	1334
1hr 1EY	15,196	19,436	7547	1471	2853
1hr 20%	23,481	35,162	12,983	2366	6281

Option 5					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Percentage (%)					
1hr 24EY	1.6	0.0	5.7	0.0	0.0
1hr 12EY	1.0	1.7	3.0	1.7	0.0
1hr 2EY	0.7	1.0	1.2	1.4	1.1
1hr 1EY	0.6	0.8	0.9	1.1	0.6
1hr 20%	0.4	0.7	0.6	0.8	0.9
Total Sewage (m^3)					
3hr 24EY	37	0	13	0	0
3hr 12EY	48	110	95	12	0
3hr 2EY	80	215	103	26	44
3hr 1EY	96	260	111	30	61
3hr 20%	131	368	120	34	85
Total Combined (m^3)					
3hr 24EY	3838	0	300	235	0
3hr 12EY	8715	10,412	5334	788	0
3hr 2EY	16,751	26,663	11,179	1734	3520
3hr 1EY	21,595	35,748	13,746	2205	5936
3hr 20%	34,018	63,755	21,002	3498	11,285
Percentage (%)					
3hr 24EY	1.0	0.0	4.5	0.0	0.0
3hr 12EY	0.5	1.1	1.8	1.5	0.0
3hr 2EY	0.5	0.8	0.9	1.5	1.2
3hr 1EY	0.4	0.7	0.8	1.3	1.0
3hr 20%	0.4	0.6	0.6	1.0	0.8

Option 5					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
6hr 24EY	37	0	34	0	0
6hr 12EY	49	180	149	3	0
6hr 2EY	76	327	194	38	75
6hr 1EY	97	383	200	48	119
6hr 20%	147	526	200	60	170
Total Combined (m^3)					
6hr 24 EY	5432	0	465	308	0
6hr 12EY	11,798	14,868	8139	738	0
6hr 2EY	20,804	38,001	16,976	2076	3858
6hr 1EY	26,754	50,297	20,218	2753	7446
6hr 20%	43,018	94,781	30,803	4546	15,879
Percentage (%)					
6hr 24 EY	0.68	0.0	7.27	0.00	0.0
6hr 12EY	0.42	1.21	1.83	0.46	0.0
6hr 2EY	0.36	0.86	1.14	1.84	1.94
6hr 1EY	0.36	0.76	0.99	1.73	1.59
6hr 20%	0.34	0.56	0.65	1.33	1.07

Option 5					
TOTALS	Hoblers	New + Old MS to Estuary	Esplanade PS including Boland, Racecourse, Lower Charles	Mowbray North including Hope St, Home St, Mowbray St, McKenzie St	Forster St to Estuary
Total Sewage (m^3)					
24hr 24EY	48	0	0	0	0
24hr 12EY	49	43	102	0	0
24hr 2EY	62	535	374	4	0
24hr 1EY	77	702	436	10	0
24hr 20%	109	977	562	32	66
Total Combined (m^3)					
24hr 24EY	8124	0	0	437	0
24hr 12EY	16,849	769	5662	1000	0
24hr 2EY	28,539	31,711	19,640	1780	0
24hr 1EY	35,408	50,704	26,495	2332	0
24hr 20%	51,490	96,355	43,863	3812	3463
Percentage (%)					
24hr 24EY	0.6	0.0	0.0	0.0	0.0
24hr 12EY	0.3	5.6	1.8	0.0	0.0
24hr 2EY	0.2	1.7	1.9	0.2	0.0
24hr 1EY	0.2	1.4	1.6	0.4	0.0
24hr 20%	0.2	1.0	1.3	0.8	1.9

Appendix D: International experience

Combined system – Risk management plan

Combined system model

USA

The Combined System Overflow Working Group sought input from an international perspective from a person who was very experienced with combined systems and current trends towards improvement of the outcomes of such systems. The very limited time frame for this project and the further difficulties associated with gaining work a visa focused the search on access via the local GHD office. The group was fortunate to gain the services in Launceston of Richard Roll, Environmental Engineer from the GHD, Buffalo, New York, USA from 18 to 24 October 2017. Richard Roll has extensive experience directing technical services for the City of Niagara Falls, New York, which is about the same population as Greater Launceston. Niagara Falls has a combined system that has completed a long-term control plan to comply with USA's combined system overflow reduction requirements. Richard offers a unique perspective of what the authority goes through in terms of meeting regulatory requirements while controlling cost to the rate payers. The following is the summary report in full from Richard Roll:

Following is a brief description of sewer collection system overflow (spill) abatement planning and implementation generally occurring in America.

Regulatory Drivers

Clean water initiatives in the US stem from the October 1972 Federal Water Pollution Control Act (Clean Water Act), PL 92-500, with subsequent amendments. The US Environmental Protection Agency (USEPA) was created and empowered to promulgate regulations controlling pollutant discharge to the waters of the United States. This impacts both public and private discharges.

The USEPA has developed a discharge permitting system, the National Pollutant Discharge Elimination System (NPDES). These permits are developed for individual (specific) dischargers and account for the assimilative capability of the receiving waters. The permits are generally issued for a five-year period. As the five years come to a close, "major" sources are subjected to a full technical review of their permit, when parameters can be added or changed, and additional requirements can be incorporated. Very often advancing analytical technology and better pollutant impact understanding will lead to tighter restrictions. Anti-backsliding provisions generally keep the reverse (relaxation) from occurring, although a good track record of negligible loading discharge may convert a pollutant from frequent analysis with a hard limit to less frequent monitoring without a hard limit. If the pollutant re-emerges as a concern it may be restored with a hard limit. "Minor" sources may simply go through an administrative renewal, where permittees certify that conditions are essentially unchanged, and are subsequently issued an extension letter authorizing another five-year period with the permit details untouched.

There are many states (not all) in which USEPA has delegated some or all of its permitting authority to the state itself. New York State (NYS) has a partial delegation of authority, and implements its State Pollutant Discharge Elimination System (SPDES) permit management system. The USEPA pays the state for this duty and retains oversight authority. If it becomes dissatisfied with the state's management of the system it can, in theory, take it back, but states strive to work with them so as to not lose the program funding on which they have planned. NYS also charges the permit holders a fee for their administrative efforts. There is a different fee structure for industrial and municipal permits, and it's further scaled by facility rated size. For example, the annual charge for a municipal facility of 180 ML/d is $38,500. If a facility is discharging flow well below their rated capacity it may fall into a lower charge category and can petition for a fee reduction (necessary each and every billing period, annually). If the example plant actually discharges 140

ML/d or less the annual fee would drop to $15,500. If the 140 ML/d discharge were from an industrial source it would cost them $56,000 per year.

Whether one has a NPDES or a SPDES permit, the components and requirements are analogous. They include:

- Identification of facility, owners, legally responsible party (often the highest elected official or executive appointee)
- Location of facility and all outfalls (discharge locations)
- Flow limitations (often a maximum monthly average)
- Individual pollutant limitations, either mass loading and/or concentration-based
- Percent removal of select pollutants, if applicable
- Authorized sampling locations
- Industrial (trade) pre-treatment requirements
- Compliance Schedules for implementing particular programs, for example a Pollutant Minimization Plan (PMP) may require additional monitoring and control activities for specific parameters like mercury, PCBs, mirex, DDT, hexachlorobenzene, BHC's, etc
- Development and implementation of a Capacity, Management, Operation & Maintenance (CMOM) collection system program
- Combined Sewer Collection System Best Management Practices (BMPs)

In addition to specific permit language, there is general environmental law that applies to all dischargers. This has the same legal authority as the permit itself. For example, a permit will contain all the numerical limitations for a given discharge, but environmental law states that, loadings notwithstanding, an effluent discharge may not create a substantial visible contract in its receiving waters. The provision is often overlooked until some kind of problem thrusts it to the forefront.

Reporting on facility performance takes two forms:

- A Discharge Monitoring Report, which is electronic and preformatted, that the permittee completes within 28 days of the monthly reporting period and electronically signs and submits to the state and USEPA database.
- A monthly report, which includes the information above and other permit-required information like chemical use, solids produced, customer backups, spill locations & durations, etc. This is a paper document mailed to the state environmental and public health agencies. Being public documents, the public has a right to request and inspect them at any time.

Violations, or exceedances, of permit parameters must be reported as soon as they are verified, in addition to the regular reporting. Depending on the severity there might be a verbal notification required within 24 hours with a follow-up written report within 5 days. The state has the authority to fine permittees $37,500 per day for each violation, but the penalty is not often imposed. A repeat offender or unusual circumstances may well draw the fine.

Dischargers with chronic noncompliance may find themselves negotiating a Consent Decree or an Order on Consent with the state to address a particular problem. An Order cannot modify a SPDES permit, but can impose its own conditions to affect corrective actions. It may require specific monitoring, studies, work or system improvements, or a combination of all these. There is always a schedule incorporated so as to make a definable (actionable) endpoint. There is also an associated fine to offset the state's legal efforts to compel compliance. Often a portion of the fine is paid up front, with the remainder held in abeyance and eventually forgiven if the permittee properly complies with all the requirements, allowing the Order to be closed out. If properly negotiated, an Order gives an owner time to correct a problem at an acceptable expense, while demonstrating that the state is aware of the problem and is ensuring its proper resolution.

Spill Abatement Programs

The USEPA issued their Nine Minimum Controls guidance to owners/operators of combined sewage collection systems in 1994. NYS incorporated them into the state's 15 Best Management Practices (BMPs). These are written right into particular discharge permits. Although Sanitary Sewer Overflows (SSO's) occur, they have been excised from permits because there was an apprehension that their mere appearance within gave them some legitimacy. SSO's are most commonly handled through Orders on Consent, with the associated specific actions, schedules, and goals. Combined Sewer Overflows (CSOs) are commonly managed through the permit program.

In addition to the BMP's, permits now routinely include a requirement to develop and implement a Capacity, Management, Operation & Maintenance (CMOM) program. The intent is to compel owners to properly care for their infrastructure and achieve its full capabilities before alterations and expensive improvements are considered. Principal measures include:

- **An outfall inspection program.** Regular inspection and documentation of all system outfalls will verify the absence of spills in dry weather. If any are found, public notification and investigative/corrective actions can promptly proceed. Wet weather inspection of outfalls lacking instrumentation is helpful for detecting and following up on unusual sewer system wet weather response behavior.

- **A sewer inspection program.** Video inspection and documentation will reveal cracked & broken pipes, illicit connections, excessive groundwater infiltration, and sediment accumulations along sags and inverse slopes. The industry has a standard rating scale for sewer problems and defects, which can be depicted graphically in CAD or GIS. This helps managers to target problem stretches of sewer main for enforcement actions or repair/rehabilitation projects.

- **A sewer cleaning and flushing program.** Regular cleaning promotes maximization of collection system conveyance, one of the nine minimum controls. Jet flushers will set up in the downstream manhole, propel the flushing head upstream to the next manhole, then high pressure clean back to the set-up manhole. Debris that is collected there is vacuumed out and offloaded into a drainage or containment area prior to final disposal. A planned program of cleaning will rotate through the entire system section-by-section until all stretches are cleaned, then it repeats. The process usually takes several years, unless problem stretches demand more frequent cleaning, or blockages develop which must be addressed promptly.

- **Pumped conveyance.** Malfunctioning or diminishing pumping station performance constitutes an unnecessary system bottleneck that can cause upstream spills. Mechanical condition, hydraulic performance measurement (flow measurement for a given set of shaft rpm's, suction pressures and discharge pressures), and proper instrumentation & control schemes must be periodically verified to maintain optimal conveyance rates.

- **A wet weather response plan.** A series of planned and reviewed procedures for high sewer flow management in wet weather will standardize operator responses and enable effective spill minimization. A typical system behavior would be quantified and pursued as an indicator of a changed condition out in the system that merits attention. In the absence of a calibrated sewer system model, having an accurate representation of the system in GIS becomes very helpful for behavior diagnosis and track-down efforts.

- **A FOG (fats, oil & grease) control program.** USEPA has estimated that about one half of overflows are cause by conveyance obstructions, with about one half of these obstructions stemming from grease build-ups. Most other obstructions take the form of root intrusion and grit/solids deposition. Local sewer use ordinances prohibit the discharge of waste streams or materials that will obstruct, inhibit, or damage the sewer collection system. Ordinances also place specific restrictions on pollutants that will impair the treatment facility operation; implementation of those restrictions is through a detailed Industrial Pre-treatment Program (IPP) permitting system. Large quantities of FOG can originate from restaurants and other food preparation establishments that fail to maintain their grease traps, or multifamily housing with several potential introduction sites that discharge into the sewer main at one connection. Offending customers are cited and fined, with fines increasing with continuing noncompliance. Disconnection from the sewer main or terminating water service are the endpoints to assure compliance if all else fails.

- **Floatables control.** A high priority is assigned to retaining floatables in the system and not discharging them to receiving waters with the liquid spill. Best measures are to keep a good amount of the materials out of the system in the first place. They include regular street sweeping, solids waste collection and adequate public litter receptacles, catch basin (street inlet & drainage structure) cleaning, and basin hood/barrier/trap maintenance. Once the materials are entrained with the flow, the simplest means to affect control involves the intelligent installation of baffles at spill points such as static weirs. Note that this will retain true floatable material, but not materials of neutral buoyancy like certain plastics. Mechanical screens are usually not deployed on their own at remote spill points, but are a part of an off-street facility that incorporates other treatment processes (e.g. solids separation and disinfection) deemed necessary to attain water quality goals.

- **Sewer Connection Offsets.** In subareas where main capacity is diminishing due to peripheral expansion, further expansion may become conditional upon removing a somewhat greater amount of infiltration and inflow from the system. For example, removing X number of downspouts at Y L/s each can enable the construction and connection of Z additional dwelling units on an existing or a proposed main. Some areas prohibit the extension of combined sewer system, and instead require the installation of separate storm and sanitary sewer systems eventually re-joining into an existing downstream combined stretch.

- **Combined sewer separation.** Wholesale separation of a combined system into sanitary and storm systems is tremendously disruptive and financially prohibitive. However, some jurisdictions will not allow replacing a defective combined sewer with a new combined sewer, exempting spot repairs or advancing collapses. A several block length of combined sewer would be replaced with sanitary and storm sewers, with twin connections to each dwelling or trade establishment. Sections ahead and/or behind may remain combined for the time being, but the theory has that all old sewers will eventually need replacement if rehabilitative measures are inappropriate, so that broader and broader portions of the system will have stormwater gradually excluded, lessening spill potential. This presumes consistent climatic precipitation patterns and intensity.

- **Rising main maintenance.** Rising mains are subject to the same problems of gradual accumulation of obstructions to flow that gravity mains are, but are less amenable for inspection and cleaning activities. Pigging or ice pigging is a less disruptive way to accomplish a measure of cleaning without taking the main out of service completely. Maintenance of air release devices at high points is important to prevent air binding that would hydraulically limit flow through the main.

With the operation of a system being brought into good shape, another BMP requires the development of a Long-Term Control Plan (LTCP) for CSO's. The two historical approaches for undertaking this has been a demonstrative approach (involving extensive in-stream sampling and analysis to affirm the attainment of water quality goals) and the presumptive approach, limiting the frequency of spills and assuring at least 85% capture of flows entering the collection system. Even with the presumptive approach, in-stream water quality testing is required to assure goal attainment.

The components of a given LTCP are as varied as the collection systems themselves. That is why a cookie cutter application of measures from a listing will not work, as a systems unique limitations and behavior must be accounted for. It's unusual for a single type of measure to be successful, but rather a coherent, planned combination of measures tailored for a community's needs. Computer modeling of the system is very often incorporated to properly characterize the as-is condition before forecasting the impacts of to-be candidate measures.

Many communities have tightly focused on the measure of removing I/I (infiltration and inflow) from their systems to impact wet weather spill volumes. For each 10 L/s of groundwater removed, another 10 L/s of wet weather conveyance is freed up, as well as reducing 10 L/s worth of dry weather conveyance and treatment facility costs. Naperville in Illinois and Halifax in Nova Scotia have recently cited large degrees of spill reduction through manhole, mainline and lateral structure rehabilitation. Lessons have included the benefits of chemical grouting prior to cured in place pipe (CIPP) renewal, and the potential for infiltration through privately owned dwelling laterals to comprise a large fraction of system-wide infiltration.

Large-scale inline storage of wet weather flows have been widely used in large urban areas. Many systems are built out, with others still being constructed at this time. Locations with large tunnel systems include Chicago (implementing their Tunnel and Reservoir Plan — TARP), Milwaukee in Wisconsin, London, Rochester in New York and Changi in Singapore. Atlanta implemented a combination of sewer separation and in-line tunnel construction. Tunnels under expansion or construction are in Colombo in Sri Lanka and Ottawa in Ontario. St. Louis is planning a 2020 construction start for a 14 km long, 9 meter diameter tunnel.

New inline storage is often constructed using tunnel boring methods. A launch shaft is constructed down to level with back bracing to support the advancement of a tunnel boring machine (TBM). A set of hydraulic jacks steer the TBM along a recalculated, laser-guided route. Plates or panels are emplaced aft of the machine for integrity, and constitute a casing pipe within which a carrier pipe is subsequently installed. The process continues toward the receiving pit. Larger mining machines bore through competent rock, and are finished with concrete, gunite or shotcrete.

Inline storage need not require the construction of new conveyances. Real Time Control (RTC) projects have modified large diameter interceptors to detain a measure of flow until a controlled release to the treatment works may be allowed. This addresses another of the nine minimum controls, maximizing collection system storage. Retrofitting sluice gates have the advantage over weirs of permitting a continual flushing flow along the pipe invert to combat grit deposition during retainage. Buffalo, NY is piloting RTC modifications of their existing conveyances. Ottawa has achieved a 65% reduction in spills using RTC and WSUD (water-sensitive urban design); their tunnel project mentioned above, in year 2 of a 5 year construction plan, has the ambitious goal of attaining complete spill prevention.

Offline storage has frequently taken the form of overflow retention facilities (ORFs). Incoming wet weather flow is screened and/or passed through vortex units before storage in a constructed basin. The basin may incorporate solids collection mechanisms and odor control measures. When the basin is filled, the excess volumes are disinfected prior to discharge, with the retained basin contents being bled back to the treatment works when able. Chlorinated overflows are usually dechlorinated for aquatic specie preservation. NYS is sunsetting the overflow aspects of such facilities. The reservoirs planned for Chicago's TARP would be an offline storage example, taking advantage of existing rock quarries.

A more sophisticated form of spill treatment can add chemically-assisted primary clarification or media filtration to the treatment train. Secondary treatment effluent quality for CSO's is unnecessary, unlike the treatment requirements for SSO's. The physical and chemical processes for CSO treatment are more amenable for rapid start-up and operation during a sudden wet weather event.

One component of some programs, such as Ottawa's, incorporates WSUD. Various implementations are well documented (permeable pavement usage, rain barrels, rain gardens, meridian and margin vegetative growth, etc.) but all seek to dampen first flush impacts on the collection system and even redirect a portion of runoff flows. Such measures are not the primary means in a LTCP, but can be useful in specific subareas and assist in keeping runoff issues in the public eye and evolving public understanding and behavior toward less impactful practices. They are also very applicable to municipal separate storm sewer systems (MS4's), also regulated by federal and state programs. Two of the six MS4 minimum control measures address minimizing runoff impacts during construction projects and post construction maintenance of onsite stormwater improvements.

To sum up, there is a highly evolved and detailed regulatory framework in America that compels point source (discharge outfall) owners to adhere to treatment standards that are properly protective of the receiving waters' intended use. Requirements apply not just to traditional treatment works, but also to spill locations and stormwater discharge points. Owners must undertake a proper characterization and understanding of their systems, which enables them to optimize their operations through many and various means. If spills continue to impair water quality then they must devise a program to mitigate them — not necessarily eliminate them — via constructed improvements. These programs can be simply accomplished in a few years for a few million dollars or less, or they may take decades at a cost in the hundreds of million dollars.

Financing System Improvements

Massive construction for water pollution prevention projects was enabled in the 1970s and 1980s by the USEPA's Construction Grants Program. The typical funding level was a 75% subsidy from the federal government and another 12.5% from the state government. The requirement to attain secondary treatment standards and a program to greatly assist with costs led to significant water quality advancements in a relatively short period of time.

Since then, the construction grants program has ended and was replaced with state revolving loan fund (SRF) programs. Seed funding from the federal government creates pools of funds from which states may issue low cost loans to municipalities for continuing infrastructure improvements. The interest rate paid by borrowers (utilities) is subsidized by the state by about 1/3. The state organizes the bond issuance, which is attractive to purchasers due to the pooled composition with many participants, spreading out investor risk. If interest rates continue downward after closing, as has happened recently, the state may refinance the bonds to lower payments from the borrowers. Grants remain possible for demonstrated hardship cases. When funding applications exceed available funds for a given pool, a priority is determined for each project based on impact, need, regulatory intervention, etc. This need is quantified in a point system. Funds are allocated starting at the highest priority project in a population category and continue down the listing until they are all assigned. This cut-off point is referred to as the funding line; one strives to have their projects rated above the funding line. SRF was also used for ARRA (the American Recovery and Reinvestment Act of 2009) grant fund distribution to "shovel-ready" projects of significance.

Utilities and municipalities may still choose to self-fund wastewater improvement projects, and many do. Those already possessing good bond ratings may judge that the marginal benefit of the subsidized rate does not merit the additional cost and effort required for SRF documentation and participation. Bond issuance may occur regularly or as needed, depending upon the deployment of their capital improvement program (CIP). The individual issuances may be highly detailed project by project or be more generalized. Many owners blend different sources of funding into their CIP, utilizing specific grants and transfer of operation and maintenance budget revenues to lessen the ongoing debt service burden of long-term financing. Wastewater improvement projects that can be demonstrated to also save energy may qualify for rebates from the local energy provider.

Regulations within the village, town, city, or county may create special districts, where the costs of specific sewer improvement projects are borne by those directly benefitting within a subset of the service area. Alternately, many utilities simply take the debt service from any and all improvement projects and equally distribute it among all customers through their pricing structure. Similarly, the cost of storm sewer maintenance is sometimes separately tallied and charged only to serviced customers, or it might be just blended into the combined and/or sanitary sewer service charges.

When considering large expenditures for water or wastewater infrastructure improvement projects, the impact on customer's rates is considered. Project-by-project costs may not be significant, but the cumulative effect on ratcheting up debt service can make it a prominent component of an annual budget, with financing repayments extending out thirty years. The USEPA has developed a general guideline relating water and wastewater charges to the median household income (MHHI) in a particular service area. When the charges grow to beyond 2% to 2.5% of the MHHI, they are judged to be exceeding the affordability threshold. This is not a regulation, but a guideline for local officials."

Richard R. Roll, P.E.
Environmental Engineer

GHD
T: 716 362 8889 | VOIP: 867889 | C: 716 342 9664 | E: richard.roll@ghd.com
285 Delaware Avenue, Suite 500, Buffalo New York 14202 USA | http://www.ghd.com/

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

Thames Water, UK

During a holiday to the UK and Europe in August 2017, City of Launceston engineer Randall Langdon spent a half day with three managers from Thames Water and Tideway to learn from their experience with the "Cleaning up the Thames" project. London still has a combined system. Launceston's combined system was modelled on London's and was commenced just a decade after London's. London did not have modern sewage treatment until after the 1950s and the Thames was considered "biologically dead" until the 1970s. There are strong parallels between the London situation and Launceston – it is just the scale that is different.

Thames Water pursued a multifaceted solution:

- capture of the first flush via detention tanks and storage
- disinfection at overflow points
- trunk interceptor sewers
- treatment plant capacity and quality improvement
- operational improvements to overcome pinch point in their system
- storage in the pipe network
- use of all available green spaces along the Thames for stormwater storage and environmental treatment solutions
- stormwater discharge direct to the river (in lieu of the combined system) if in close proximity to the river
- use of greenfield rates as the allowable stormwater discharge for all new development and major redevelopment (Developer provides for the remainder onsite — eg onsite detention, storage tanks, wetlands, etc)
- "Bin it, don't block" initiative as part of the overall suite of solutions to stop "nasty" solids getting into the sewers (and drains) at the source
- tunnel storage and conveyance system (Thames Tideway Tunnel) to the enlarged treatment plants

Separation, ie, building a new sewer system, was considered but was not viable given the cost, difficulty in finding all the connections, and the disruption to the city. Screening was also considered but was deemed uneconomical, impractical and too labour intensive.

Thames Water, in response to climate change, adopted new policy whereby a development should utilise sustainable urban drainage systems (SUDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible in line with the following drainage hierarchy:

1. Store rainwater for later use.
2. Use infiltration techniques, such as porous surfaces in non-clay areas.
3. Attenuate rainwater in ponds or open water features for gradual release.
4. Attenuate rainwater by storing in tanks or sealed water features for gradual release.
5. Discharge rainwater direct to a watercourse.
6. Discharge rainwater to a surface water sewer/drain.
7. Discharge rainwater to the combined sewer.

The sustainable drainage hierarchy ensures all practical and reasonable measures are taken to manage surface water higher up the hierarchy (1 is the highest) and that the amount of surface water managed at the bottom of the hierarchy, is minimised.

International examples of CSO mitigation options

City	Population	Solutions	Pros	Cons	Cost	Notes
USA						
Connecticut		Separation of system — 15 communities had combined systems, now down to 6. Connecticut has enacted a bill: The public's right to know of a sewage spill 2012 — live webpage notifying of likely spill events. One page fact sheet on history & current status of CSOs for each district that still has combined network.			By 2013, approx USD 1.2 Billion spent on sewer separation in 40 years.	
Hartford, Connecticut	125,000	157ML, 6.6km storage tunnel 60m below the surface	Minimise overflows to local waterways during major storms	Drilling through rock	USD 279.4M	
New Haven, Connecticut	130,000	Separation work near Yale University Treatment plant upgrade to include a CSO wet weather train scheduled for 2013 USD40M upgrade for preliminary treatment (screening, pumping, grit removal) for up to 95 MGD (395ML) — plus existing treatment of micro drum screening + chlorination. All wet weather flows receive full preliminary treatment followed by micro drum screening & chlorination. Green infrastructure to mitigate stormwater flows	Between 1997 and 2015, 66% reduction in average annual CSO volume	Cost Complicated, multi-faceted solution Difficult construction environment (existing infrastructure)	2011 estimate to remove CSOs will cost at least USD 550M	1997: 34 permitted CSOs, 1999 cost to eliminate 0.5ey 6 hour storm USD297 million Currently 24 permitted CSO locations All dry & wet weather flows up to 30M gallons/day (MGD) (113ML) receive 1 & 2 treatment + N removal
Portland, Oregon	640,000	Sustainable Stormwater Program: disconnection of >49000 downpipes, reducing > 4542ML from reaching sewer and reducing CSOs by 10%	Reduced peak stormwater flows by 80-85%, retaining at least 60% of a CSO-causing storm event		USD 2.5M	
Minneapolis, Minnesota	380,000	2005: charged a fee for impervious surface & credits for green infrastructure Sewer separation since 1960s Flood mitigation program to increase stormwater capacity	Large reduction in CSOs to waterways — only two overflow events from 2006 to 2014	Remaining CSOs difficult & costly to separate		
Cleveland, Ohio	390,000	98% of all wet weather flows to be treated before release Construction of 7 x 2.5 mile x 24feet dia tunnels for underground storage	Treatment of wet weather flows Reduction in CSOs	Costly Disruptive	USD 3B	Consent decree with EPA to reduce CSOs by 90%.

City	Population	Solutions	Pros	Cons	Cost	Notes
Detroit, Michigan	680,000 (declining)	In-line storage (as per Hartford & Cleveland) Green infrastructure to mitigate stormwater Drainage Charges for individual landowners — can be reduced by installing green infrastructure	CSOs reduced by >80% from pre-1995 levels	Cost — upgrades and improvements out of reach of a city in economic difficulties Climate change has altered rainfall pattern, increasing CSOs		User Pays: raise funds to treat CSO by charging individual property owners for their stormwater contribution: $750/impervious acre
Saginaw, Michigan	52,000	7 retention treatment basins (227ML storage capacity)	Zero untreated CSO discharges to waterways: primary settlement and disinfection for all overflows Retained stormwater & solids sent to STP	Cost	USD 110M	
Omaha, Nebraska	500,000	Improvements to STP to treat 150M gallons per day during wet weather (680ML) — 64MGD full secondary treatment, remainder disinfected prior to discharge to Missouri River Extensive sewer separation CSO Tunnel 5.4 miles x 17 feet dia (5100mm) Two high rate treatment units (Retention Treatment Basins) Two storage tanks Green Solutions Program — important element — large-scale centralised stormwater management to save >$30M in grey infrastructure for CSO controls Largely passive, trying to replicate hydrologic response of natural systems	Approx 94% of average annual volume of combined would be controlled ≤4 CSO events per year Deactivation of nine of the 29 CSO outfalls Modelling indicates Missouri River in compliance with rec water standards during recreation season (E. coli 126/100mL)	15 year implementation Cost — 2006 $10 per month for residents; 2014 $37; 2018 >$50. These costs do not include impacts from new regulatory requirements	USD 1.66B in 2009	45sq miles, 790 mile wastewater collection; 480miles is combined conveyance; city's total wastewater service area is 333sq miles
Valparasio, Indiana	32,000	Disinfection of up to 100M gallons (379ML) per day — tank holds up to 4.5MG (17ML); screened and chlorinated 5 year Stormwater Control Plan — staged separation for Connor Creek CSO Control Facility — 30MG screening and disinfection.	Removed 50.5MG of stormwater from combined system		USD 2.35M in 2012 USD14M	

City	Population	Solutions	Pros	Cons	Cost	Notes
European Union and the United Kingdom						
EU Water Framework Directive 2000		Water management by river basin based on the natural geographical and hydrological unit — not on administrative or political boundaries.				River basin management plan — detailed account of how objectives are set for the basin (ecological, quantitative status, chemical status, protected area objectives).
London, England	8,788,000	Upgrading 6 STPs across London Construction of the Tideway Tunnel: 25km long interception, storage and transfer tunnel up to 66m below the River Thames.	Improved effluent quality Predicted reduction of CSO volume by more than half	Large-scale project with long timeframes 7-year construction Cost	GBP 717M GBP 13B	Tideway project has a strong community and education focus, and WSUD in conjunction with the hard engineering solutions
Western UK & Wales		Construction of STPs in major centres such as Blackpool Carnforth: underground stormwater tank to reduce sewer spills into the River Keer Blackpool South Strategy: extension of outfall to 1km offshore; separation of sewerage & stormwater, construction of additional storage for CSS Ribble and Wyre Rivers Trust — to understand and manage diffuse inputs from agriculture	More capacity to treat sewerage Reduced likelihood of CSOs Improved water quality for recreation and aquaculture Manage diffuse pollutants	Cost Major capital works disruptive to commercial and tourism ventures	GBP 1B over 25 years GPB 7M GBP 1.5M	1271ML daily, 72,000km of pipeline CSO reduction strategy varies depending on source of pollutants for each town — process managed by United Utilities CSOs to the environment regulated by the Environment Agency

City	Population	Solutions	Pros	Cons	Cost	Notes
Canada						
Winnipeg	>700,000 people	Online sewer overflow information system for community CSO Management Strategy 2002 Monitoring Program to identify and quantify CSO events Proactive elimination of wet weather flows from the combined sewer district through infrastructure upgrades Regulated by the Province of Manitoba through the Environment Act	Contribute to general wellness of community through improved perception. Modest WQ improvements.	CSO control found to be costly, with benefits difficult to quantify	>CAD 290M since 1970	Hydraulic model of CSO outfalls found that most cost-effective options include storage, esp in-line storage 1,037km of combined sewers, 77 outfalls to the river, an average of 22 CSOs per year
Sarnia, Ontario		Near-surface tanks for storage Upgrading of STPs Separation of 15km of combined sewer network Automated flow meters to improve flow management and reduce need for bypass to river	Reduced CSO volume by 50% since 2000 Restoration of 165ha of wetland and 2km of nearshore fish habitat	Cost Numerous stakeholders, including across the border with the USA	CAD 70M	St Clair River declared an Area of Concern in 1985 Actively working with agricultural sector to also reduce diffuse pollution
Toronto, Ontario	2,700,000	Near-surface tanks for storage City by-law — any new roof >2000sqm is required to install a green roof.	Mitigate storm flows, capture nutrients and pollutants, provide habitat for insects & birds, mitigate urban heat-island effect. By-law created instant demand and requirement for education, research and upskilling of consultants and installers	Mandated. Relies on legislation and regulation — and ensuing professional practice, technology and education. Green roofs >8 storeys high have lower ecosystem benefits. Embedded costs of maintenance Perceived conflict with solar power generation		

Appendix E: Mitigation options development

Combined system improvement

Project "Logic"

The basic objective of the Combined System Project is to improve the health of the rivers and Tamar Estuary by removing or reducing the volume of sewage discharged to the rivers from combined system (sewage) overflows.

The combined system comprises the vast majority of the Ti Tree Bend STP catchment, as shown on TasWater Drawing No. TWA-16-0411. There are currently about 10,590 ETs in the Ti Tree Bend STP catchment. Within this catchment there are significant sub-catchments which have a separated sewerage system, but these sub-catchments discharge back into the combined system. During dry periods all flows (sewage and permanent groundwater infiltration) are pumped to the Ti Tree Bend STP for treatment. However during rain events, flows that exceed the capacity of the collection system or pumps are discharged (as combined sewer overflows – CSOs) to the rivers or estuary.

The above is summarised in Table 21

Table 21 Equivalent tenements per catchment

Sub-catchment	Total ETs in sub-catchment	Separated ETs in sub-catchment	% separated ETs in sub-catchment	Comments
Margaret Street	10,590	3371 (West Launceston and Trevallyn)	32%	Can be directly connected to the STP (diverted from combined system).
Esplanade/St John Street	8257	3101 (Kings Meadows/Newstead and Boland Street)	38%	Can be directly connected to the STP (diverted from combined system).
Forster Street	2526	45	2%	
Hope Street	1202	961	80%	
TOTALS	22,575	7478	33%	

Removal of 100 per cent of the sewage from the existing combined drainage pipe network (full separation) would require construction of a separate sewage-pipe network, and associated pump stations and rising mains. As indicated above some sub-catchments already have a separate sewage-pipe network. The estimated cost to construct a "complete" separated sewage system is estimated at about $435M. This estimate takes into account the existing separated sewer network (West Launceston/Trevallyn and Kings Meadows/Newstead) within the Margaret Street and Esplanade sub-catchments.

Removing the sewage from the combined system will not remove all the pollution from the catchment to the rivers and estuary, as there is a significant pollution load in stormwater — particularly in the "first flush" of stormwater after dry periods, when significant pollution from oil and grease, sediment, dog and animal faeces, papers, cans, etc. is "washed" from roads and surrounding surfaces into the stormwater-pipe network. Ideally this should be treated. The existing combined system will "catch" this stormwater first flush and transport it to the STP for treatment. This would not happen in a conventional separated sewerage system.

TasWater is planning to implement the Launceston Sewerage Improvement Program (LSIP), although there is currently no “firm” timeline. LSIP will de-commission six SPTs in the Greater Launceston area and replace these with a new STP at the Ti Tree Bend STP site, with new transfer systems comprising pump stations and rising mains at each current STP. LSIP will include the connection of all currently separated sub-catchments to the new transfer systems. **Hence LSIP will remove about 7478 ETs (partial separation) from the existing combined system, ie, remove 33 per cent of the sewage load. The estimated cost of the LSIP project is about $180M (Stage 1), which comprises a new STP as well as new transfer systems from the six STP sites.**

LSIP is shown on Drawing Nos. TWP-15-145-002 and 260.There are other lower cost alternatives or parts of the LSIP which will reduce the volume of sewage discharged to the rivers from combined system sewer overflows, as discussed below.

Hydraulic modelling of the combined system undertaken by the City of Launceston indicates that three sub-catchments of the system contribute about 74 per cent of the total discharge to the river from the CSOs. The major combined system catchments discharging to the rivers are set out below. The volumes and percentage below are for the 1-hr 2EY rain event:

- Margaret Street = 23.1 ML (45%)
- Esplanade (St John Street, Shields Street, Tamar Street and Willis Street) = 8.9 ML (17%)
- Forster Street/Invermay = 6.1 ML (12%)
- Remaining areas (Hope Street, Newstead etc) = 26%
- Lower cost CSO reduction alternatives (to full separation, and LSIP/partial separation) are discussed below.

A. Remove separated sub-catchments in West Launceston and Trevallyn.

The separated 3371 ETs in the West Launceston and Trevallyn areas could be readily diverted directly to the Ti Tree Bend STP by constructing part of the proposed LSIP transfer system for Prospect Vale STP, at a cost of about $4.6M (LSIP estimate). The extent of pipework would be as described in the LSIP Drawing Nos. TWP-15-045-265 and 331 to 335, and would comprise a new DN400PE100PN16 pipeline from Penny Royal to the STP.

Hydraulic modelling shows that this will reduce river contamination by about 19 per cent.

This alternative would not require any upgrade works to the Ti Tree Bend STP as this flow is currently discharged to the STP via the Margaret Street Pump Station (where it will partly overflow to the Tamar River during rain events).

This is a relatively low (compared to LSIP) cost alternative which significantly reduces combined sewage overflows to the Tamar River, and can be quickly implemented. This option removes 3371 ETs from the combined drainage catchment, ie, it removes about 20 per cent of the ETs from the catchment.

B. Remove separated sub-catchments in Kings Meadows/Newstead/Boland Street area.

The separated 3101 ETs in the Kings Meadows/Newstead/Boland Street areas could be readily diverted out of the combined system and directly to the Ti Tree Bend STP. This was proposed as part of the LSIP project by diverting the South Launceston Trunk Sewer to the Hoblers Bridge Transfer Pump Station, and also diverting the Boland Street Area into the Hoblers Bridge Transfer Pipeline.

This could be undertaken at an early “stage” (prior to the construction of LSIP), by constructing a pump station in the vicinity of Black Bridge/Boland Street area, and extending or upgrading the South Launceston Trunk Sewer from Hoblers Bridge Road to the new pump station, and upgrading or diverting the Boland Street separated sewer area to this pump station. A new rising main would need to be constructed to the Ti Tree Bend STP from the pump station, which would become part of the proposed LSIP Hoblers Transfer Pipeline.

The pump station would be the central part of the proposed Willis Street Overflow Storage Tank as described in Option E below.

The pump rate would need to achieve the self-cleaning velocity in the rising main which would be (over)sized for future LSIP flows.

This will remove about 3326 ETs from the Esplanade/St John sub-catchment and significantly reduce river pollution from CSOs during rain events.

The existing South Launceston Trunk Sewer west of Hoblers Bridge Road is undersized and overflows during high rain events. The new South Launceston Trunk Sewer extension or upgrade could be constructed adjacent to the existing combined drain, but clear of private property. This would likely be DN450 to cope with a design flow of 7 X ADWF = 88.7 L/s (LSIP Preliminary Design Report). The new South Launceston Trunk Sewer extension would operate as a pressure gravity pipeline from between Lyttleton Street and the pump station.

This alternative would not require any upgrade works to the Ti Tree Bend STP as this flow is currently discharged to the STP via the St John Street Pump Station (where it is will partly overflow to the North Esk River during rain events).

This is a relatively low (compared to LSIP) cost alternative which significantly reduces combined sewage overflows to the Tamar River, and can be quickly implemented.

The estimated cost of this option is about $18.1M as shown below:

- South Launceston Sewer Upgrade (separated sewers diversion) = $4.2M
- Boland Street Separated System diversion works (part of LSIP) = $1.6 M (LSIP estimate)
- Esplanade Overflow Storage Pump Station = $5.3M (part of Esplanade Overflow Storage)
- DN710PE100PN16 rising main from pump station to STP = $7M (LSIP estimate)

TOTAL = $18.1M.

C. Increase low flow (sewage) pump rate from New Margaret Street Pump Station (NMSPS).

This is discussed in the October 2001 GHD report Decommissioning of the Old Margaret Street Pump Station. The works include the decommissioning of the Old Margaret Street Pump Station (OMSPS) and diverting these flows to the NMSPS, **and increasing the combined low (sewage) flows to the STP from about 400 L/s to about 800 L/s.**

The estimated cost of this alternative is about $3.4M based on inflating the 2001 GHD report estimate of $1.9M at 3.5% PA. (Some of the proposed works included in this estimate may have already been undertaken).

It is not practical to increase the capacity of the existing City Rising Main (to the STP) by 400 L/s, hence it will be necessary to install a new rising main to the STP to accommodate the total flow from the Margaret Street sub-catchment, ie, about 800 L/s. This would likely require a DN900PE100PN16 pipeline. This would provide the following benefits to the existing system:

- reduce the flow/pressure in the existing, old RC City Rising Main
- enable a greater flow to be pumped from the Forster Street Pump Station, and the St John Street Pump Station thereby reducing CSOs from these sub-catchments
- provide an alternative pipeline to the STP (to the existing sole City Rising Main to the STP), ie, provision of redundancy to a critical piece of infrastructure

The new rising main route would likely follow the alignment of the existing rising main across Kings Park/ Royal Park, across the Charles Street Bridge and then follow the LSIP Transfer Pipeline route to the STP.

To achieve the “full benefit” of this increased flow it will be necessary to provide overflow storage at the Ti Tree Bend STP so that the additional volume pumped to the STP is not “overflowed” to the Tamar River at the inlet works to the STP during high inflow periods. (Refer Option I).

A “low cost” refinement of this alternative would be to connect the rising main from the Margaret Street Pump Station to the LSIP transfer system for Prospect Vale STP. This could connect to the Prospect Vale Transfer Main adjacent to Penny Royal. The Prospect Vale Transfer Main could not accommodate the total flow from Margaret Street Pump Station (without significantly increasing the size of the main), but it would provide an alternative or emergency discharge option in the event that the City Rising Main was out of service.

The estimated cost of this option is about $11.8M as described below:

- Increase pumping rate to 800 L/s and decommission ONSPS = $3.4M (Inflated GHD 2001 Report)
- DN900PE100PN16 Rising main from MSPS to Ti Tree Bend STP = $8.5M
  TOTAL = $11.8M

D. Provision of overflow storage — Margaret Street sub-catchment.

In addition to increasing the pumping capacity of the low or sewage flow pumps from the Margaret Street Pump Station and Margaret Street sub-catchment (as discussed in Option C above), and the diversion of the separated West Launceston and Trevallyn sub-catchments (as discussed in Option B above), additional storage can be provided to the pump station to store more of the first-flush flows, thereby reducing the quantity of the more highly sewage-contaminated stormwater overflow to the Tamar River during rain events.

The only location close to the existing NMSPS is immediately to the west of the NMSPS in Kings Park between the levee and the Tamar River. This means that the storage is on the river side of the levee. It is unlikely that the existing levee could be moved to beside the river to protect the storage from flooding as the ground is known to be “less stable” close to the edge of the river.

The Launceston Flood Authority is very reluctant to allow pipelines through levees for reasons of levee damage and flood protection. Isolating valves would be installed on pipes through the levee (between the NMSPS and the storage) so the pipes can be "closed" during flood-risk periods.

The overflow storage would be a circular reinforced-concrete-covered underground tank located in the park immediately to the west of the existing New Margaret Street Pump Station, with gravity inlet and outlet pipelines from the NMSPS.

The objective would be to enable gravity overflow into the storage from the existing pump station, with gravity drainage back to the existing pump station at low pump well level (or pump back to the existing pump station if the base of the storage is lower than the gravity discharge level to provide more storage volume). The site's dimensional constraints would limit the overflow storage tank diameter to about 25 metres. A storage volume of about 4.2 ML can be provided.

The estimated cost of the 4.2 ML overflow storage is about $10M, but this estimate is subject to geotechnical conditions and constraints of the site.

E. Provision of overflow storage and increased pumping — Esplanade/ St John Street (Willis Street) sub-catchment.

The St John Street sub-catchment comprises a series of sub-sub-catchments draining the area approximately east of Talbot Road/George Street in the west, to approximately Elphin Road in the east, and from Sandhill in the south, to the Esplanade/North Esk River in the north.

During rain events low or sewage flows are directed in a northerly direction to the Esplanade, and then along the Esplanade to the St John Street Pump Station where low or sewage flows are pumped to the Ti Tree Bend STP.

During rain events a series of stormwater overflow pump stations (at Shields, Tamar and Willis Streets) lift (sewage contaminated) stormwater over the levee banks into the North Esk River to minimise the risk of flooding to the lower-level areas of Launceston. These CSOs during rain events result in (sewage) contamination of the North Esk or Tamar rivers.

These overflow pump stations (Shields Street, Tamar Street and Willis Street) are located partly within the flood levee between the Esplanade pavement edge and the river, hence there is negligible space available to construct any significant storage tank(s). The construction of any structure in this area would also be likely to create a significant risk to the flood levee stability.

Additional storage can be provided in the vicinity of the Willis Street Overflow Pump Station to store more of the first-flush flows from about 80 per cent of the Esplanade/ St John Street sub-catchment thereby reducing overflow of the more highly sewage-contaminated stormwater to the North Esk River during rain events. The reasons for providing this at or adjacent to the Willis Street Overflow Pump Station are as follows:

- The Willis Street Overflow Pump Station contributes about 60 per cent of the Esplanade/St John Street sub-catchment CSOs.

- The construction of any structure in this area would create a significant risk to the flood levee stability. Land is potentially available for the construction of an overflow storage in the Boland Street vicinity, which is reasonably close to Willis Street.

The estimated cost of a 3ML covered overflow storage (to the pump station as described in Option B) is about $5.7M (in addition to the cost of the pump station) allowing for diversion of the existing flood levee and associated rail-line flood gates.

The overflow storage would be a circular reinforced-concrete-covered underground tank located in the Boland Street/Black Bridge area to the east of the existing Willis Street Overflow Pump Station. Discharge from the storage would need to be pumped to the Ti Tree Bend STP, and would form part of the future LSIP Hoblers Bridge transfer pipeline, as described in Option B above.

It is proposed to divert the trunk combined drain from the Willis Street Overflow Weir Manhole into the proposed Esplanade Overflow Storage. This could be achieved by installing a low height weir in the manhole, at a level just below the overflow weir, to divert the low or sewage flows away from the Willis Street/Esplanade sewer and into the new Esplanade Overflow Storage. This pipe would likely be DN450 graded at about 1 in 600.

Another option would be to provide a DN375 diversion from the trunk collection pipeline along Racecourse Crescent at a higher level to allow pressure gravity discharge into the storage.

The estimated cost of this option is about $6.7M as shown below:

- Esplanade Overflow Storage (3ML) = $5.7M (also refer Option B)

- DN450 overflow diversion from Willis Street Overflow Weir Manhole = $1M

TOTAL = $ 6.7M

This overflow from the Willis Street/Esplanade area will be pumped to the Ti Tree Bend STP via the pumps and rising main constructed as Option B above.

F. Provision of overflow storage — Forster Street sub-catchment.

Additional storage can be provided to the existing pump station to store more of the first-flush flows from the Forster Street sub-catchment thereby reducing overflow of the more highly sewage-contaminated stormwater to the Tamar River during rain events.

The only "space" available in the vicinity of the existing Forster Street Pump Station is an "unused" privately owned rectangular area (about 25m X 45m) immediately to the west of the existing pump station. To maximise the storage volume it would be necessary to construct a rectangular reinforced- concrete-covered underground tank with gravity inlet and outlet pipelines. Due to the small area available, and the soft ground conditions, it would be necessary to construct the storage as a (rectangular) caisson. A storage volume of about 2.5ML (15 X 44, 7m deep) would likely be possible on the site, and is estimated to cost about $11M. The cost is "high" due to the confined site and difficult ground conditions. The structure would need to be supported on piles. The risk with this option is the difficulty of sinking such a large rectangular caisson.

A lower risk option would be to construct two conventional circular caissons with a combined storage volume of 2.5ML. Each caisson would be about 18 metres ID X 7.5 metres deep. The estimated cost of this alternative is about $8.4M.

G. Provision of increased pump rate — Forster Street sub-catchment.

In the event that a new (DN900PE100PN16) rising main is installed from the NMSPS (as discussed in C above), there would be spare capacity in the existing City Rising Main to significantly increase the pump rate from the Forster Street Pump Station by operating the existing (sewage) pumps as DUTY/ASSIST instead of DUTY/STAND-BY. Hence it would be possible to reduce CSOs from the Forster Street sub-catchment by simply increasing the pump rate from about 220L/s (currently) to about 400L/s. This pump station was originally designed to discharge about 400L/s, but TasWater has reduced the pump rate to about 220L/s.

This would provide a significant reduction in CSOs at a low or nil cost.

Alternatively a new rising main could be constructed between the Forster Street PS and the STP.

H. Provision of increased pump rate — St John Street sub-catchment.

In the event that a new (DN900PE100PN16) rising main is installed from the NMSPS (as discussed in C above), there would be spare capacity in the existing City Rising Main to significantly increase the pump rate from the St John Street Pump Station by operating the existing pumps as DUTY/ASSIST instead of DUTY/STAND-BY. Hence it would be possible to reduce CSOs from the St John Street sub-catchment by simply increasing the pump rate from about 420L/s (currently) to about 600L/s.

This would likely require the upgrade of the existing DN450 rising main to DN600, as well as the replacement of at least two pumps.

This would provide a significant reduction in CSOs at an estimated cost of about $1.50M.

I. Provision of overflow storage at Ti Tree Bend STP.

The existing Ti Tree Bend STP treats wastewater from the Launceston combined system, as well as the separated sewer areas in West Launceston, Trevallyn, Kings Meadows and Newstead (which discharge to the combined system), as shown on TasWater Drawing Nos. TWA-16-0411 Sheets 1 and 2.

The capacity of the Ti Tree Bend STP is as follows:

- screening and de-gritting = 200ML/d (2 No. channels/screens)
- primary sedimentation = 65ML/d
- aeration/chlorination = 45ML/d

Current Average Dry Weather Flow = 24.5ML/d

Pumping capacity to the STP/peak inflow is about 120ML/day, ie, 1400L/s.

The LSIP program will enable the closure of existing STPs at Legana, Prospect Vale, Norwood, Hoblers Bridge, Newnham and Riverside and the construction of a new STP (at the Ti Tree Bend STP site), as well as the separated sewage sub-catchments currently discharged to the Ti Tree Bend STP. The new LSIP STP will treat sewage to a significantly higher level than the existing STPs, so the "health" of the river/estuary will be improved.

The existing Ti Tree Bend STP will be retained to treat only the discharge from the combined system.

Currently all (up to about 200ML/d) discharge to the STP is screened and de-gritted, after which about 65ML/d (75 L/s) passes through the Primary Sedimentation Tank, followed by about 45ML/d (520L/s) through the aeration or chlorination stage. Excess flows for each process stage is progressively overflowed or spilled to the Tamar River.

Due to the “limited” capacity of treatment with respect to inflow capacity, it is recommended that an overflow storage “basin” be provided so that all flows not fully treated (downstream of the inlet screens and de-gritting works) are stored and pumped back through the STP during lower inflow periods. This will significantly reduce the quantity of CSO to the Tamar River.

The overflow storage could be a combination of covered and uncovered/open storage similar to the Margaret Street Detention Basin, located in (part) of the “soon to be de-commissioned” sludge drying lagoons, or the existing (disused) dredging silt ponds, as shown on Drawing No. 10.

There are about 10 hectares of disused silt ponds located immediately to the west of the existing STP. It will likely be necessary to pump into the overflow storage (from the STP Inlet Works) so that the floor of the storage(s) is above the groundwater table during winter/wet periods. It is also likely that the silt pond will need to be emptied of contaminated silt to avoid contamination of the overflowed sewage. Assuming this silt pond area can be used, the estimated cost of a 10ML covered storage and 100ML of open storage is about $13.5M. Alternatively, wetlands could be constructed on this area in place of the open storage. Stored wastewater would be pumped back through the STP during low inflow periods.

The actual size of the overflow storage would need to be determined on the basis of cost effectiveness. Based on a record of inflow volumes to the STP for the period July 2010 to June 2012, the STP “overflowed” only about eight per cent of the time. Flow to the STP will increase during rain events for Options C, E, G and H, hence STP overflows will become more frequent unless some overflow storage is provided.

TasWater is in the process of providing an upgraded sludge dewatering system at the STP, hence the existing four sludge storage lagoons will become redundant. Part of this area was to be used as the site of the new LSIP STP, however some or all of these lagoons could be used as a temporary or low cost overflow storage as there is currently no commitment by TasWater to implement LSIP. These lagoons provide about 80ML of storage volume. Pumps and pipelines to get flows into and out of the storage would need to be provided, generally as discussed above for the 10ML covered or 100ML uncovered storages.

J. Hope Street /Mowbray Street system improvements.

The existing Hope Street and Mowbray Street pumps stations serve a partially separated system, comprising the Mowbray area (separated) and the northern Invermay area (combined).

LSIP proposed to separate this system completely by installing a new stormwater system to the northern Invermay area, to collect stormwater from the streets and properties and discharge this directly to the river. In “normal” operation the stormwater will drain via existing stormwater outlets to the Tamar River, and sewage would be pumped to the STP via the existing rising main. During high tide or flood conditions stormwater would not be able to gravitate to the river (due to the river water level), and would “back up” into the pump station, and hence would be pumped to the STP.

This is an “imperfect” system, but would be a significant improvement over the current system.

To fully separate the system would require the construction of a new stormwater pump station.

The estimated cost of this “improved” system is about $2.2M.

K. Operational/optimisation improvements.

It is important that the existing infrastructure is operating as efficiently and effectively as possible to ensure that CSOs are minimised. For example the existing Margaret Street Detention Basin is designed to store discharge from the large “upper Margaret Street” sub-catchment and not overload the low or sewage flow pumps in the NMSPS. TasWater needs to ensure that the system does operate in this manner.

Also there is a significant amount of gravel or grit washed into the combined system (off roads and construction areas), and this settles in the flat graded pipes and reduces the drainage capacity of the system, which results in overflows during rain events. TasWater needs to regularly monitor this situation and instigate a monitoring or cleaning procedure to minimise the risk of overflows due to (partially) blocked pipes.

Also, it is likely that some improvements can be implemented to the existing infrastructure to optimise the effectiveness of this infrastructure to reduce CSOs. For example, actuated weirs could be installed in the BBS and the PGP so that more storage can be provided within the system during short or low rain events and therefore reduce CSOs.

L. Other options.

Other options to reduce the impact or quantity of CSOs would likely be limited to identifying larger or concentrated discharges of separated sewage discharged to the combined drainage network, and to separate these from the network. These could include the following:

- LGH = 370 ETs
- Old LGH/Charles Hotel Development (adjacent LGH)
- Boags Brewery = 122 ETs
- Inveresk/Aurora/UTAS area = 124 ETs, but this will increase significantly when the University relocates to Inveresk.

These options have not been costed.

It will be important to manage the future UTAS Inveresk relocation as sewage from this large development should not be discharged into the existing combined system.

CSO reduction options summary.

The estimated cost to provide a separate sewage collection system is about $435M

Following is a summary of possible CSO reduction options:

A. West Launceston/Trevallyn separated sewers diversion.

This is described as Option A above.

The estimated cost of this option is $4.6M.

B. Kings Meadows/Newstead /Boland Street separated sewers diversion.

This is described as Option B above.

The estimated cost of this option is about $18.1 as shown below:

- South Launceston sewer upgrade (Separated sewers diversion) = $4.2M
- Boland Street separated system diversion works (Part of LSIP) =$ 1.6M
- Esplanade Overflow Storage (3 ML) = $5.3M
- DN710PE100PN16 rising main to STP = $7M

TOTAL = $18.1M.

C. Increase low flows pump rate from NMSPS.

This is described as Option C above.

The estimated cost of this option is about $11.8M as shown below:

- Increase pumping capacity from 400 L/s to about 800 L/s and decommissioning of OLSPS = $3.3M
- DN900PE100PN16 rising main to STP = $8.5M

TOTAL = $11.8 M

D. Provision of overflow storage to Margaret Street sub-catchment.

This is described as Option D above.

The estimated cost of this option is about $10M as shown below:

- Construction of 4.2 ML Overflow storage = $10M.

E. Provision of overflow storage and increased pumping to Esplanade/Willis Street sub-catchment.

This is described as Option E above.

The estimated cost of this option is about $6.7M as shown below:

- Esplanade overflow storage (3ML) = $5.7M (Part of Option B)
- Overflow diversion from Willis Street Overflow Weir Manhole = $1M

TOTAL = $6.7M.

If the storage is provided without Option B, the estimated cost is about $19M, as shown below:

- Esplanade overflow storage (3ML) = $11M
- DN710PE100PN16 rising main to STP = $7M
- Overflow diversion from Willis Street Overflow Weir Manhole = $1M

TOTAL = $19M.

F. Provision of overflow storage — Forster Street sub-catchment.

This is described as Option F above.

The estimated cost of this option is about $8.4M as shown below:

- Construction of two 18-metre diameter storage wells = $8.4M.

G. Provision of increased pump rate — Forster Street sub-catchment.

This is described as Option G above.

The estimated cost of this option is NIL as the existing pumps would be used as DUTY/ASSIST (instead of the current DUTY/STAND-BY mode).

This option is only practical if a new rising main is installed from the NMSPS which provides “spare” capacity in the existing City Rising Main.

Alternatively a new rising main could be constructed between the Forster Street PS and the STP.

H. Provision of increased pump rate — St John Street sub-catchment.

This is described as Option H above.

The estimated cost of this option is about $1.50M to increase the size of the rising main, and the replacement of at least two No. pumps.

This option is only practical if a new rising main is installed from the NMSPS which provides “spare” capacity in the existing City Rising Main.

I. Provision of overflow storage at Ti Tree Bend STP.

This is described as Option I above.

The estimated cost of this option is about $13.5M as shown below:

- 10 ML covered storage and 100 ML of open storage = $13.5M.

This “option” should be included as part of all options that increase the flow to the STP as the existing STP overflows all inflows in excess of about 65ML/day. Hence this should be part of Options C, E, G and H.

J. Hope Street /Mowbray Street System improvements.

This is described as Option J above.

The estimated cost of this “improved” system is about $2.2M.

K. Operational/optimisation improvements.

This is described as Option K above.

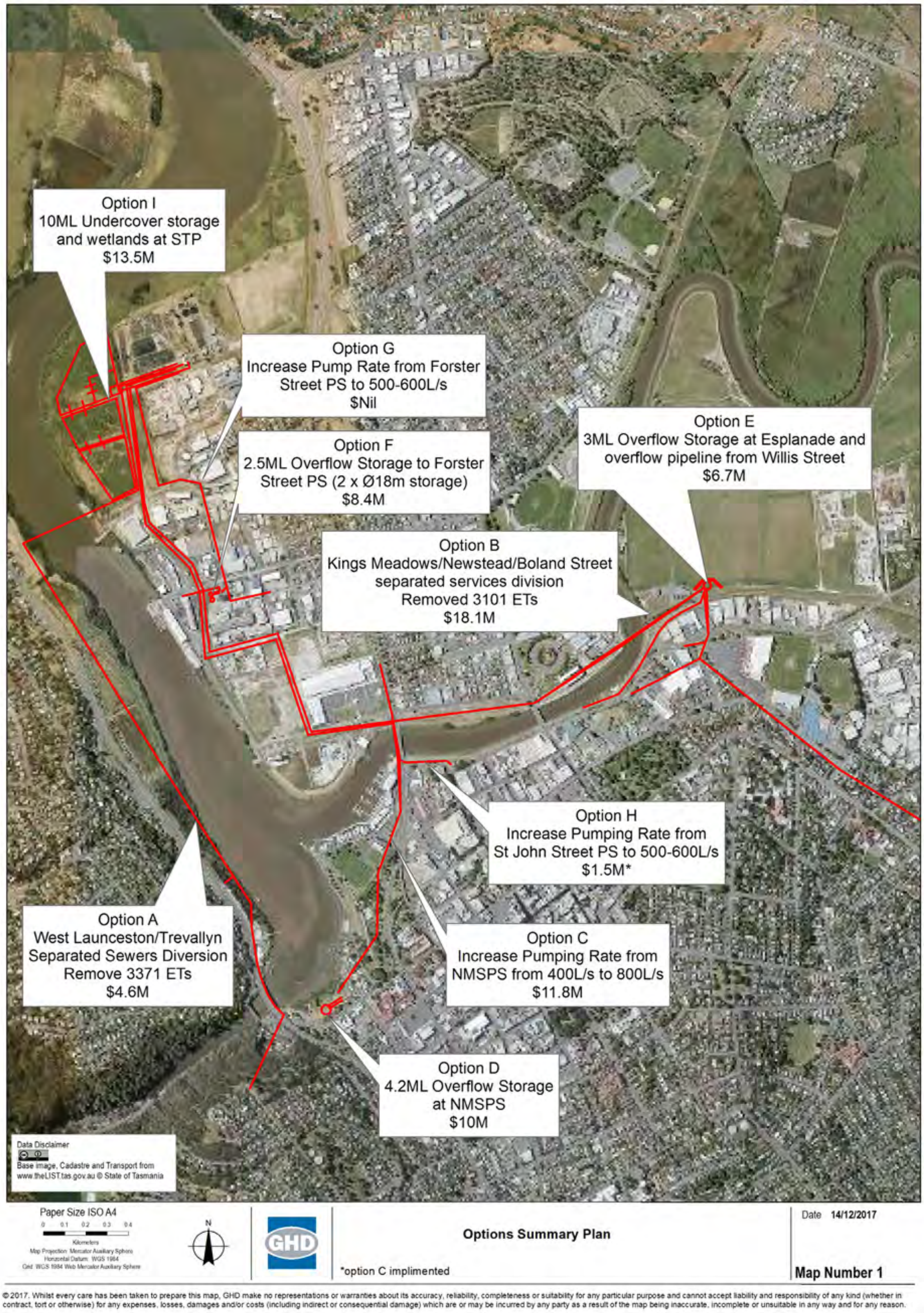
Estimates

Estimates for the LSIP works (West Launceston/Trevallyn and Kings Meadows/Newstead/Boland Street separated system) have been taken from the LSIP report directly. These estimates have been undertaken on the preliminary design of the pipelines and pump stations for the transfer systems and include allowances for design, approvals and construction. The construction cost estimates have been done by John Holland within a +/–20% range of accuracy.

Estimates for non-LSIP options have been prepared based on conceptual designs, using similar construction rates used for LSIP. Estimates include an allowance of 20 per cent (of construction cost) for engineering or approvals, and a 30 per cent construction contingency.

Concept drawings

Options summary plan



Option A: West Launceston/Trevallyn separated sewers diversion

Option B: Kings Meadows/Newstead/Boland Street separated sewers diversion

Option C: Increase pumping rate from NMSPS from 400L/s to 800L/s

Option D: 4.2ML overflow storage at NMSPS

Paper Size ISO A4

0 0.0075 0.015 0.0225 0.03

Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere
Data source: the LIST © State of Tasmania. Created by: jabush

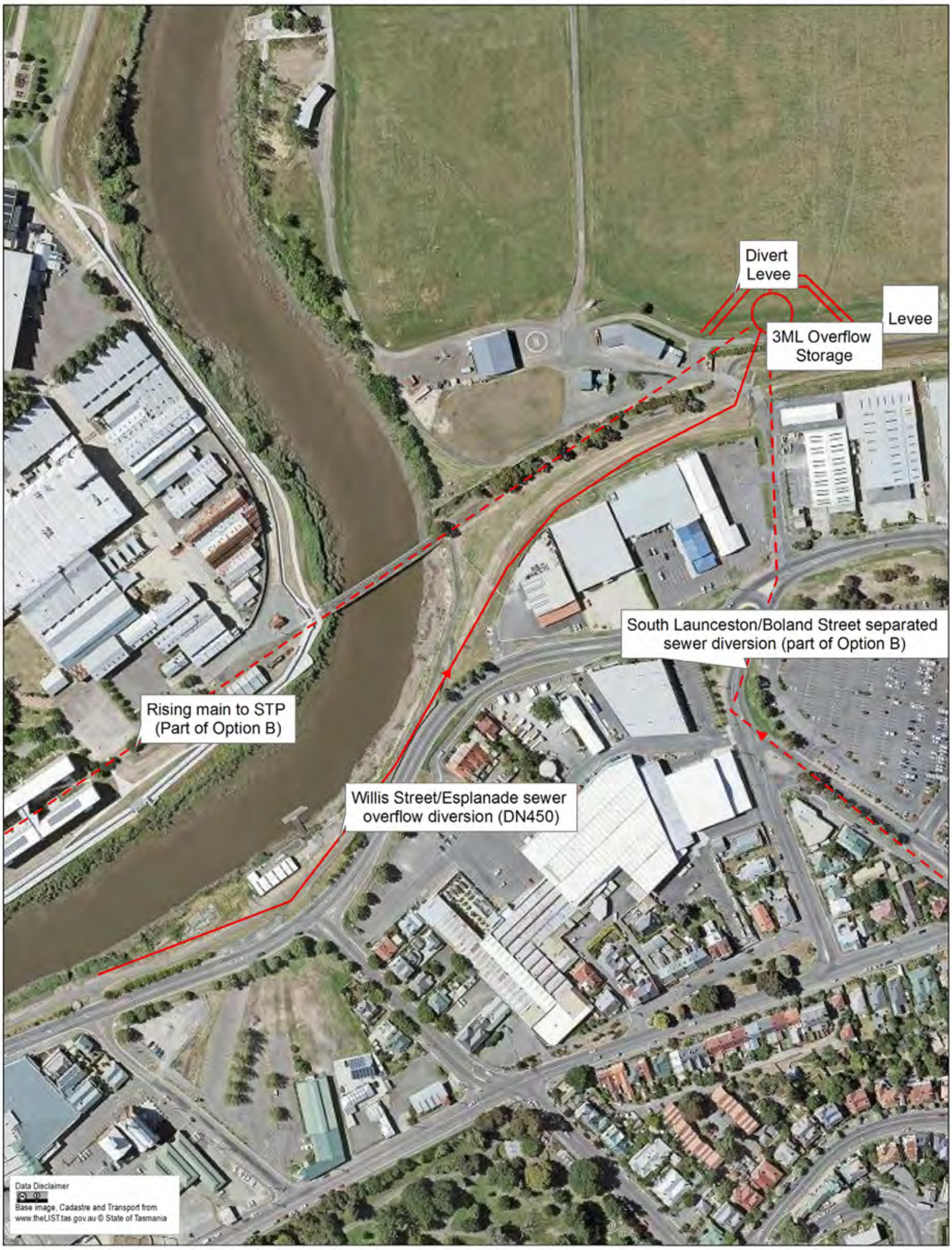
Option D
4.2ML Overflow Storage at NMSPS
Estimated cost = $10M

Map prepared based on information including options summary and cost estimates supplied by the City of Launceston.

Date 14/12/2017

Map Number 5

Option E: 3ML overflow storage at Esplanade and pipeline from Willis Street



Paper Size ISO A4
0 0.02 0.04 0.06 0.08
Kilometers
Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere
Data source: the LIST © State of Tasmania. Created by: jabush

N

Option E
3ML Overflow Storage at Esplanade and Overflow Pipeline from Willis Street
Estimated cost = $6.7M

Map prepared based on information including options summary and cost estimates supplied by the City of Launceston.

Date 14/12/2017

Map Number 6

Option F: 2.5ML overflow storage to Forster Street PS

Option G: Increase pump rate from Forster Street PS to 500–600L/s

Option H: Increase pumping rate from St John Street PS to 500–600L/s

Option I: 110ML overflow storage STP

Appendix F: Tamar Estuary and Esk Rivers: Water quality report

Combined System Overflow Working Group

Background

The kanamaluka/Tamar Estuary extends on a south-east to north-west axis for approximately 70km following a meandering path from Launceston to its mouth into Bass Strait at Low Head on Tasmania's north coast. The river is formed through the convergence of the North Esk and South Esk rivers at Launceston. Estuaries are very complex, dynamic environments with many interacting processes, and they vary both spatially and temporally. The Tamar is no exception, particularly given the tidal-driven mixing of oceanic water and gravity-driven riverine freshwater (AMC Search 2015[1]).

There is a strong twice-daily three to four metre oceanic tide from Bass Strait that becomes amplified up the estuary due to its length, bed friction, the rate of propagation of the tidal wave and tidal storage of inter-tidal shoals (Foster et al. 1986 in AMC Search 2015). This results in a "distortion" of the tidal curve in the upper estuary, and an asymmetric tidal curve (shorter flood tide with higher current velocities, prolonged period of high-water slack tide and an extended ebb tide with lower current velocities). This often results in a net up-estuary residual current.

Overlaying this are additional processes such as atmospheric pressure, wind, floods and water diversion. Up to 28 cumecs of water from the South Esk River pass through the Trevallyn Power Station, which discharges into the Tailrace at Riverside. Of the 28 cumecs, approximately 27 per cent consists of water diverted from the Great Lake via the Poatina Power Station. The statutory environmental flow requirement for the Trevallyn Power Station was set at 0.425 cumecs in 1955, however in 2003 Hydro Tasmania voluntarily increased the daily flow to 1.5 cumecs, and to 2.5 cumecs in 2011, primarily to restore recreational and aesthetic values in the Cataract Gorge. The installation of new valves in the dam in 2015 allows for easier releases of high flows (up to 20 cumecs) down the South Esk River to assist with sediment mobilisation and for white-water kayaking events.

The Tamar Estuary and Esk Rivers (TEER) catchment area covers 10,000km^2 (approximately 15 per cent of Tasmania). It supports urbanised areas, agricultural activities, industrial operations and recreational pursuits, as well as having rich and diverse aquatic ecosystems. The estuary supports a diverse range of use and environmental values, including a large industrial area at Bell Bay, salmon farming, fishing, swimming, tourist boats and highly valued waterfront commercial and residential areas.

At 214km, the South Esk River is the longest river in Tasmania. The South Esk basin, consisting of Macquarie, Brumbys Lake, Meander and South Esk catchments, is the main source of freshwater flows and sediments to the Tamar; the North Esk is considerably smaller. The topology of the catchment varies from low hills and plains characterised by agriculture in the Northern Midlands, to plateaus of the Western Tiers, Ben Lomond and Eastern Highlands. Together the Tamar and its tributaries drain a catchment area of approximately 10,000 square kilometres or 15 per cent of the state of Tasmania.

Pollutant inputs into the Tamar River Estuary are from both diffuse and point sources. Diffuse sources are pollutant loads carried by rainfall run-off from the land surfaces. In the greater TEER catchment, point sources include aquaculture, sewage treatment plants (STP) and combined system overflows (CSO). Launceston has a combined sewerage system: a sewer network that collects rainwater run-off, sanitary sewage and industrial wastewater into one pipe for delivery to a treatment plant. Combined system overflows are the discharges of a mix of sewage and urban stormwater that occur during high flow events from the combined sewage and stormwater system that services Launceston. At other times the combined sewage and stormwater is directed to the Ti Tree Bend STP and is treated before being discharged to the estuary

Water quality has been monitored in the Tamar Estuary and the North and South Esk rivers since the 1970s, with historical data predating the Ti Tree Bend and Hoblers Bridge STPs. Continued monitoring of pollutant concentrations and flows in-stream systems in the TEER catchment, with reference to historical data, is vital to understanding current condition and pressures on water quality in these systems, and improvements from past condition.

The City of Launceston implemented a program to monitor in-stream and stormwater water quality under a variety of flow conditions. Event monitoring to understand the impact of rainfall events on the Tamar Estuary has long been identified as a gap in understanding and the program was developed to provide the stakeholders (City of Launceston, TasWater and NRM North) with an understanding of the impact of rainfall events on the ambient environment in the Tamar Estuary from key point sources of pollutants, including stormwater and combined sewer overflows.

[1] AMC Search 2015 *Tracer analysis of sediment redistribution of Tamar Estuary for Launceston Flood Authority.* AMC Search, Launceston

Aims:

- To validate modelling and quantify CSOs entering waterways from the combined system.
- To assess impact of CSOs on water quality in the North Esk and upper Tamar River Estuary, particularly contribution of loads following long dry spells.
- To assess pollutant loads from stormwater entering the upper Tamar.
- To develop a base case for water quality in the Tamar Estuary during rainfall events to provide a benchmark against which improvements can be measured.

This report presents the results of the water quality monitoring program and compares these with historical data from the catchment.

Methods

Historic data

Historic water quality data were compiled from a number of sources, including original hand-drawn charts plotted on film from the 1970s (Figure 48), recreational water quality data collected by Environmental Health Officers, TasWater and NRM North ambient water quality data, and published DPIPWE reports.

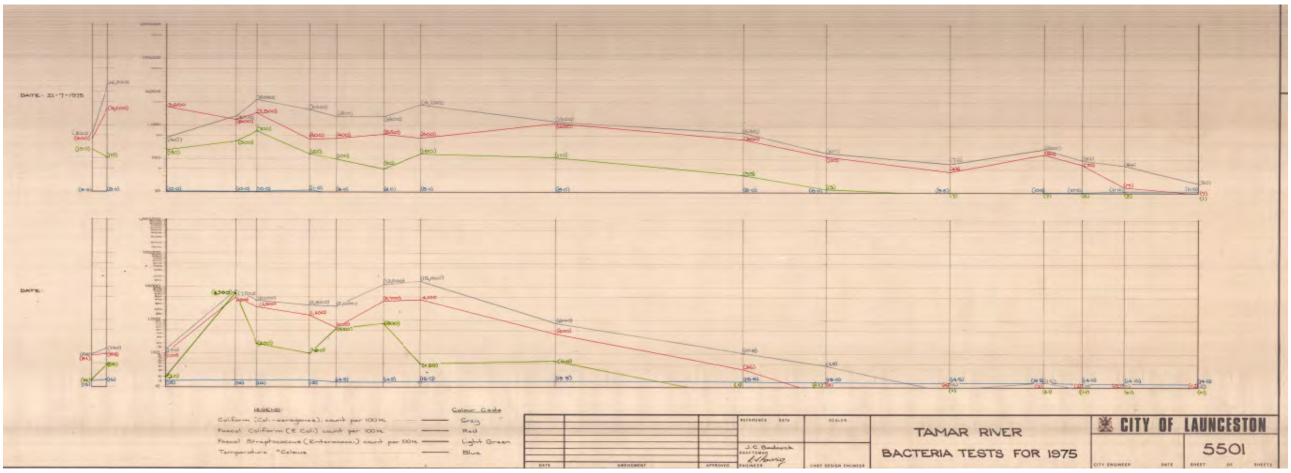


Figure 48: Example of historic charts displaying ambient water quality data from the Tamar River

Monitoring program

The 2016–17 water quality monitoring program assessed a standard suite of physico-chemical parameters (electrical conductivity, turbidity, dissolved oxygen, temperature and pH) at each nominated site using handheld instruments. Samples were collected weekly for bacterial analysis (Enterococci), monthly for total suspended solids, and quarterly for total nutrient concentration (total nitrogen and total phosphorus; Table 22). Enterococci are used as a bacterial indicator for determining the extent of faecal contamination of recreational waters.

In addition to regular weekly sampling, water quality data were captured opportunistically during heavy rainfall and/or flooding events. Opportunistic monitoring was conducted when substantial rain was encountered in the days following regular weekly sampling.

A single daily event monitoring sampling was planned when the likelihood of rainfall in Launceston was >80% of ≥5mm. Daily samples were collected for five days at 11 sites, including 4 sites on the Tamar Estuary that are monitored monthly by NRM North (T1–T4; Table 23 and Figure 49).

Sample sites were selected to build a representative picture of the water quality within the Tamar catchment at sites where potential impact can be detected. Sample sites are presented in Table 23 and Figure 49. A review of data in June 2016 resulted in a revision of the monitoring sites, with some sites discontinued and one site, Trevallyn Stormwater, included in both weekly and event monitoring (Table 23).

Table 22 Water quality monitoring sites: Weekly sampling and opportunistic rain event

Site Code	Site	Easting	Northing	Comment	Parameters
DC_SW	Stormwater – Distillery Creek	514565	5413198	Site discontinued following review	pH, temperature, electrical conductivity, dissolved oxygen, turbidity Lab analyses: Enterococci total suspended sediments^ total nitrogen* total phosphorus*
SWT	Stormwater – Trevallyn#	510253	5413142	Site added to weekly schedule following review	
DC	Distillery Creek	515943	5413436	Site discontinued following review	
GRS	Tamar Estuary – Grammar Rowing Sheds	510671	5415580	Site discontinued following review	
RP	Tamar Estuary – Royal Park	510927	5412638		
IB	North Esk River – Inveresk footbridge	511967	5413702		
SP	North Esk River – Sea Port	511087	5413275		
KMR	Kings Meadows Rivulet – Punchbowl	514081	5410606		
FB	South Esk River – First Basin	510000	5411687		
SL	North Esk River – St Leonards	516054	5409842		
CL	North Esk River – Corra Linn	518548	5406833	Site discontinued following review	
WL	Waverly Lake	515784	5413396	Site discontinued following review	

^ total suspended sediment samples collected monthly
* total nitrogen and total phosphorus samples collected quarterly
# weekly from 20 June 2017

Table 23 Water quality monitoring sites: Event monitoring

Site Code	Site	Easting	Northing	Parameters
SWT	Trevallyn Stormwater	510253	5413142	pH, temperature, electrical conductivity, dissolved oxygen, turbidity Lab analyses: Enterococci, Thermotolerant coliforms, *E. coli*, total suspended sediments, total phosphorus and total nitrogen
RP	Tamar Estuary – Royal Park	510927	5412638	
IB	North Esk River – Inveresk Footbridge	511967	5413702	
SP	North Esk River – Sea Port	511087	5413275	
KMR	Kings Meadows Rivulet – Punchbowl	514081	5410606	
FB	South Esk River – First Basin	510000	5411687	
SL	North Esk River – St Leonards	516054	5409842	
T1	Kings Bridge	510750	5412470	
T2	Kings Wharf	510265	5413692	
T3	Hunters Cut	509889	5416144	
T4	Tamar Island	507260	5419663	

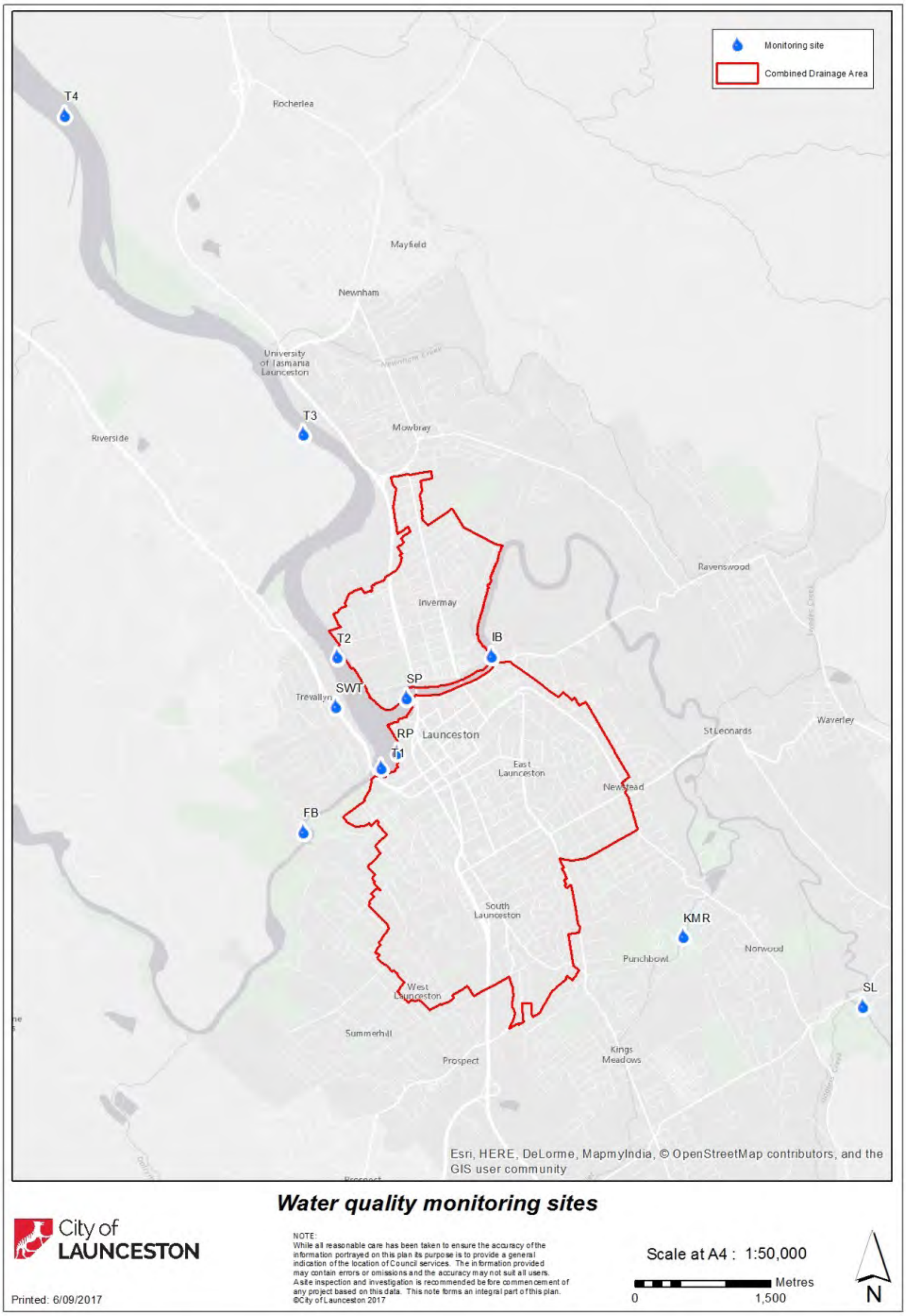


Figure 49 Location of water quality monitoring sites

Data analysis

Water quality data were compiled from historical and current monitoring programs. External data sets analysed were primarily sourced from DPIPWE, NRM North and TasWater. Data trends and summaries were examined and, where appropriate, water quality data were assessed against the following water quality guidelines:

- Recreational Water Quality Guidelines 2007
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)
- Site-specific trigger values for physico-chemical indicators monitored under the DPIW Baseline Water Quality Monitoring Program (DPIW 2008)

For the purposes of analysing rain event data, a rain event was defined as either >2mm in an hour, or >4mm in 24 hours. More than 2mm of rain in an hour spread over the Margaret Street CSS catchment will produce stormwater run-off that exceeds the capacity of the Margaret St Pump Stations' sewage pumps, causing the stormwater pumps to discharge to the estuary. Jessup (2015) demonstrated that rainfall in excess of 4mm of rain in 24 hours would produce stormwater run-off that exceeds the capacity of the Margaret St Pump Stations' sewage pumps, causing the stormwater pumps to discharge to the estuary.

A one-way analysis of variance (ANOVA) was used to determine if there was a statistically significant difference between the "rain event" and "no rain event" data. A p-value ≤ 0.05 indicates strong evidence that rain is the likely cause of elevated Enterococci in the water samples.

Results and discussion

Water quality in the North and South Esk rivers is generally good or moderate in the cleared foothills and lowland plains, with variable grades (from poor through to very good) in the forested hills and highlands (Newall et al. 2012). Recreational water quality is generally very good, with popular swimming locations on both the North and South Esk rivers. In general, water quality at these sites (eg First Basin on the South Esk and St Leonards on the North Esk) is suitable for swimming, unless there has been rain in the catchment in the days prior to testing. It is well documented that rainfall in the catchment contributes pollutants and faecal contamination to the waterways, from diffuse sources such as livestock, pets and native wildlife.

Water quality in the Tamar Estuary improves with distance downstream towards the mouth of the estuary. The lower estuary is well flushed, and the volume of water and the tidal marine influence dilutes the concentration of nutrients, metals, pathogens and sediments from the upper reaches (Attard et al. 2012). In Zone 1 of the estuary, from Launceston to Tamar Island, the water quality consistently scores a C or D (Fair to Poor) in the Tamar Estuary Report Cards prepared by NRM North's TEER Program. The grades are generally as a result of poor scores for Enterococci (faecal contamination), turbidity, nutrients and metals.

Water quality parameters have been monitored in the Tamar Estuary and the North and South Esk rivers since the 1970s, with historical data predating the Ti Tree Bend and Hoblers Bridge STPs. Thermotolerant coliforms in the North Esk River at Hoblers Bridge and in the Tamar Estuary at the Tamar Yacht Club were observed to be present in the millions of cells/100mL in the 1970s, with the highest count peaking at 8.8 million cells/100mL at Hoblers Bridge in June 1991 (Figure 50).

Mirroring the trend observed globally, there has been a strong trend of significantly improved water quality since the construction of wastewater treatment plants (Figure 13).

The average cell count for thermotolerant coliforms at Tamar Yacht Club from 1974 to 1994 was 166,963 cells/100mL; from 1995 to 2017, the average was 2631. This represents a 98.4 per cent reduction in the mean thermotolerant coliform count following the introduction of disinfection at Hoblers Bridge STP. Subsequent to disinfection, at the Tamar Yacht Club the highest cell count has been 32,000 (May 1995). The majority of high cell counts prior to 1995 were observed within two days of "sale day" at the Killafaddy sale yards. The sale yards and associated abattoirs were connected to the Hoblers Bridge STP in 1994, putting an end to the very high coliform counts in the North Esk River and Tamar Estuary.

Monitoring data from the current program (November 2016 to November 2017) indicate that while Enterococci counts occasionally peak, generally in response to rain events, the median cell count is generally low (eg 1418 cells/100mL at Royal Park, Figure 51). Stormwater sites from separated catchments within Launceston (Kings Meadows Rivulet and Trevallyn Stormwater) show elevated levels of Enterococci, nutrients and sediments during rainfall, indicating that substantial quantities of pollutants are mobilised during rain. The stormwater monitoring sites outside the combined catchment (Trevallyn and Kings Meadows) have a higher median than the Esk rivers and Tamar Estuary sites, and Trevallyn has a much higher mean cell count that other monitoring sites (Figure 51). These pollutants are delivered to local waterways, where they are then discharged directly to the Esk rivers and the Tamar.

Turbidity and nutrient concentrations are highly variable between sites (Figure 52 b, c, d).

Upstream sites at St Leonards and First Basin are generally lower than the downstream and stormwater sites. Despite the sediment inputs to the waterways, dissolved oxygen is consistently high across all sites, and with little variation between sampling events (Figure 52).

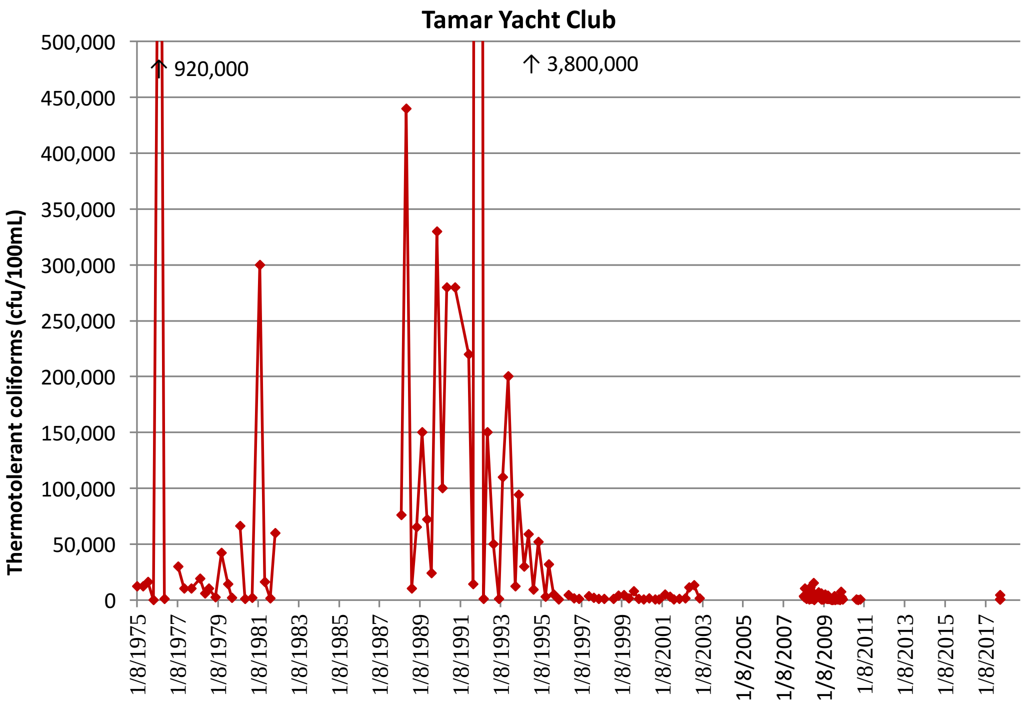


Figure 50 Progressive reduction in coliforms at Tamar Yacht Club

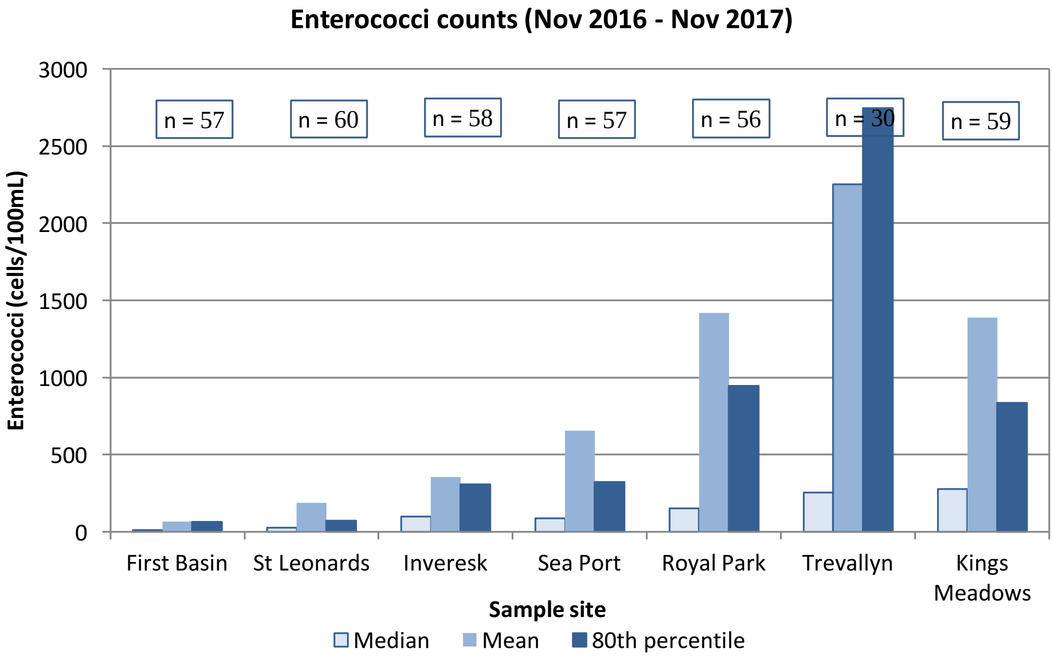


Figure 51 Enterococci result summaries from selected monitoring sites (Nov 2016–Nov 2017)

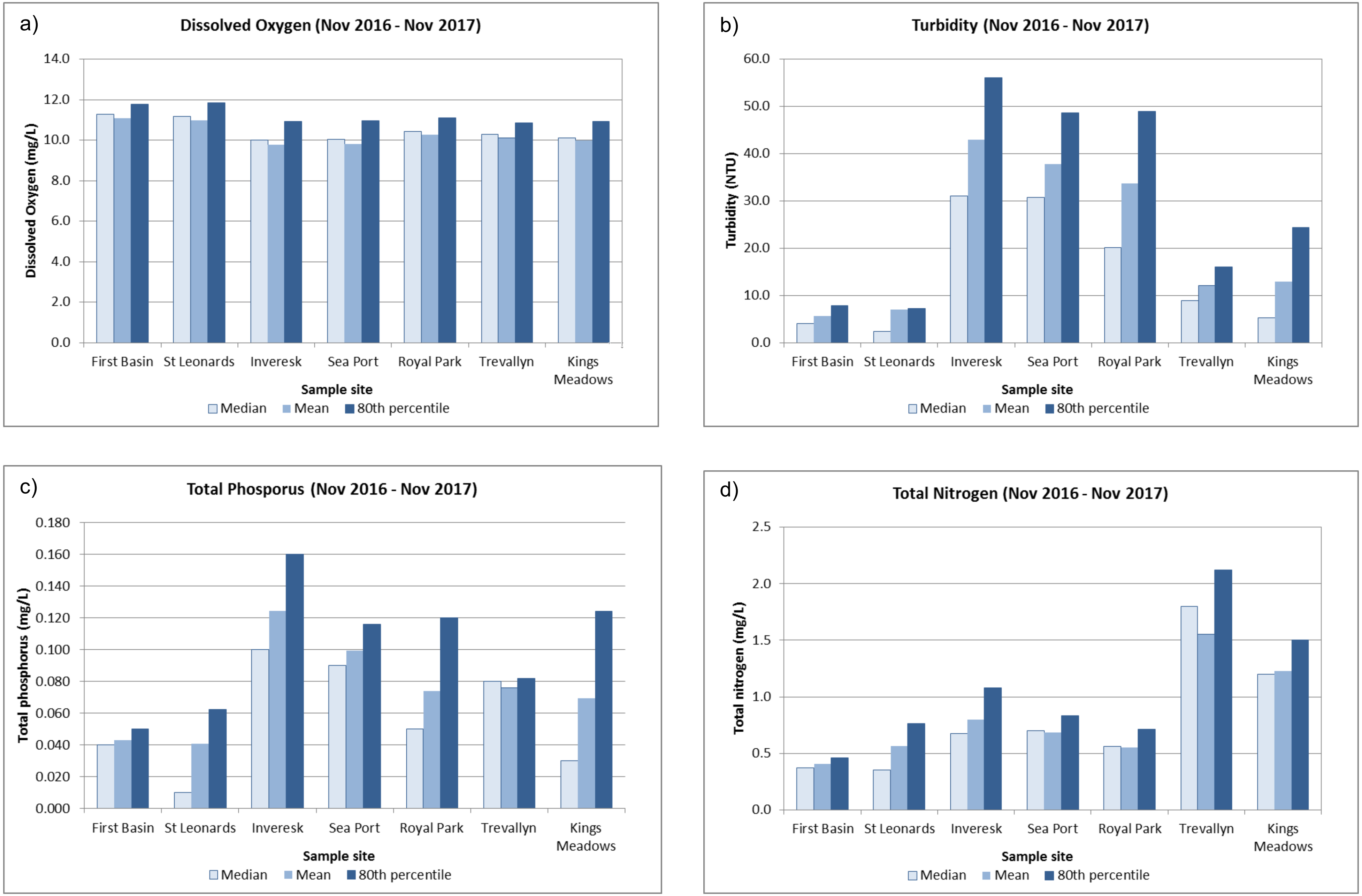


Figure 52 Water quality summaries from selected monitoring sites (Nov 2016–Nov 2017): a) dissolved oxygen b) turbidity c) total phosphorus d) total nitrogen

Data collected from November 2016 to November 2017, summarised and presented in Table 24 below, show a strong relationship between rain events and elevated Enterococci levels in the waterways. A one-way analysis of variance (ANOVA) was used to determine if there was a statistically significant difference between the "rain event" and "no rain event" data. The difference between "rain event" and "no rain event" is statistically significant at these sites (ie, p-value is ≤0.05; Table 24).

Further, as presented in Table 25, this relationship is also evident when rainfall in the catchment exceeds 1mm in a 24-hour period. On average, Launceston experiences 89 days per year where rainfall exceeds 1mm. Very light rainfall (<1mm) does not produce statistically significantly higher bacteria counts in the estuary, but rainfall ≥1mmm does (Table 25). At sites upstream of Launceston's urban discharges (eg the North Esk River at St Leonards), the water quality meets the recreational guidelines most of the time (Figure 53).

Table 24 Comparison of Enterococci counts – rain events vs no rain

Enterococci (cells/100mL)	Royal Park Tamar Estuary		Inveresk – Black Bridge North Esk River		Sea Port North Esk River	
	No rain event	Rain event	No rain event	Rain event	No rain event	Rain event
Mean	338	3638	122	419	85	781
SD	561	7296	121	346	85	1076
Median	110	663	84	313	63	404
80th percentile	415	1782	185	661	119	856
Min	10	97	10	41	10	218
Max	3076	24,196	591	1223	448	4106
Count	45	11	46	12	45	12
ρ-value	0.0032		0.00001		0.00005	

Table 25 Comparison of Enterococci counts — Any rain vs no rain

Enterococci (cells/100mL)	Royal Park, kanamaluka/Tamar Estuary					
	No rain	Any rain	<1mm rain	≥1mm rain	<2mm rain	≥2mm rain
Mean	408	222	362	2736	353	2772
SD	680	359	605	7549	577	7129
Median	108	110	109	334	116	650
80th percentile	640	288	463	757	419	1334
Min	10	10	10	10	10	10
Max	3076	1259	3076	24,196	3076	24,196
Count	27	11	38	10	42	11
ρ-value	0.206		0.032		0.011	

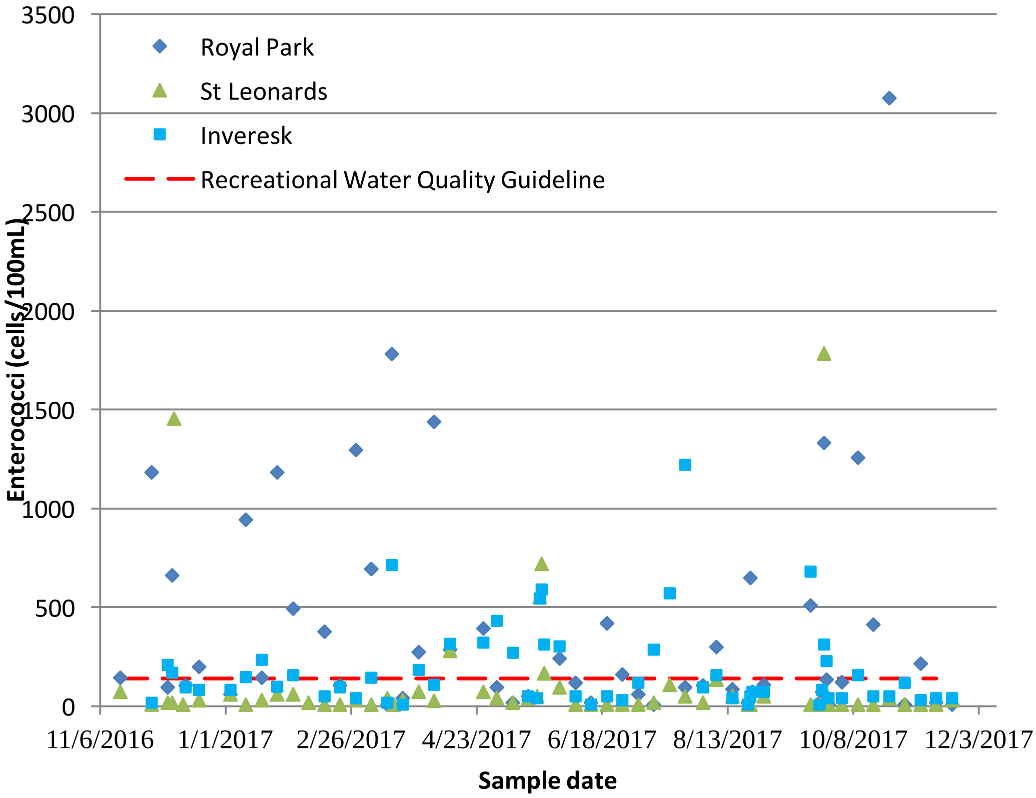


Figure 53 Enterococci cell counts from selected monitoring sites: Performance against the recreation water quality guideline

On several occasions during the monitoring program, elevated bacteria counts, nutrient concentrations and turbidity were observed in the downstream sites (Inveresk, Sea Port and Royal Park) that do not have an obvious cause. For example, on 7 March 2017, 697 cells/100mL Enterococci were observed at Royal Park, with a high turbidity (33.8 NTU) and suspended solids (49mg/L). On the same day, suspended solids at Inveresk and Sea Port were 176mg/L and 226mg/L, respectively while at the Basin and St Leonards, the suspended solids were 3mg/L and 2mg/L, respectively. Nutrient concentrations at Inveresk were very high: at 1.5mgN/L and 0.39mgP/L they were more than double the median concentrations of 0.68mgN/L and 0.10mgP/L, and far exceeded ANZECC (2000) and DPIW (2008) trigger values. There was no rainfall recorded in the previous 14 days, no discharges from the TasWater stormwater ejector stations (CSOs) along Esplanade or Margaret Street, and no silt raking. The weather was fine and sunny, indicating that wind fetch and wave action would not be responsible for the poor water quality, and the samples were collected on an outgoing tide. One cause may be the remobilisation and resuspension of fine sediments from the mudflats and un-vegetated banks of the North Esk River on the outgoing tide. Wildlife, boat wake and agricultural activities may also be a factor.

From 1 January to 10 October 2017 (a period of 282 days), there were 50 CSOs to the kanamaluka/ Tamar Estuary from the New Margaret Street Pump Station, discharging an estimated 426ML direct to the Estuary. Of these, 30 events discharged ≤5ML, and 11 coincided with water quality sampling. Enterococci counts in the Tamar Yacht Basin (Royal Park) coinciding with discharge from New Margaret Street Pump Station were substantially higher than those with no discharge (Table 26), further supporting the hypothesis that rainfall and CSOs have a direct negative impact on the water quality in the Tamar Estuary. It should be noted that on at least five occasions during the sampling period, elevated bacteria levels and turbidity (and nutrient concentrations where data was available) were observed in the lower North Esk and upper Tamar Estuary with no correlation with rainfall or pump-station discharges. Upstream data from St Leonards and the First Basin indicate that the elevated bacteria and turbidity is localised.

Table 26 New Margaret Street Pump Station overflow volumes and ambient Enterococci counts at Royal Park (Tamar Yacht Basin)

Date	Overflow Volume (ML)	Rainfall (mm) (48 hours prior to sampling)	Enterococci (cells/100mL)	
			Overflow	No overflow
24/01/2017	2.8	7.2	1184	
16/03/2017	11.5	7.8	1782	
27/03/2017	0.6	4.6	275	
25/04/2017	3.3	9.0	393	
23/05/2017	3.3	2.4	24,196	
30/05/2017	23.8	12.4	243	
18/07/2017	14.4	13.4	9208	
25/07/2017	1.9	4.6	97	
23/08/2017	1.7	6.4	650	
19/09/2017	8.1	21.0	512	
24/09/2017	10.1	12.2	1334	
Total overflow volume	81.6			
Median			650	129
Mean			3625	357
Standard Deviation			7301	440
Minimum			97	10
Maximum			24,196	1439
80th percentile			1558	439
20th percentile			334	83
Count			11	24

Samples collected on five consecutive days in September 2017 captured data from 11 sites in waterways in Launceston, including four sites in Zone 1 in the Tamar (down to Tamar Island). A total of 11mm of rain fell during the second day of sampling, causing the Margaret Street Pump Stations to discharge 10.1ML of untreated effluent to the estuary, resulting in elevated turbidity and Enterococci on the third day, with levels particularly high at St Leonards and Royal Park (Figure 54). High pathogen load at the upstream site at St Leonards is largely catchment driven, with livestock the likely source of most of the Enterococci. Enterococci count at St Leonards spiked from 10 cells/100mL on Day 2, to 1785 cells/100mL on Day 3, before falling sharply back to 41 cells/100mL on Day 4 (Table 27). Nutrient concentrations (total nitrogen and total phosphorus) were elevated at St Leonards, spiking on Day 3, with a similar pattern observed on Day 4 at the First Basin (albeit with far lower concentrations). This same pattern was not observed further downstream at Inveresk or Royal Park, where nutrient concentrations peaked slightly on Day 2, and then declined by Day 3. Increases in nutrient concentration are more difficult to identify at the downstream sites due to the increased volume (and therefore dilution of the nutrients). By Day 4, Enterococci counts at most sites had returned to baseline levels, with the exception of North Esk River at Inveresk and Royal Park, and the Tamar Estuary at T2 Kings Bridge (Figure 54 and Table 27). Potentially, these sites remain elevated as the pulse of water from the North Esk catchment makes its way downstream and into the upper estuary.

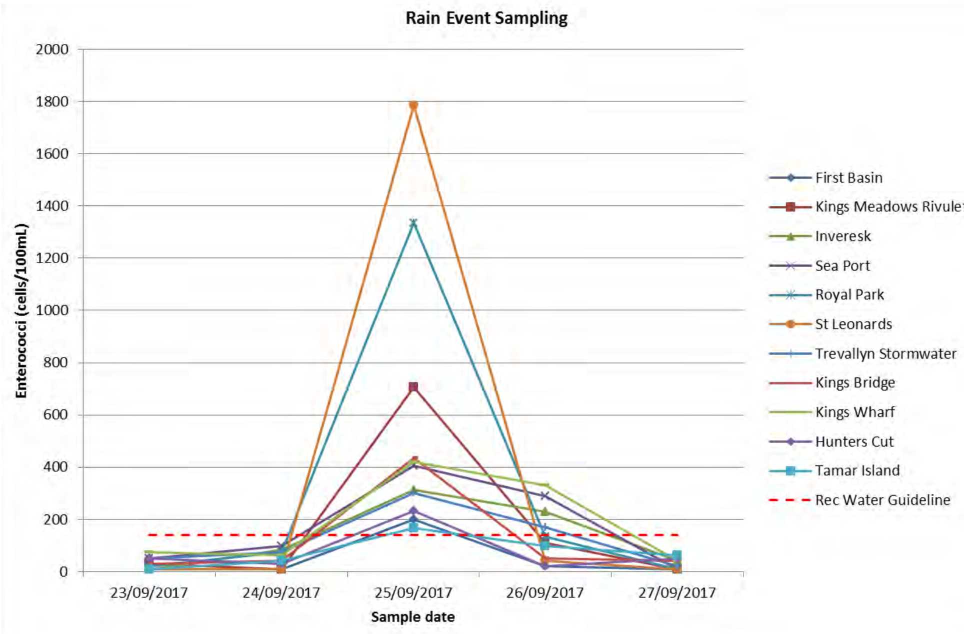


Figure 54 Sampling over five consecutive days in September 2017

Table 27 Water quality data: Rain event monitoring 23–27 September 2017

	FB	KMR	IB	SP	RP	SL	TSW	T1	T2	T3	T4
Enterococci (cells/100mL)											
23/09/2017	10	31	10	52	20	10	52	31	75	52	10
24/09/2017	10	10	84	97	75	10	74	41	63	31	41
25/09/2017	199	706	313	404	1334	1785	301	435	420	233	166
26/09/2017	20	109	228	288	135	41	169	52	332	20	98
27/09/2017	10	10	41	10	10	10	20	41	41	52	63
Turbidity (NTU)											
23/09/2017	4.6	7.8	20.9	31.5	14.0	3.6	3.9	9.7	19.7	22.7	27.6
24/09/2017	7.2	4.9	23.4	28.9	19.4	3.2	5.9	11.8	41.2	42.8	32.1
25/09/2017	8.9	33.1	19.4	23.7	17.6	68.0	10.7	11.7	23.5	20.0	47.0
26/09/2017	6.8	17.8	24.8	35.0	13.2	15.7	8.4	10.0	20.8	12.5	32.1
27/09/2017	7.9	10.7	16.3	21.0	11.6	7.5	2.2	6.9	20.1	19.7	29.3
Total Phosphorus (mg/L)											
23/09/2017	0.03	0.03	0.07	0.10	0.04	0.01	0.05	0.03	0.05	0.06	0.06
24/09/2017	0.04	0.03	0.09	0.10	0.06	0.01	0.08	0.04	0.10	0.10	0.06
25/09/2017	0.05	0.05	0.07	0.09	0.05	0.10	0.08	0.04	0.06	0.09	0.09
26/09/2017	0.05	0.03	0.07	0.07	0.04	0.03	0.08	0.04	0.05	0.04	0.07
27/09/2017	0.04	0.02	0.05	0.05	0.04	0.02	0.07	0.04	0.05	0.05	0.07
Total Nitrogen (mg/L)											
23/09/2017	0.28	1.2	0.57	0.7	0.4	0.18	1.8	0.35	0.52	0.48	0.45
24/09/2017	0.41	1.2	0.69	0.75	0.62	0.22	2.2	0.45	0.8	0.78	0.58
25/09/2017	0.45	0.79	0.45	0.66	0.39	1.1	1.9	0.41	0.61	0.58	0.75
26/09/2017	0.53	1	0.66	0.68	0.45	0.57	2.5	0.43	0.73	0.41	0.61
27/09/2017	0.47	0.98	0.62	0.57	0.56	0.36	2.1	0.49	0.7	0.65	0.7

Diffuse sources from the catchment contribute substantially to faecal contamination and nutrients to the estuary as a whole; however sewage treatment plants (STPs) and the combined sewerage system contribute a considerable proportion. Monitoring data collected from waterways receiving stormwater in Launceston outside the combined sewerage network show a strong response to rainfall events, with turbidity and bacteria levels far higher during rain events (Table 28).

Turbidity is very strongly driven by diffuse sources in the catchment, contributing almost 100 per cent of the sediment to the estuary (TEER 2015[2]), which is demonstrated by the City of Launceston's water quality monitoring program. Mass load calculations indicate that under normal flow conditions, the North Esk River contributes approximately 150kg of sediment to the Tamar each day. However, during high flow events following rainfall, the sediment load increases to 150 tonnes per day. A similar pattern is observed with Enterococci, with counts substantially higher following rainfall in the catchment (Figure 55 and Table 28). This site, at St Leonards, is upstream and independent of any STP inputs from Launceston. The results correlate with findings from the NRM North Faecal Source Tracking Project, where bacteria from the upstream site (St Leonards) are predominantly from livestock sources, and downstream sites are from a combination of livestock, stormwater and wastewater treatment plants.

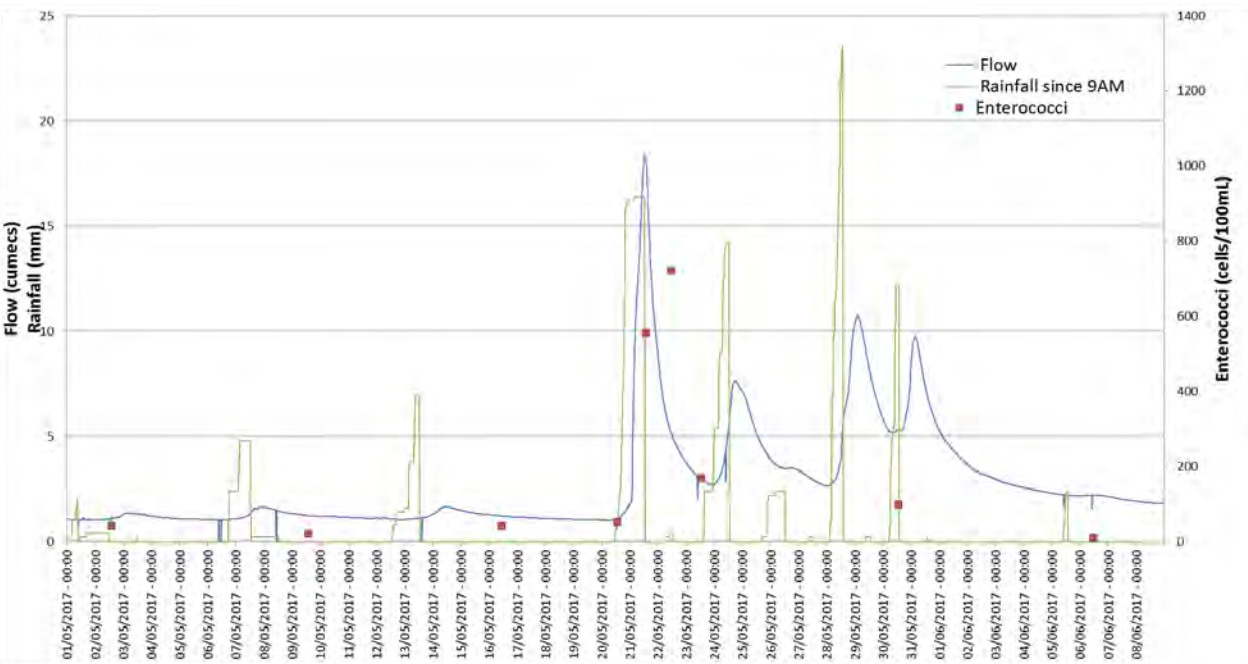


Figure 55 North Esk River at St Leonards: Enterococci counts in response to rainfall and flow

[2] Tamar Estuary and Esk Rivers Program 2015 *Tamar Estuary and Esk Rivers Catchments Water Quality Improvement Plan.* NRM North, Tasmania

Table 28 Enterococci, suspended sediments and nutrient concentrations in stormwater
(values in red exceed the Enterococci recreational water quality guideline or ANZECC trigger values for nutrients)

Sample date	Enterococci (cells/100mL)		Total Nitrogen (mg/L)		Total Phosphorus (mg/L)		Turbidity (NTU)		Rainfall (mm)		Weather	Comment
	KMR	TSW	KMR	TSW	KMR	TSW	KMR	TSW	Prev 24 hours	Prev 48 hours		
29/11/16	1091						4.2				Fine & sunny	
6/12/16	771						4.9				Fine & sunny	
8/12/16	6488	9804	1.5	0.54	0.16	0.09	18.1	14.3	10.0	10.0	Rain & wind	
14/12/16	309						4.1				Fine & sunny	
20/12/16	331						1.9		1.0	1.0	Fine & sunny	
3/01/17	309						8.4				Fine & sunny	
10/01/17	192						2.5				Sunny & windy	
17/01/17	1014						2.6				Fine & sunny	
24/01/17	324						7.2		7.2	7.2	Rain	
31/01/17	345						2.3		0.2	0.2		
14/02/17	292						0.9					
21/02/17	279						2.3					
22/02/17	259										Fine & sunny	
24/02/17	573										Fine & sunny	
28/02/17	75						1.0				Fine & sunny	
7/03/17	359		0.66		<0.01		3.0				Fine & sunny	
14/03/17	613						4.3					
16/03/17	3076	6488	1.4	1.8	0.16	0.09	7.8	6.0	7.8	7.8	Rain	
21/03/17	134						7.8				Fine & sunny	
28/03/17	327						5.7		3.4	4.6	Overcast & windy	
4/04/17	63						1.5				Fine & sunny	
11/04/17	428						5.2		0.2	1.2		
26/04/17	932						4.0		1.0	9.0		
2/05/17	243						2.5		0.4	2.4		
9/05/17	134						6.0					
16/05/17	171						1.2					
20/05/17	3255	5172	1.8	0.57	0.24	0.07	30.1	16.0	7.0	7.0		
21/05/17	3130	529	1.3	1.6	0.05	0.07	9.4	2.8	9.4	16.4		
22/05/17	1515		1.5		0.03		4.5		0.4	9.4		
23/05/17	19,863						52.8		2.4	2.4	Overcast & rainy	
30/05/17	3873						75.2		12.2	12.4	Overcast & cool	

Sample date	Enterococci (cells/100mL)		Total Nitrogen (mg/L)		Total Phosphorus (mg/L)		Turbidity (NTU)		Rainfall (mm)		Weather	Comment
	KMR	TSW	KMR	TSW	KMR	TSW	KMR	TSW	Prev 24 hours	Prev 48 hours		
6/06/17	63		1.6		0.02		12.7				Fine	Significant works in Kings Meadows catchment to identify and rectify blockages and cross-connections
13/06/17	52						4.0		0.2	0.2	Light rain	
20/06/17	31	9208					2.4	27.6	1.0	1.0	Drizzling	
27/06/17	10	275					2.9	9.8	0	0.2	Fine & sunny	
4/07/17	443	2142					7.8	36.2	3.8	3.8	Overcast & raining	
11/07/17	31	20					1.6	9.3	0.2	0.2	Fine & sunny	
18/07/17	3255	9208					44.7	27.4	13.4	13.4	Cloudy & raining	
25/07/17	435	1043					26.0	15.1	4.4	4.6	Cloudy & raining	
2/08/17	134	75					33.9	7.1	0	0.2	Fine & sunny	
8/08/17	187	97					43.3	7.3	0.4	8.6	Fine & sunny	
15/08/17	63	201					46.6	6.9			Overcast	
22/08/17	10	10					33.4	18.5	0.6	0.6	Overcast	
23/08/17	309	733	0.99	0.52	0.07	0.08	41.7	12.9	5.8	6.4	Raining	
29/08/17	169	552					8.8	8.6	0	6.2	Light rain	
19/09/17	683	324					27.3	16.0	21.0	21.0	Raining	
23/09/17	31	52	1.2	1.8	0.03	0.05	7.8	3.9			Fine	
24/09/17	10	74	1.2	2.2	0.03	0.08	4.9	5.9	1.0	1.2	Light rain	
25/09/17	706	301	0.79	1.9	0.05	0.08	33.1	10.7	11.2	12.2	Rain overnight	
26/09/17	109	169	1	2.5	0.03	0.08	17.8	8.4	0	11.2	Fine	
27/09/17	10	20	0.98	2.1	0.02	0.07	10.7	2.2			Fine	
3/10/17	10	238					12.8	6.8	0.2	0.2	Fine	
10/10/17	63	158					3.8	11.2	4.6	4.6	Fine & sunny	
17/10/17	20	41					6.6	6.7			Fine & sunny	
24/10/17	10	75					4.1	5.2			Overcast	
31/10/17	20	213					2.3	7.8	2.8	3.6	Fine & sunny	
7/11/17	10	410					5.3	3.7			Overcast	
14/11/17	10	121					4.3	10.1			Fine & sunny	

Conclusion

The water quality data indicate that water quality in Launceston's waterways is much improved from the 1970s to 1990s, and very often water in Zone 1 in the upper estuary meets the recreational water quality guidelines of 140 cells/100mL Enterococci. However, despite coliform counts in the Tamar Estuary being demonstrably much lower than in previous decades, they are still observed to peak, primarily during rainfall events and after CSOs, rendering the water in Zone 1 unsuitable for primary recreation activities.

The results also demonstrate that rainfall has a significant effect on the water quality in the upper estuary, with pollutants coming from the catchment, the stormwater network and Launceston's combined system.

The results of the monitoring program established that while Launceston's combined sewerage network has a significant impact on water quality it is not the only driver of poor water quality in Zone 1 of the Tamar Estuary. In order to affect substantial water quality improvements, solutions need to be implemented for diffuse catchment and urban stormwater inputs, as well as the combined system overflows.

Combined system overflows

Technical Report

December 2017

Acknowledgements

This report has been developed for the Tamar Estuary Management Taskforce to aid in the development of a River Action Plan for the Tamar Estuary. The modelling and analysis contained in this reports has been undertaken by Dr Rebecca Kelly of isNRM Pty Ltd using data from a hydraulic model and costings provided by City of Launceston – Michael Newby, Kathryn Pugh, Randall Langdon, Ray Dodson (GHD) and Cameron Jessup (TasWater). The development of this report has been oversighted by a Combined System Overflow working group consisting of: Shane Eberhardt (City of Launceston), Andrew Truscott, (TasWater), Geoff Brayford (Johnstone, McGee and Gandy Pty Ltd) and Stewart Sharples (Infrastructure Tasmania).

Executive Summary

This report provides a detailed analysis of the effects of a series of potential investment options for reducing CSOs which have been developed by City of Launceston. This analysis has been undertaken using an improved version of the TEER CAPER DSS that was originally developed to support the TEER Water Quality Improvement Plan. In order to be used for analysis of these CSO options significant changes have been made to the DSS to allow results from the CoL hydraulic model to be incorporated and to better represent connections between the combined system and Ti Tree Bend STP. This analysis first looked at the benefits of individual projects before developing a recommended pathway of preferred options.

- The final options which have been assessed using the City of Launceston hydraulic model and which are analysed in this report are:

- Esplanade storage – 3 ML storage located in the vicinity of Black Bridge and Boland St.

- Forster St storage – 2.5ML underground storage adjacent to Forster St Pump station.

- New Margaret St storage – 4.2ML storage in Kings Park adjacent to New Margaret St Pump station.

- South Launceston Diversion – takes the separated sewage from South Launceston including Kings Meadows/Newstead and Boland St direct to Ti Tree Bend away from the Forster St pump station.

- West Launceston Diversion – takes the separated sewage from West Launceston and Trevallyn and diverts this directly to Ti Tree Bend STP along the West Tamar highway and directly across the Tamar estuary via a new main reducing the load on new Margaret St.

- New combined rising main – divert flows to New Margaret St with decommissioning of Old Margaret St, installation of new sewage pumps to increase sewage pump capacity, Installation of new rising main works to connect New Margaret St to a storage at Ti Tree Bend and to the Ti Tree Bend STP, reconfiguration of Forster St and St John SPS to increase pump rate to Ti Tree Bend and construction of a storage or wetland at Ti Tree Bend.

A preferred pathway of investment has been developed from the analysis which maximises benefits with minimal costs and disruption. This pathway of options and costs is shown in Table A.

Table A. Pathway of preferred investment options for reducing CSOs

Option	Description	Cost ($ million)
Option 1	West Launceston Diversion	4.6
Option 2	Option 1 plus New Combined Rising Main	31.4
Option 3	Option 2 plus offline storage located at New Margaret St Pump Station	41.4
Option 4	Option 3 plus South Launceston Diversion in conjunction with Esplanade offline storage	66.2
Option 5	Option 4 plus offline storage located at Forster St Pump Station	74.6
Full separation	Development of a full separated sewer and stormwater system in the combined area	435

The potential for avoided CSOs to put additional pressures on treatment at Ti Tree Bend has also been explored together with the potential benefits of an additional $10 million investment in upgraded nutrient treatment capacity at Ti Tree Bend.

Figure A shows the impact of the preferred CSO Investment Options in conjunction with a treatment upgrade at Ti Tree Bend on Greater TEER catchment total loads. Note that loads and concentrations of TSS and Enterococci are assumed to be unaffected by this upgrade. This figure shows that with this upgrade included Greater TEER catchment nutrient loads can be expected to decrease by 3 to 4 per cent. Investment in the combined system can be expected to lead to large decreases in Enterococci loads. The curve shows decreasing returns to scale of the investment, such that the initial investment in Option 1 (West Launceston Diversion) achieves approximately 20 per cent of the decrease in Enterococci loads from full separation at 1 per cent of the cost. Option 5 achieves roughly 85 per cent of the full benefit at 17 per cent of the total cost, and with significantly less disruption to the residents and businesses in the combined system area.

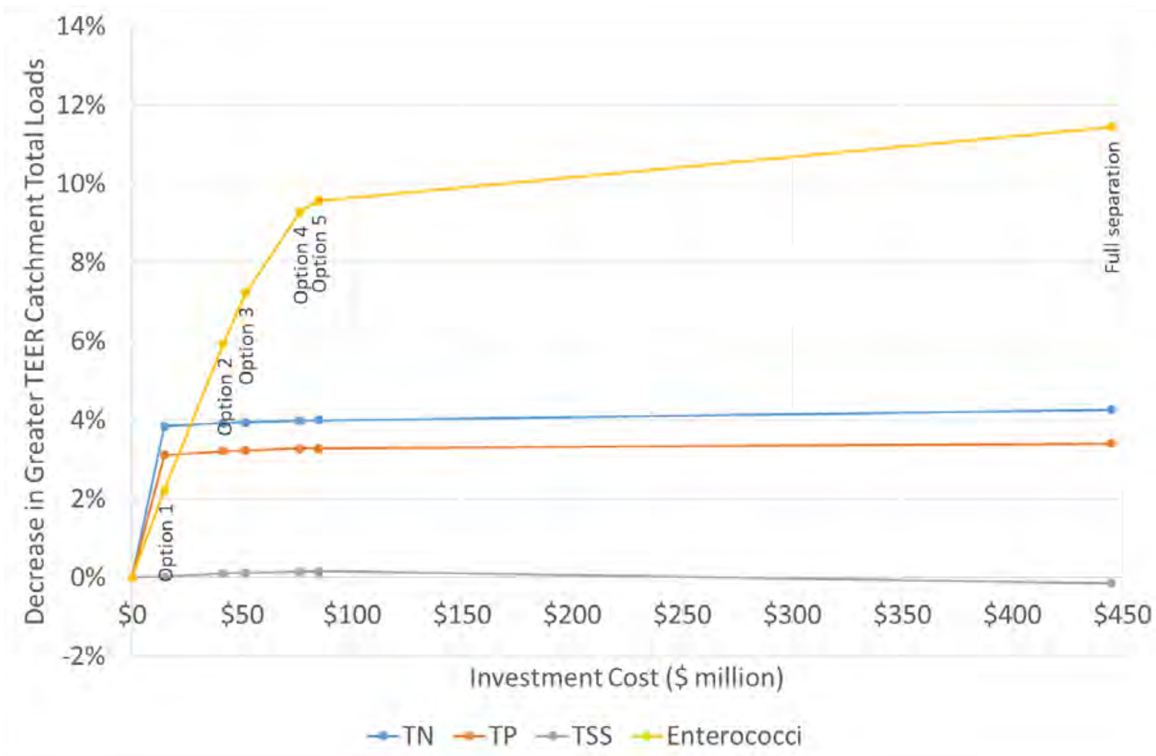


Figure A. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Figure B shows the impacts of these Investment Options with the treatment upgrade at Ti Tree Bend on Tamar Estuary Zone 1 concentrations. CSOs are the largest contributor to Tamar Estuary Zone 1 concentrations. This pathway of preferred investment in reducing CSOs can be expected to have very large and significant benefits in terms of reduced Enterococci concentrations in the upper estuary. As shown in this figure, Enterococci concentrations can be expected to decrease by nearly 10 per cent. Investment in Option 5 can be expected to decrease Enterococci concentrations by 37 per cent, which can be expected to have very significant benefits for recreational users of the upper estuary.

This figure also shows substantial benefits of the treatment upgrade in terms of decreased nutrient concentrations. It is estimated that TP concentrations would decrease by 18 per cent and TN by 26 per cent. This investment option allows the benefits of reduced CSOs in terms of Enterococci to be retained while substantially decreasing nutrient concentrations, avoiding the potential decline that could be expected without such an upgrade.

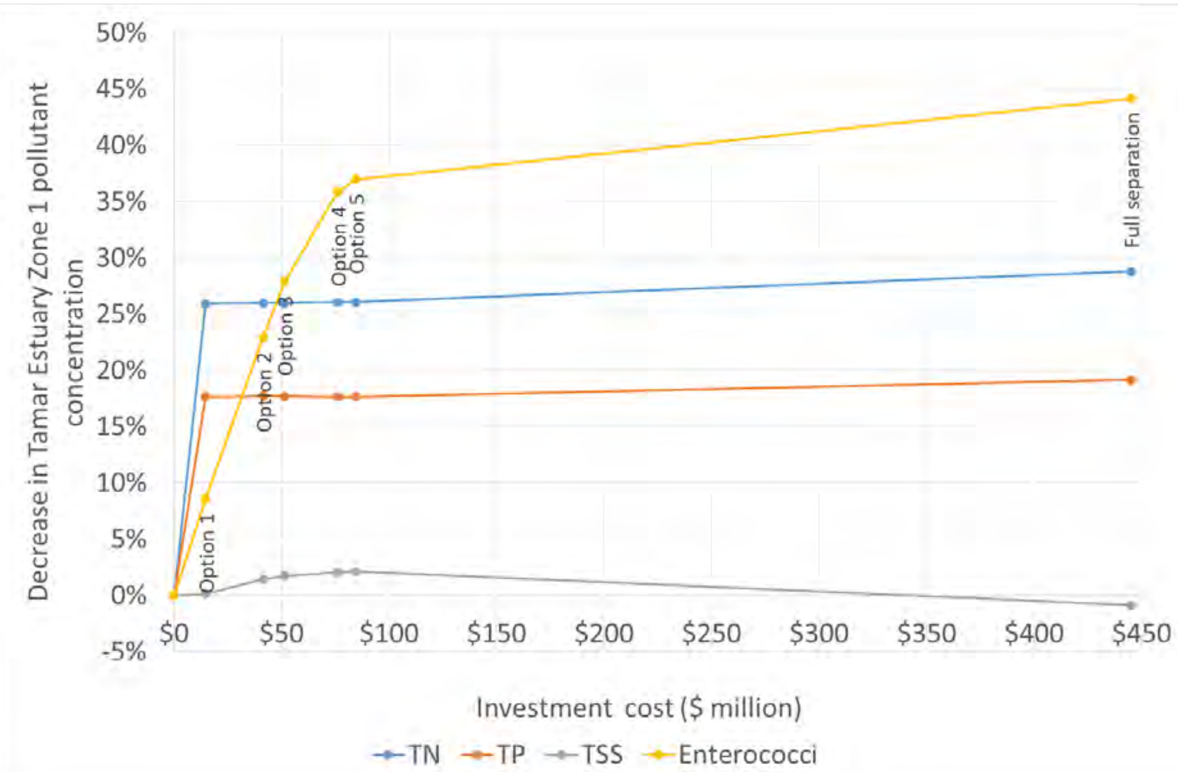


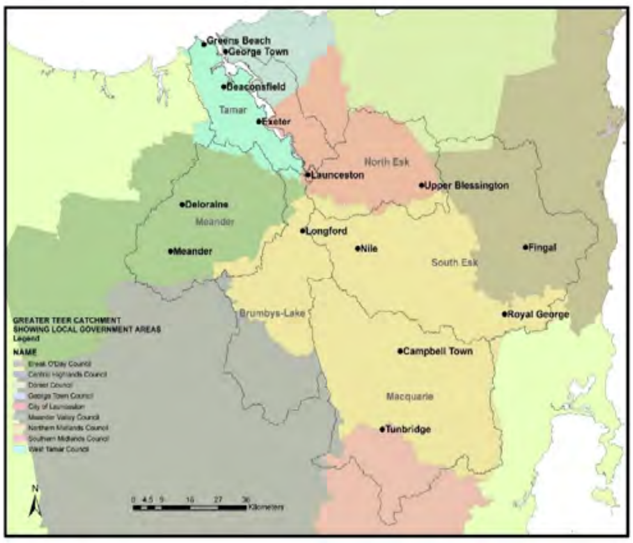
Figure B. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Based on the analysis in this report:

- There is a clear pathway of investments in reduced CSOs that has the potential to provide large improvements in Enterococci (and other pathogen) concentrations in Zone 1. These investments could be undertaken using a staged approach, progressively capturing the benefits of full investment. Decreasing returns to the scale of investment mean that this approach captures most of the benefits in the early stages of the investment pathway. Investment in Option 5 is expected to lead to a 37 per cent decrease in Tamar Estuary Zone 1 Enterococci concentrations for a total cost of roughly $75 million. This represents 85 per cent of the total benefit that could be achieved by fully separating sewage and stormwater in the combined system at 17 per cent of the cost. Full separation is considered to be infeasible given the enormous disruption it would cause over many years to businesses and residents in the combined system. These results demonstrate that this option is not needed to effect very large decreases in pathogen concentrations in the upper estuary.
- Increased influent volumes to Ti Tree Bend STP from avoided CSOs have the potential to increase nutrient concentrations in the upper estuary. Very little data are available to accurately estimate this impact but significant trends in treatment effectiveness with increased influent volume are observed in the data that are available. Ti Tree Bend was not designed to effectively reduce nutrient concentrations. It is recommended that nutrient treatment upgrades at Ti Tree Bend are considered as part of the investment pathway to reduce CSOs. TasWater already has some preliminary investigations of upgrade options which could be further developed in the design phase of any investment in CSOs. The analysis here shows this type of upgrade in conjunction with the CSO investment options could lead to significant water quality benefits in the upper estuary with concentrations of TN and TP decreasing by 26 per cent and 18 per cent respectively.
- More data on influent and effluent volumes and pollutant concentrations at Ti Tree Bend would significantly reduce the uncertainty of estimates of the impacts of increased influent volumes on treatment effectiveness. TasWater should continue to add to their understanding through continuation and refinement of their monitoring program.

1 Introduction

The Tamar Estuary and Esk Rivers (TEER) drain approximately 15 per cent of Tasmania, consisting of the North Esk, South Esk, Brumbys Lake, Macquarie, Meander and Tamar foreshore catchments (see Figure 1). The kanamaluka/Tamar Estuary is a drowned river valley, running for approximately 70 kilometres from Launceston to Bass Strait. The majority of flows to the Estuary come from the North Esk River and the South Esk River, with flows passing from the South Esk River through Trevallyn Dam to the upper estuary.



App G Figure 1. Location of the Tamar estuary and its catchment (Greater TEER catchment), including major sub-catchments and Local Government Areas

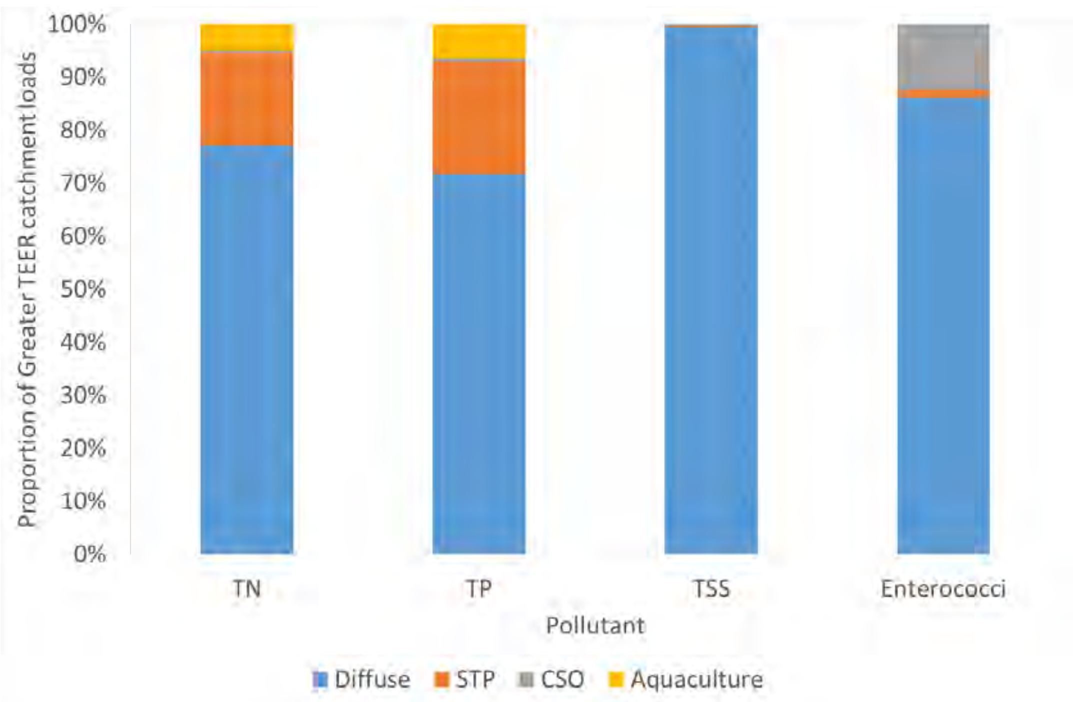
The City of Launceston sits at the top of the Tamar River Estuary. Parts of Launceston city drain into a combined sewer–stormwater system where sewage and stormwater are directed to the Ti Tree Bend sewage treatment plant in a single piped network. This combined system is designed to provide some level of treatment to both sewage and stormwater in the combined area. Flows greater than the volume able to be carried by the network or treated at the STP are discharged as combined system overflows from other parts of the network directly to the Estuary. In this way flows may overflow from the combined pipe network itself at pump stations or at Ti Tree Bend if insufficient capacity is available at the STP to treat the volume of water arriving there. This section provides a detailed description of the results from modelling and analysis undertaken to develop an investment plan for managing combined system overflows (CSOs). It provides further analysis of a suite of options developed by the City of Launceston and detailed in their Technical Report (City of Launceston 2017), considering the impacts at a catchment scale and on the Estuary itself. This CSO Investment Plan complements a second investment plan being developed by the Catchment Action Working Group under the TEMT objectives. That plan is focused on reducing pollutants exported from diffuse catchment sources into the Estuary (see Kelly 2017). The investment plans have been developed as part of a broader suite of management recommendations forming a River Health Action Plan being prepared by the Tamar Estuary Management Taskforce.

The recommended actions within the investment plans target the upper reaches of the Tamar Estuary from Launceston to Legana (referred to as Tamar Estuary Zone 1). They build on the work previously undertaken to develop a Tamar Estuary and Esk Rivers (TEER) Water Quality Improvement Plan (WQIP) by NRM North for the catchment and are a considerable step forward in its implementation (Tamar Estuary and Esk Rivers Program, 2015).

The WQIP and these investment plans consider the impact of investment actions on four major pollutants: total nitrogen (TN), total phosphorus (TP), total suspended sediments (TSS) and Enterococci. TN and TP are nutrients. Elevated nutrient levels can feed the growth of nuisance algal growth in streams, dams and the Estuary. These algae can increase turbidity and can smother and replace native plant and animal species. It can also make water dangerous for recreation and drinking. High levels of TSS make water turbid and dirty looking, and can smother and replace native plant and animal species, decreasing the health of waterways. Sediment exports from the freshwater system to the Estuary can also contribute to sediment accumulation in the upper estuary. Enterococci is a bacteria used as an indicator of pathogen pollution. Pathogens come from animal or human faeces and when elevated can make people sick if they drink or recreate in water.

2 The role of CSOs in water quality in the Tamar Estuary and its catchment

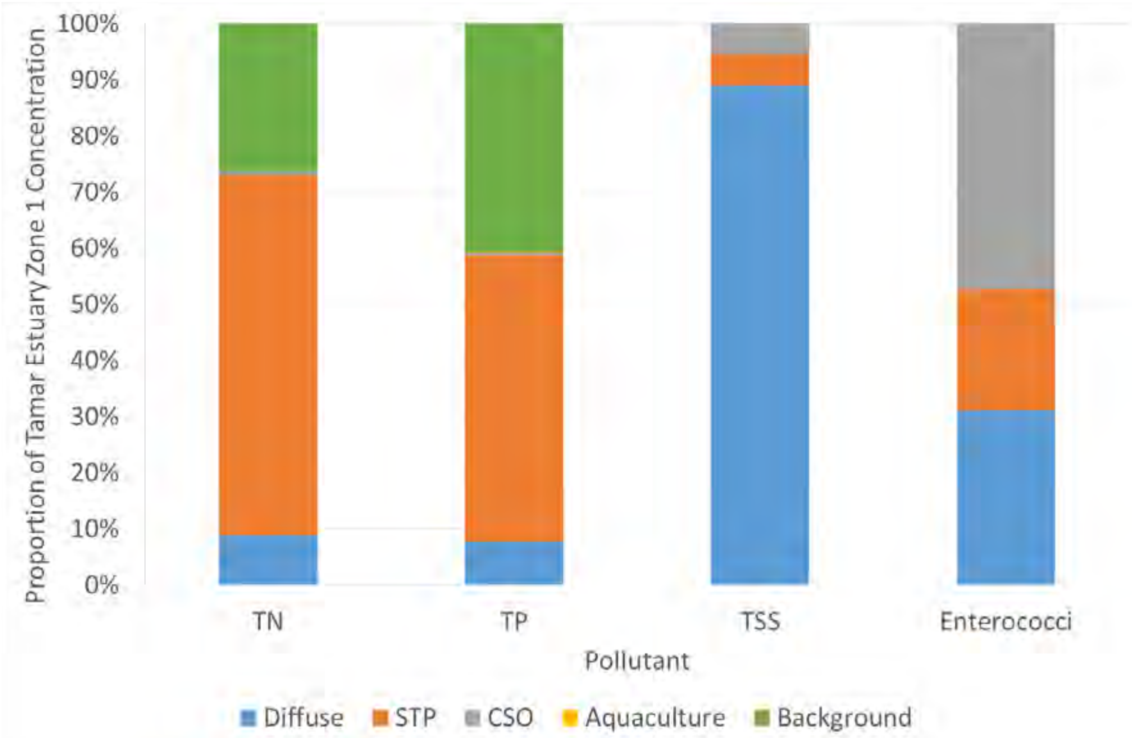
Pollutant loads in the TEER catchment come from a range of diffuse and point sources: directly off the catchment from the various land uses that cover the land surface (diffuse); 26 sewage treatment plants in the catchment and some discharging directly into the estuary; a salmon farm operating in the lower reaches of the estuary; and from combined system overflows. Figure 2 provides an estimate of the proportion of pollutant loads derived from each of these sources.



App G Figure 2. Proportion of Greater TEER catchment pollutant loads from various sources

This figure shows that diffuse sources, that is pollutants delivered through runoff from the land surface (or as groundwater input to stream influenced by pollutant infiltration to groundwater), is the dominant source of pollutants across the catchment, producing 99 per cent of sediments, 86 per cent of Enterococci and over 70 per cent of nutrient loads in the catchment. Sewage treatment plants are a significant contributor to nutrient loads in the catchment (17% to 21%) with aquaculture also producing approximately five to seven per cent of nutrient loads. CSOs make their largest contribution to Enterococci concentrations, producing approximately 12 per cent of the enterococci load for the Greater TEER catchment.

In terms of the impact on Tamar Estuary Zone 1 concentrations, the size of pollutant loads of each source is moderated by how directly it enters this portion of the Estuary. Sewage treatment plants discharging into the upper Estuary, urban areas around Launceston and combined system overflows can be expected to have a greater impact on Tamar Estuary Zone 1 pollutant concentrations than loads generated higher up in the catchment, particularly those upstream of Trevallyn Dam. Figure 3 shows an estimate of the influence of all these sources on average pollutant concentrations in Tamar Estuary Zone 1. This figure should be read with several caveats. Results shown here presume that each pollutant source is "switched off". This means that it is assumed that no flow enters the Estuary from the catchment. In reality, management changes can affect loads without reducing flows. A background concentration of nutrients is assumed in the modelling. This accounts for the influence of processes such as nutrient cycling within the Estuary and oceanic inputs of nutrients to the Estuary. This is treated as a fixed value so does not respond to the changes in flow and loads from other sources being modelled here. Background concentrations are not considered to be "controllable" — rather they are naturally occurring and not subject to management. This information is intended to show the relative leverage of actions to reduce loads from these sources on Tamar Estuary Zone 1 concentrations only and should be read in this context.



App G Figure 3. Estimated contribution of various sources on pollutant concentrations in Tamar Estuary Zone 1

This figure shows that Tamar Estuary Zone 1 nutrient contributions are driven, to a large extent, by STP discharge direct to the Estuary. Diffuse sources have a smaller impact on Tamar Estuary Zone 1 concentrations. Most of this impact will come from catchment areas that contribute directly to the Estuary — the upper Tamar foreshore and North Esk River catchments. There is some tidal influence on pollutants entering Zone 1 — for example aquaculture and urban areas further down the Estuary can have a small impact on Zone 1. TSS concentrations are largely driven by diffuse rather than point sources, with much of this delivered from urban areas around Launceston and other land use areas in the North Esk catchment. CSOs and STPs do make some contribution to TSS concentrations in Tamar Estuary Zone 1, but this is estimated to be in the order of five per cent for each compared to 90 per cent from diffuse sources. CSOs are significant drivers of Enterococci concentrations in the Tamar Estuary Zone 1, contributing nearly half of the average concentration. The remaining portion comes from a mix of diffuse and STP sources, with diffuse inputs estimated to have slightly more impact than STPs on Enterococci concentrations.

3 Focus of the investment plan

This Investment Plan focuses entirely on combined system overflows and their impacts at Ti Tree Bend. The primary focus of both investment plans is the reduction of pathogen concentrations in the Tamar Estuary Zone 1. However it is recognised that the goal of the TEMT is to improve water quality in all its facets therefore impacts on nutrients and sediments are also discussed. This is particularly important as some actions recommended to reduce CSOs can have negative effects on nutrient concentrations in the Estuary. This report considers not only the benefits of the proposed investments for Enterococci concentrations in the upper Estuary but also actions to address these negative trade-offs for nutrients.

This report is entirely focused on management of pollutants entering the Estuary from combined system overflows and issues around the impact of these investments at Ti Tree Bend. The Catchment Action Working Group Technical Report (Kelly 2017) contains similar analysis and recommendations for catchment management actions to manage diffuse pollutant sources.

4 Potential actions to reduce CSOs

City of Launceston (CoL) staff has undertaken a significant assessment of potential options for reducing combined system overflows. These options were considered in light of their feasibility, cost and potential impact. A detailed analysis and justification of the final options selected can be found in City of Launceston (2017).

The final options which have been assessed using the City of Launceston hydraulic model are:

- Esplanade storage – 3 ML storage located in the vicinity of Black Bridge and Boland St
- Forster St storage – 2.5ML underground storage adjacent to Forster St Pump Station
- New Margaret St storage – 4.2ML storage in Kings Park adjacent to New Margaret St Pump Station
- South Launceston diversion – takes the separated sewage from South Launceston including Kings Meadows/Newstead and Boland St direct to Ti Tree Bend away from the Forster St Pump Station.
- West Launceston diversion – takes the separated sewage from West Launceston and Trevallyn and diverts this directly to Ti Tree Bend STP along the West Tamar Highway and directly across the Tamar Estuary via a new main reducing the load on New Margaret St
- New combined rising main – divert flows to New Margaret St with decommissioning of Old Margaret St, installation of new sewage pumps to increase sewage pump capacity, installation of new rising main works to connect New Margaret St to a storage at Ti Tree Bend and to the Ti Tree Bend STP, reconfiguration of Forster St and St John SPS to increase pump rate to Ti Tree Bend and construction of a storage or wetland at Ti Tree Bend

The estimated cost of each potential action is given in Table 1.

App G Table 1. Estimates cost of potential actions to reduce CSOs

Project	Cost ($ million)
Esplanade storage	6.7
Forster St storage	8.4
New Margaret St storage	10
South Launceston Diversion	18.1
West Launceston Diversion	4.6
New combined rising main	26.8

These options were all assessed for their relative impact on total loads from the Greater TEER catchment (as a percentage reduction against the sum of diffuse and point source loads) and on Tamar Estuary Zone 1 concentrations. This allows options to be compared with actions recommended in the Diffuse Management Investment Plan.

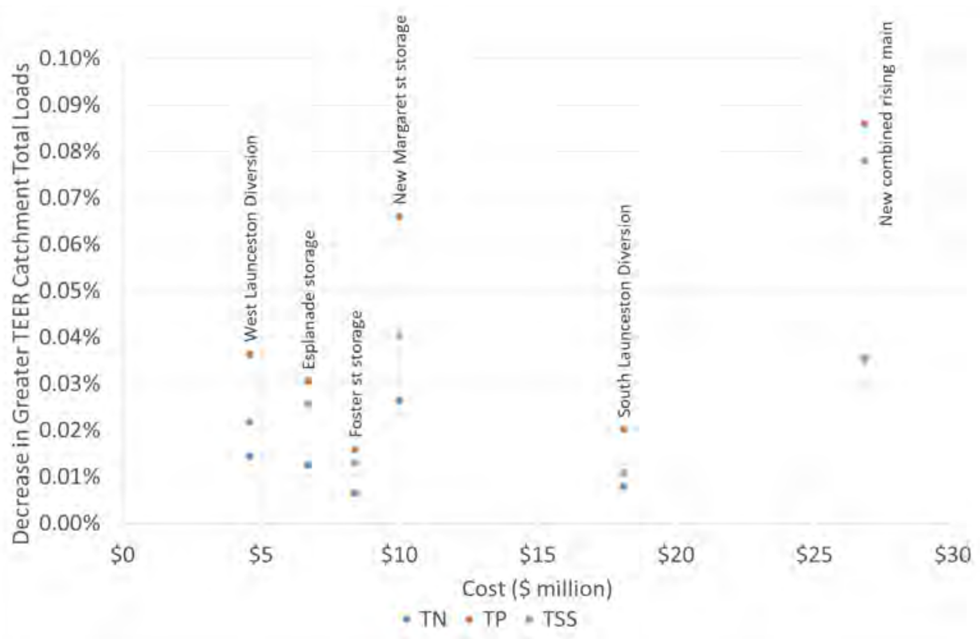
This section describes these impacts. The first section considers impacts of reduced combined system overflows only, assuming that avoided overflows can be treated at Ti Tree Bend STP without any impact on treatment effectiveness. The second section explores the potential impacts on treatment effectiveness of increased flows to Ti Tree Bend from reduced CSOs, and the potential changes that could be expected in Greater TEER catchment loads and Tamar Estuary Zone 1 concentrations resulting from this.

4.1 Water quality improvements assuming no impact on treatment effectiveness at Ti Tree Bend

In this section it is assumed that avoided overflows pass for treatment at Ti Tree Bend STP. A uniform rate of treatment is assumed to be achieved regardless of the flow that enters the plant.

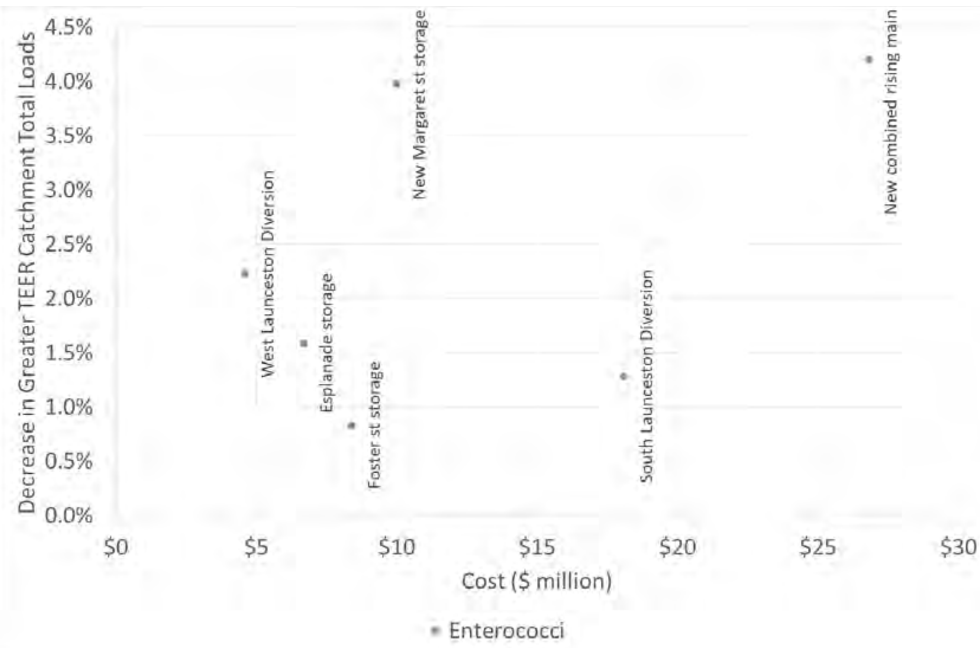
4.1.1 Impacts of individual actions on Greater TEER catchment diffuse and point source loads

The impact of each of the potential actions on Greater TEER catchment total nutrient and sediment loads (diffuse plus point source) is shown in Figure 4. Figure 5 shows impacts on Enterococci loads. Note that impacts are shown in terms of the decrease in load – so a negative value means an increase in load and decline in water quality.



App G Figure 4. Decrease in Greater TEER catchment diffuse and point source loads – nutrients and sediments

This figure shows that the impact on Greater TEER catchment total nutrient and sediment loads is relatively small. If no change in treatment effectiveness at Ti Tree Bend is considered then all options would be expected to lead to a very small decrease in sediment and nutrient loads, with the greatest benefits for TP loads and smallest for TN.

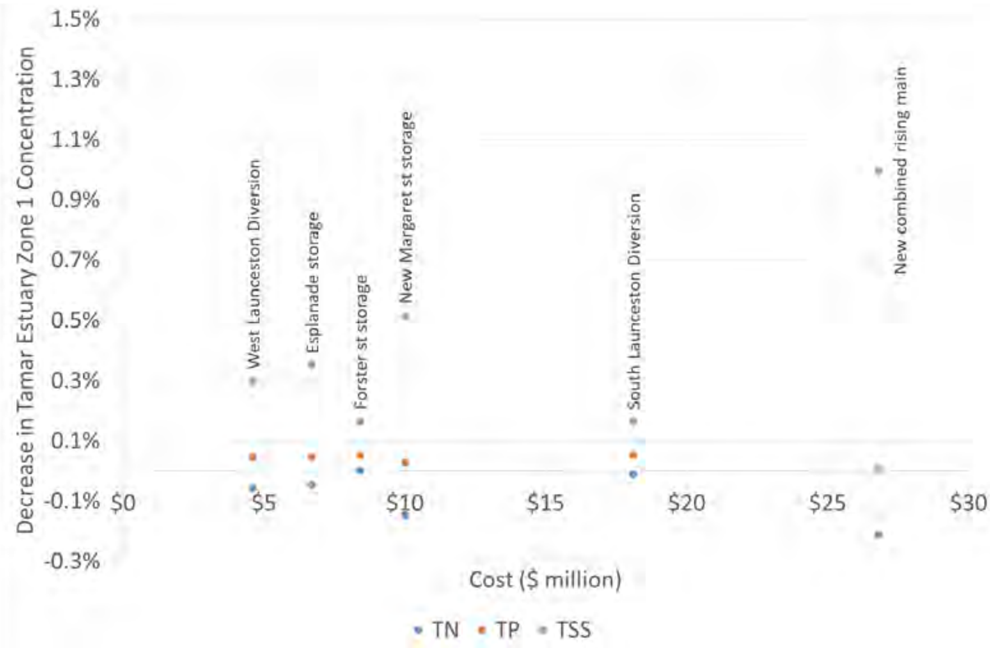


App G Figure 5. Decrease in Greater TEER catchment diffuse and point source loads - Enterococci

This figure shows that the scale of decreases of Enterococci loads is significantly greater than for nutrient or sediment loads, with decreases of over four per cent of loads expected for some options. The most cost effective action is shown to be the West Launceston Diversion which achieves more than two per cent decrease in Enterococci loads for a budget of less than $5 million. By comparison the Forster St storage is expected to cost over $8 million and achieve less than a one per cent decrease in loads. The New Margaret St storage is also very cost effective achieving a four per cent decrease in Enterococci loads for approximately $10 million.

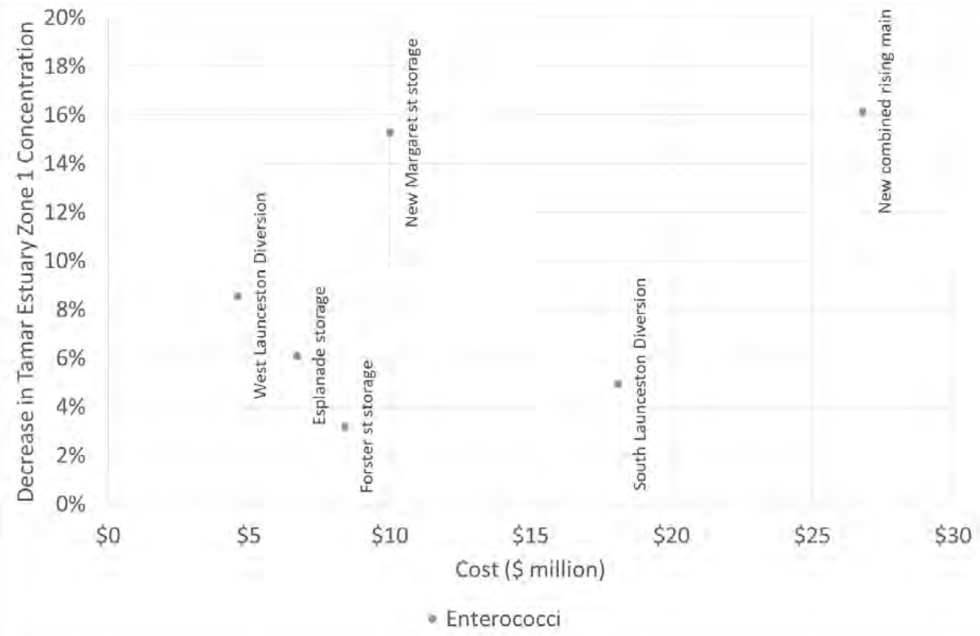
4.1.2 Impacts of individual actions on Tamar Estuary Zone 1 concentrations

Impacts of these individual actions on Tamar Estuary Zone 1 concentrations are shown in Figures 6 and 7 for nutrients and sediments, and Enterococci respectively.



App G Figure 6. Decrease in Tamar Estuary Zone 1 concentration – Nutrients and sediments

This figure shows that the scale of potential impacts on Tamar Estuary Zone 1 concentrations of nutrients and sediments is greater than was the case for Greater TEER catchment total loads but is still fairly small, at least for nutrients. TN concentrations have the potential to increase slightly even though total loads are reduced. This is in part due to the effect of averaging concentrations across Zone 1, where a spike in the vicinity of Ti Tree Bend has a greater impact on the average value than a smaller reduction across other areas of the zone where CSOs are avoided. Very little impact on TP is expected. Impacts on TSS are greater, with the greatest benefit with the new combined rising main option expected to decrease TSS concentrations by roughly one per cent.

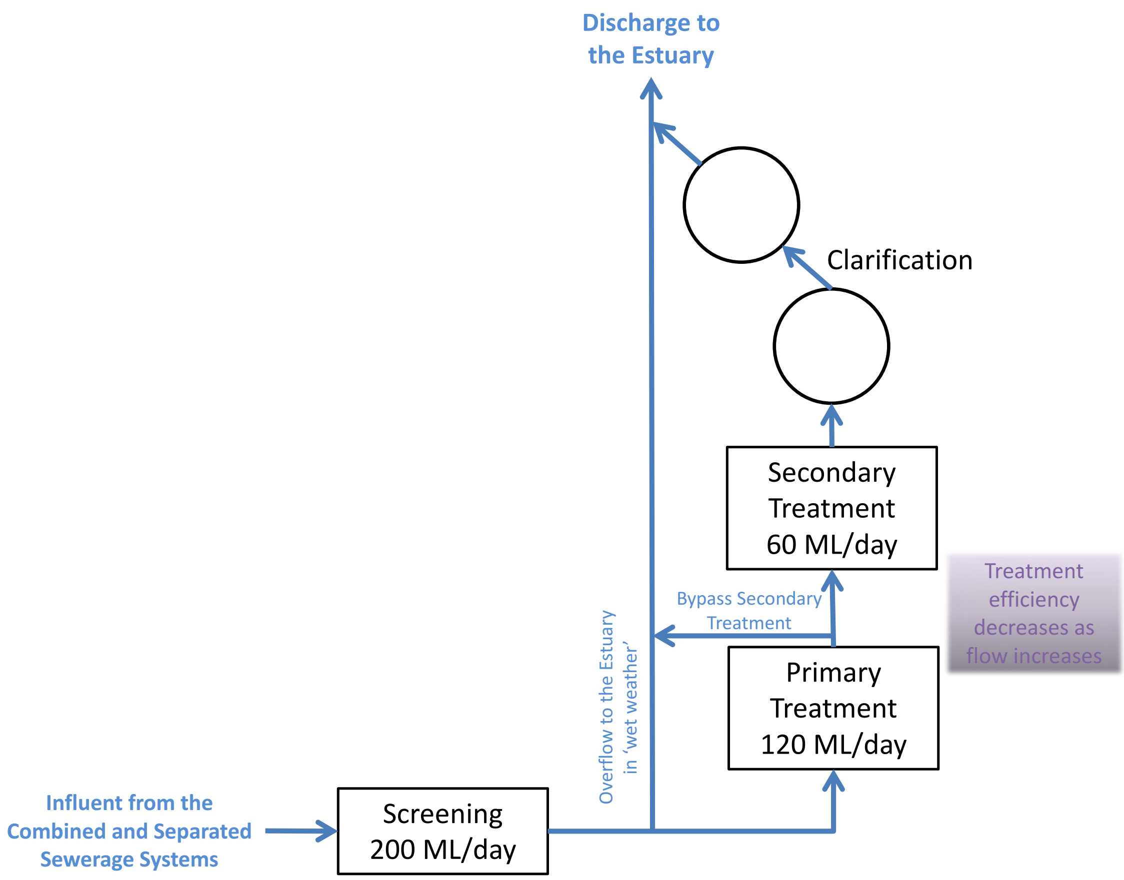


App G Figure 7. Decrease in Tamar Estuary Zone 1 concentration – Enterococci

As was the case for Greater TEER catchment loads, impacts of these individual actions on Tamar Estuary Zone 1 concentrations are significantly greater than for nutrients and sediments. The New Margaret St storage and new combined rising main can both be expected to lead to substantial decreases in Tamar Estuary Zone 1 Enterococci concentrations (15% to 16%). The West Launceston diversion is also very cost effective, leading to an eight per cent decrease in concentrations for less than 20 per cent of the cost of the new combined rising main.

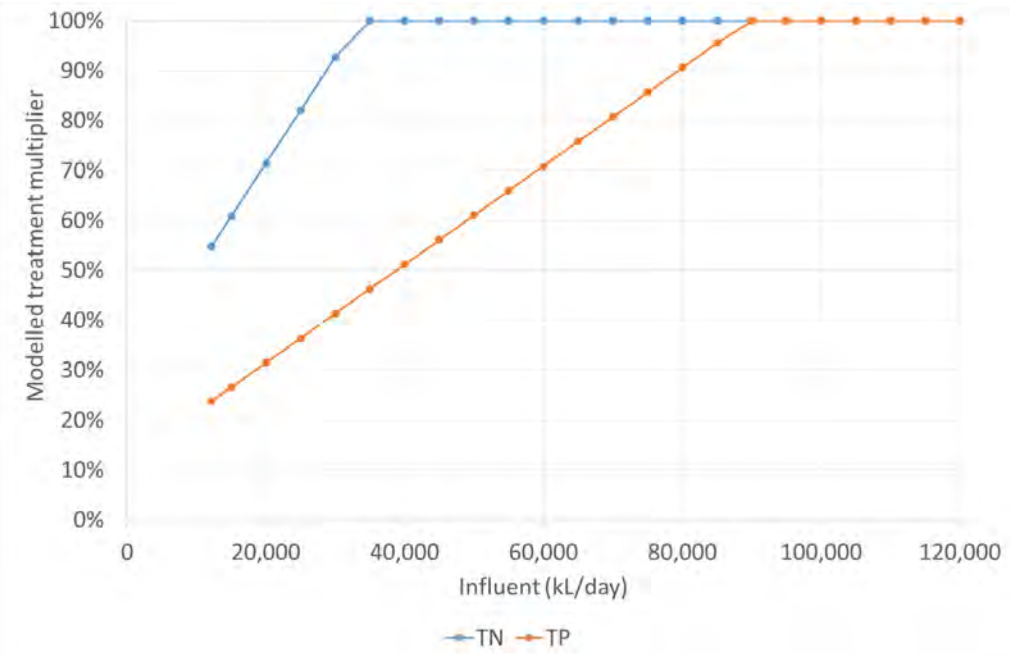
4.2 An exploration of water quality impacts if reduced CSOs affect treatment effectiveness at Ti Tree Bend

The results in Section 4.1 assume that increased flows at Ti Tree Bend STP due to avoided CSOs have no impact on the treatment effectiveness of the plant. This is however not the case. Figure 8, a simplified schematic of the operation of Ti Tree Bend, shows that the STP works with a series of bypasses. Flows up to 200ML/day can pass through screening, removing a significant proportion of sediments. Primary treatment has a capacity to treat up to 120ML/day. Flows greater than this bypass the STP and effectively overflow at the STP site direct to the Estuary. The treatment capacity of the secondary treatment phase is approximately 60ML/day. Flows greater than this bypass secondary treatment and are discharged direct to the Estuary. Chlorination reduces pathogen concentrations of bypassed flows. Both primary and secondary treatment effectiveness are reduced as flows increase through the plant. Flows near capacity have the potential to mobilise pollutants, particularly nitrogen, and the lower treatment time affects, for example, the amount of sediments that fall out during treatment. Ti Tree Bend was not designed to remove TN and TP so generally removes less of these pollutants than it does TSS or Enterococci.

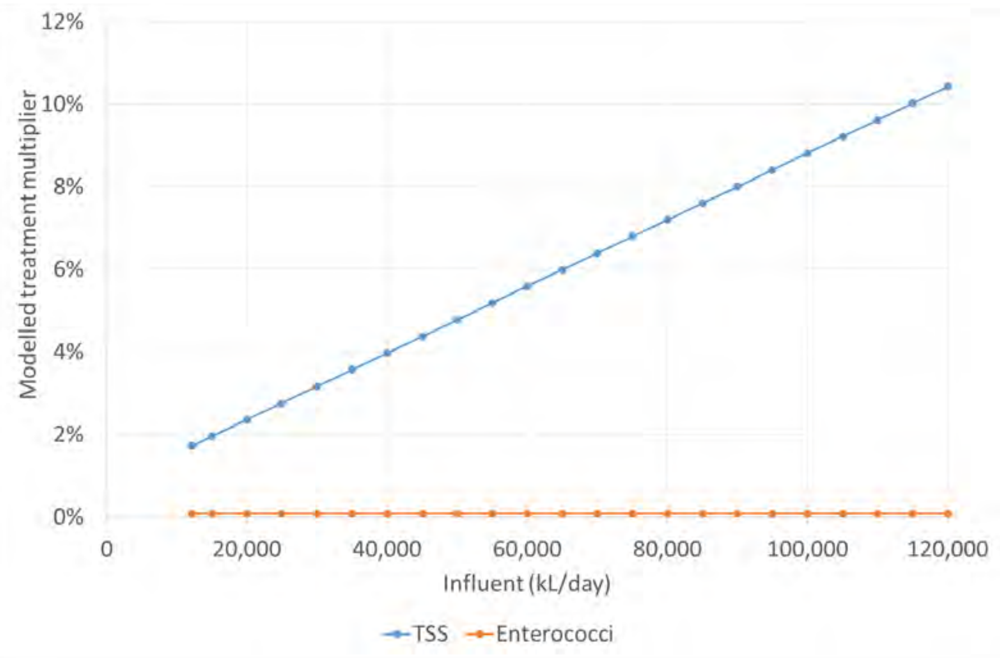


App G Figure 8. Simplified schematic of treatment at Ti Tree Bend STP (pers comm: Andrew Truscott)

Limited concentration data was available before and after treatment to estimate the effects of increased influents on treatment effectiveness. Available data was used to create an empirical model. A full description of this analysis and the final models used is given in Appendix 2. These models were significant with very good p-values on fitted trends but had a significant scatter around the fitted line and relatively low R2 values. These characteristics indicate that increased influent significantly affects treatment effectiveness but that there is a lower degree of certainty around the magnitude of this effect. Given this, a model based on these fits has been used to explore the potential impacts this decrease in effectiveness has on load and concentration decreases. These models are shown in Figure 9 for nutrients and Figure 10 for sediments and Enterococci. They use a multiplier for the proportion of influent load for each pollutant that becomes discharged load. Note the different scale of multipliers for nutrients, sediments and Enterococci. Nutrient multipliers were capped at 100 per cent. There was some indication that these continue to increase over 100 per cent as flows increase, indicating that additional nutrients are mobilised from those within the plant system once flows increase over a given threshold (in the case of TN estimated to be between 30,000 and 40,000 kL). Given the quality of the data available for fitting the model it was decided to cap this multiplier to 100 per cent to avoid large overestimates of the impact on nutrient loads. This may mean that impacts shown here are conservative (note a range of impact is also provided with this cap removed). Given the uncertainties involved these results should be considered indicative of the magnitude and direction of changes which may be expected, while acknowledging that the true impact is likely to vary from the modelled impact.

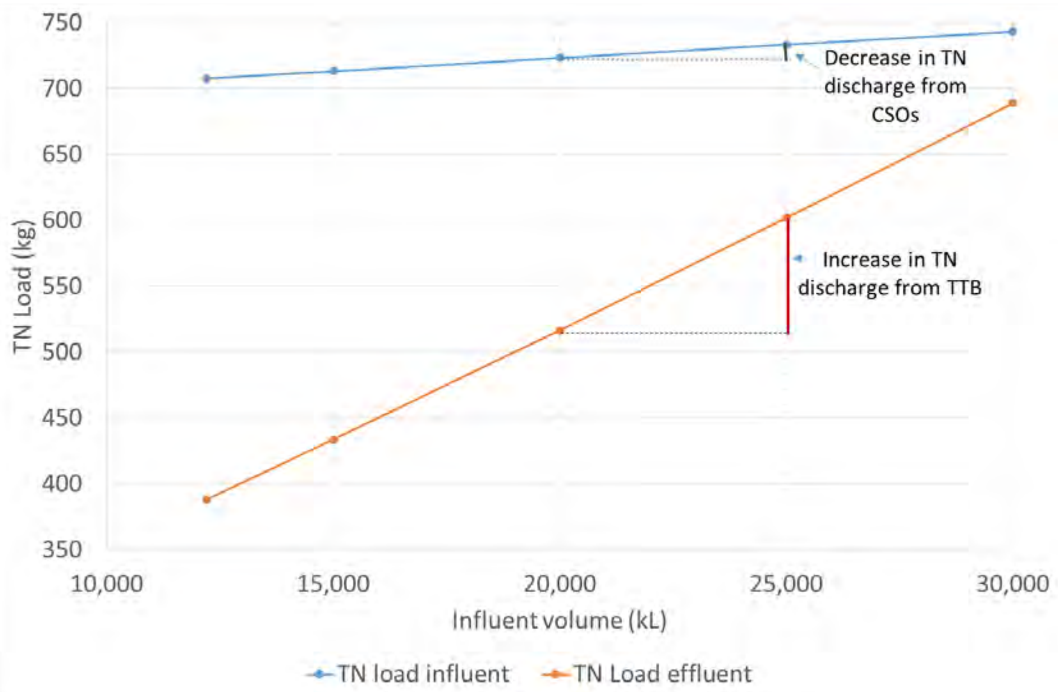


App G Figure 9. Modelled impacts of increased flows through Ti Tree Bend STP on treatment effectiveness – nutrients



App G Figure 10. Modelled impacts of increased flows through Ti Tree Bend STP on treatment effectiveness – Sediments and Enterococci

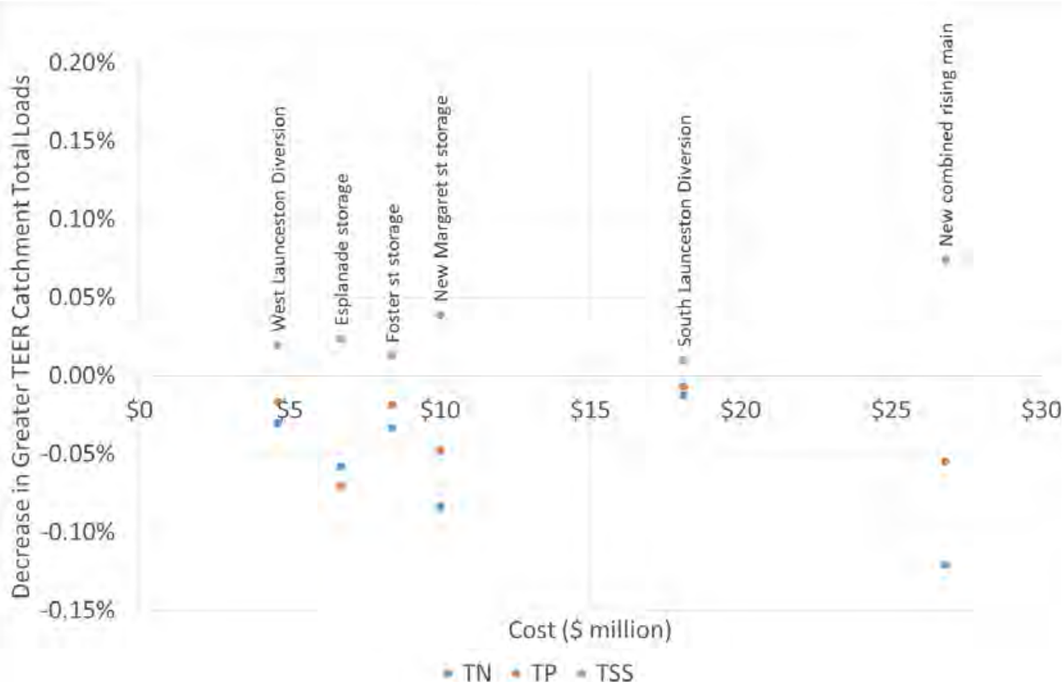
The consequence of these changes in treatment effectiveness can be that total loads to the Estuary increase even though CSOs are avoided, and loads that would have been discharged untreated are now receiving some level of treatment at Ti Tree Bend STP. Figure 11 demonstrates this effect for TN load. In this figure the influent TN load for each flow volume is estimated as a mix of sewage and stormwater. Note that the slope of this reflects the relatively lower concentration of TN in stormwater compared to sewage (increasing influent adds TN load through additional stormwater rather than additional sewage). The TN effluent is then the multiplier for each influent volume multiplied by the influent load. As this figure shows the gradient of the effluent curve is significantly steeper than for the influent curve, reflecting the decreasing treatment effectiveness as influent increases. Importantly this impact occurs for every kL of flow influent not just for the additional volume entering the plant. The green and red lines demonstrate the relative scale of avoided CSOs (which is equal to the increase in influent load to Ti Tree Bend) versus the additional effluent load from Ti Tree Bend for a shift from 25,000kL to 30,000kL influent to the plant. As is seen in the figure the scale of increase of effluent from Ti Tree Bend is significantly greater than the avoided CSOs (87kg versus 10kg). In this way avoided CSOs have the potential to increase nutrient loads discharged to the Estuary. This effect does not occur for Enterococci as no decline in treatment effectiveness was found. For TSS the scale of the increase in effluent loads from Ti Tree Bend is significantly less than the decrease in loads from avoided CSOs (54kg versus 700kg), meaning overall a net improvement in water quality is still achieved.



App G Figure 11. Example of change in TN load discharged with a change in influent volume

4.2.1 Impacts of individual actions on Greater TEER catchment diffuse and point source loads

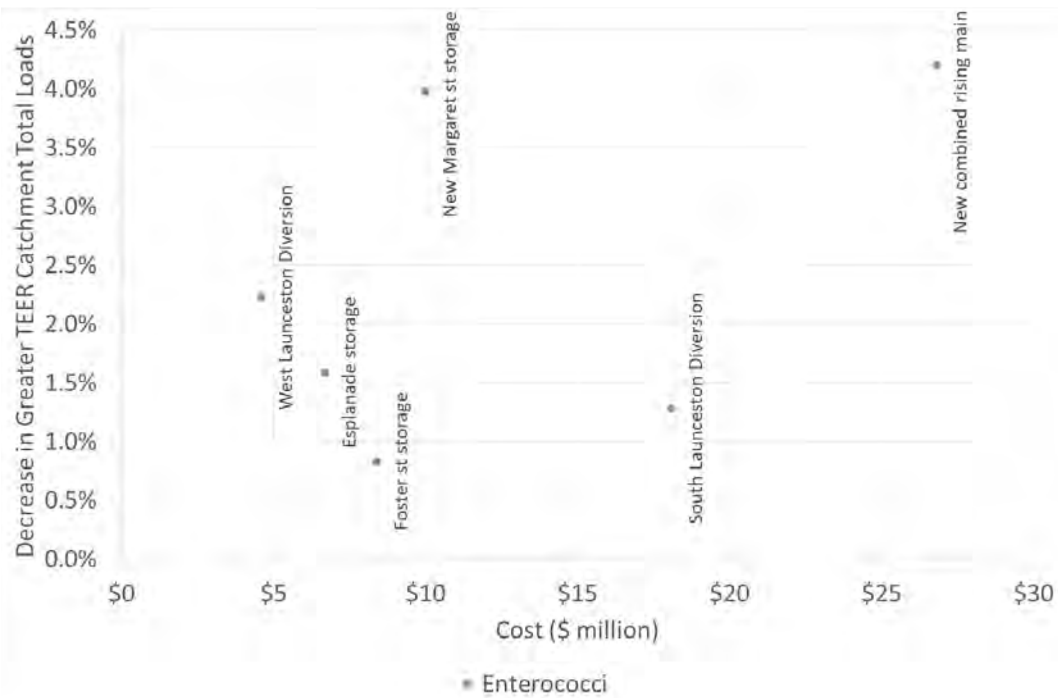
Figures 12 and 13 show the effect of the individual actions on Greater TEER catchment total loads of nutrients and sediments, and Enterococci respectively. These figures incorporate the effect of decreasing treatment effectiveness as influent volumes increase due to avoided CSOs.



App G Figure 12. Decrease in Greater TEER catchment diffuse and point source loads – nutrients and sediments

This figure shows that decreasing treatment effectiveness has the capacity to affect nutrient removal to the extent that loads increase for both TN and TP — the greater the effect on reducing CSOs the larger the increase in nutrient loads.

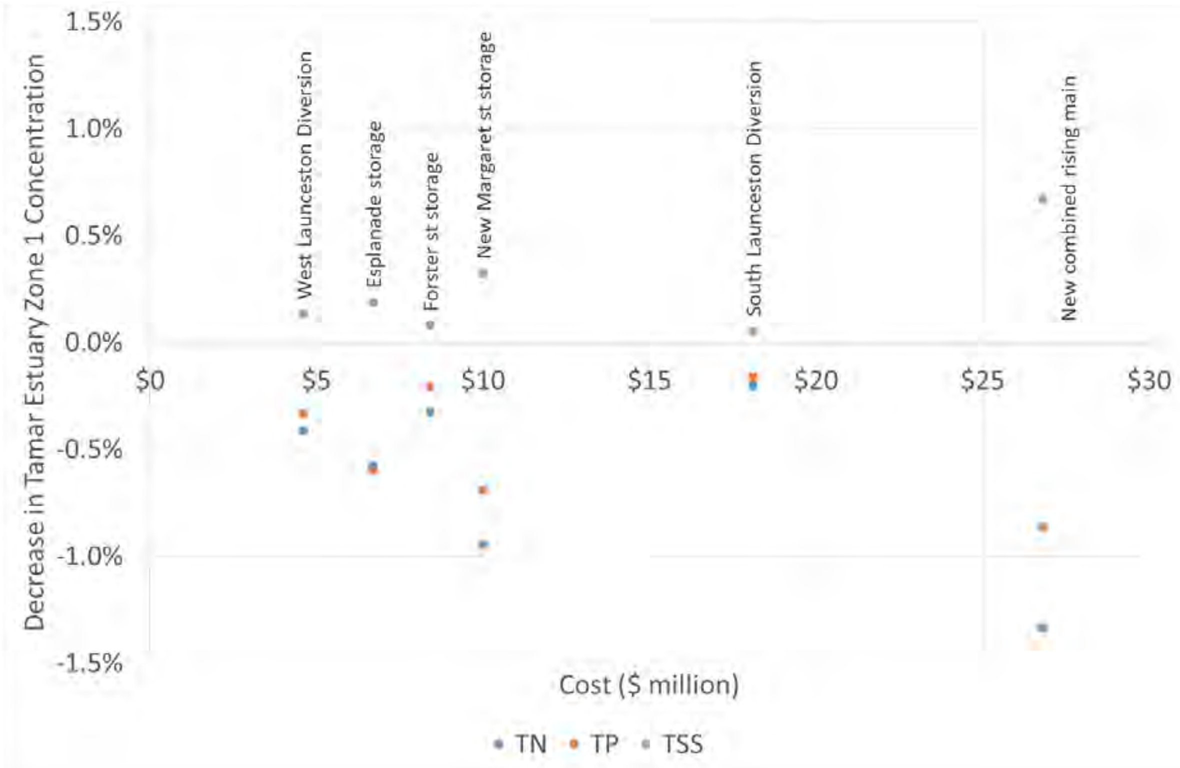
No significant relationship between increased influent volume and Enterococci removal was found so increasing influent does not affect the decreases in Enterococci expected.



App G Figure 13. Decrease in Greater TEER catchment diffuse and point source loads – Enterococci

4.2.2 Impacts of individual actions on Tamar Estuary Zone 1 concentrations

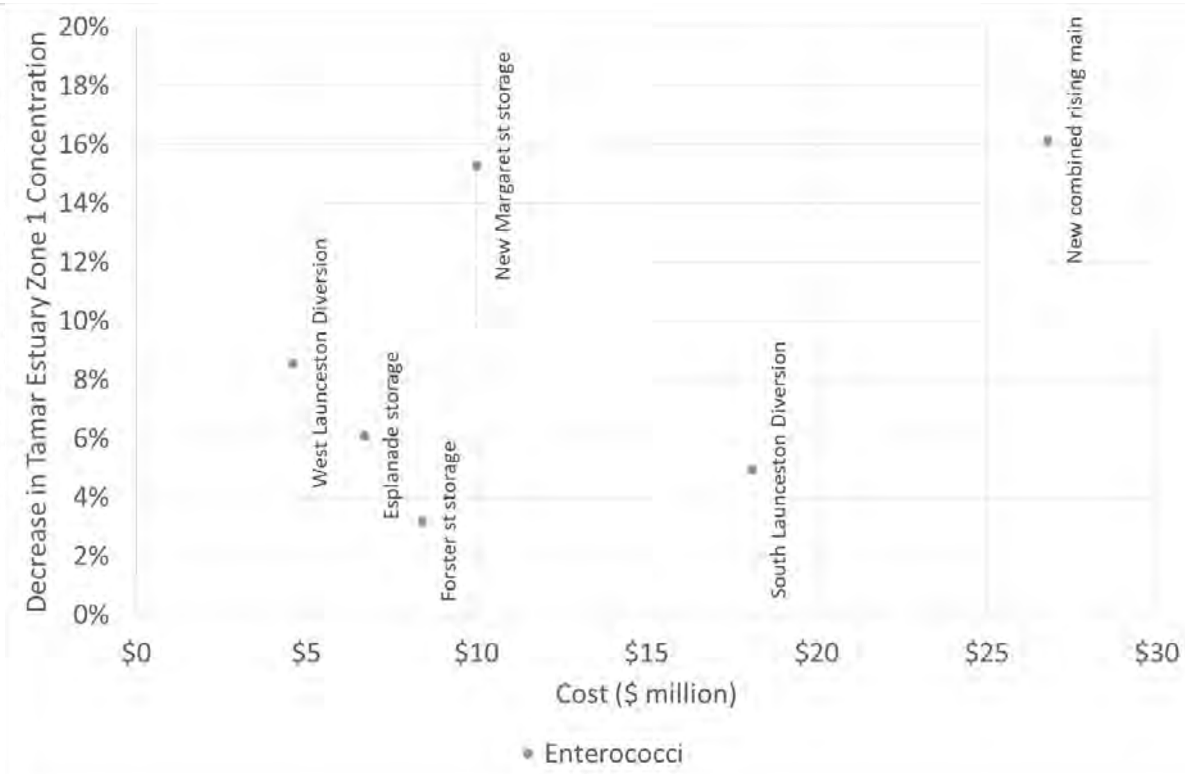
The effect of these actions on Tamar Estuary Zone 1 concentrations is shown in Figures 14 and 15 for nutrients and sediments, and Enterococci respectively. These results include the impact of increasing influent volumes on treatment effectiveness.



App G Figure 14. Decrease in Tamar Estuary Zone 1 concentration – nutrients and sediments

This figure shows these actions have the potential to significantly increase nutrient concentrations in Tamar Estuary Zone 1. The largest increase is expected for the new combined rising main action, with an estimated 1.3% increase in TN and 0.9% increase in TP concentrations.

All options lead to some decreases in TSS concentrations, though these are lower than what was estimated when impacts on treatment effectiveness were not accounted for (reduced from 1% down to 0.7%).



App G Figure 15. Decrease in Tamar Estuary Zone 1 concentration – Enterococci

As was the case for Greater TEER catchment loads, no change in Enterococci treatment effectiveness is expected. Estimated decreases in Tamar Estuary Zone 1 Enterococci concentrations are substantial, up to a maximum of 15 to 16 per cent for the new combined rising main and the New Margaret St storage.

These results show the importance of considering the impacts of increased effluent at Ti Tree Bend on treatment effectiveness. It is important that the combined sewer–stormwater network and Ti Tree Bend STP are considered as a whole system. In order to avoid negative effects on nutrient concentrations in the Estuary resulting from decreased CSOs it will be important to consider upgrades to the treatment capacity of Ti Tree Bend for removing nutrients as part of the package of recommended projects. The individual actions investigated here are all effective at reducing Tamar Estuary Zone 1 Enterococci concentrations. The next section outlines a recommended priority for these projects to be undertaken in combination, provided by City of Launceston from their analysis of the Combined System Hydraulic Model. Effects are considered first with no impact on treatment effectiveness at Ti Tree Bend before an analysis with treatment impacts. The final part of the section explores impacts incorporating a further project to upgrade nutrient removal at Ti Tree Bend incorporated into the options.

5 Investment options and their impacts

The individual actions described in Appendix G Section 4 were prioritised based on their relative cost and water quality benefit. These actions can interact with each other affecting both the cost of the combined action and the impact on water quality. For example the cost of building two pieces of infrastructure together can be less than the sum of costs for the two individual projects. Also, one option may reduce overflows at a point which means the reductions from building the second project component are less than if that component was built as a standalone project.

Prioritised actions are shown as a series of investment options in Table 2. The total cost of each of these options is provided. Note that full separation has been included as an option in this analysis even though it is not considered to be a feasible action due to the enormous disruption it would cause to businesses and residents in the combined system. This option has been included for comparison to show the proportion of the maximum potential decrease in CSOs achieved by each of the recommended options.

Table 2. Description and costs associated with prioritised feasible CSO reduction options

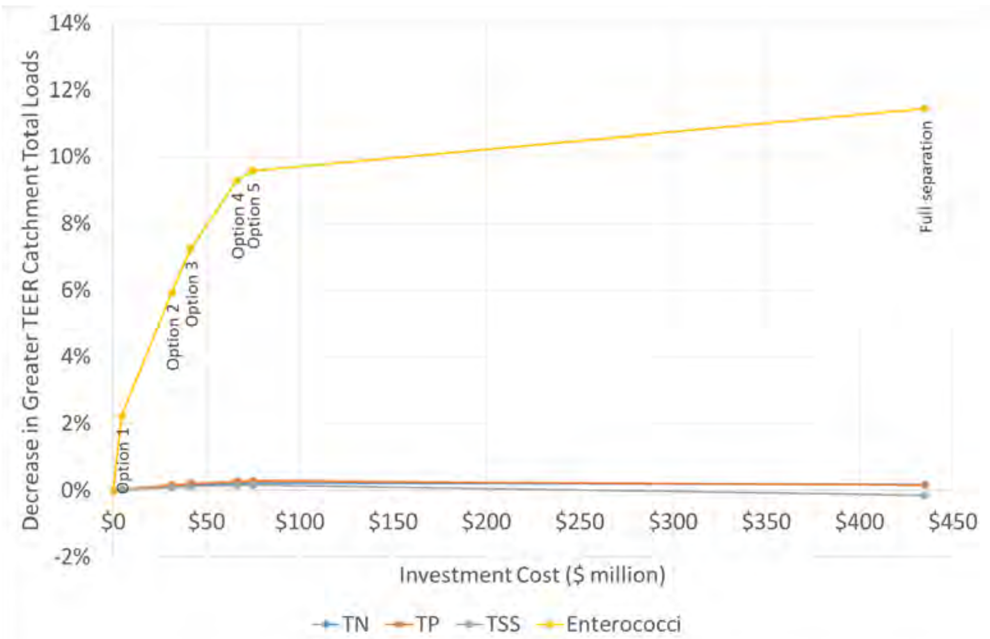
Option	Description	Cost ($ million)
Option 1	West Launceston Diversion	4.6
Option 2	Option 1 plus New Combined Rising Main	31.4
Option 3	Option 2 plus offline storage located at New Margaret St Pump Station	41.4
Option 4	Option 3 plus South Launceston Diversion in conjunction with Esplanade offline storage	66.2
Option 5	Option 4 plus offline storage located at Forster St Pump Station	74.6
Full separation[50]	Development of a full separated sewer and stormwater system in the combined area	435.0

As in Appendix G Section 4 these options are assessed first considering no impact on treatment effectiveness at Ti Tree Bend and then with potential impacts on treatment effectiveness from increased flows. A third analysis applys an upgrade option for Ti Tree Bend for which TasWater has some data on cost and potential impacts on effluent quality.

[50] Note that full separation is not considered to be a feasible option due to the enormous disruption it would cause to residents and business in the combined system area. This option has been included for comparison with feasible alternatives to demonstrate their effectiveness and cost relative to this frequently cited option. Costs attached to this option may be significantly underestimated given the many unknowns involved in a project of this scale and type.

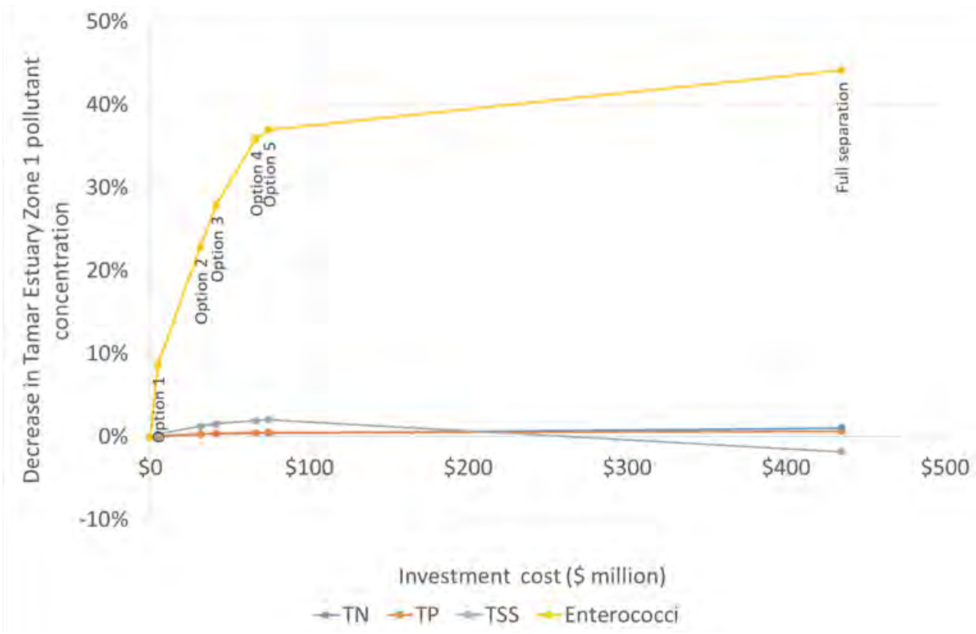
5.1 Impacts without considering effects on treatment at Ti Tree Bend

This section explores the impacts of recommended investment options without considering effects of increased effluent volumes on treatment effectiveness at Ti Tree Bend. The decrease in Greater TEER catchment total loads is shown in Figure 16. This figure shows the substantial decreases in Greater TEER catchment loads of Enterococci that could be achieved with these investments. Option 5 achieves nearly 85 per cent of the potential benefits of full separation at only 17 per cent of the cost (and with significantly less disruption to businesses and residents in the combined system). Option 1, the West Launceston Diversion is very cost effective, with nearly 20 per cent of the potential benefits achieved at only one per cent of the cost. Prioritising the most cost effective actions means that there are decreasing returns to scale of investment – for the additional spend each project achieves a relatively smaller water quality benefit. The cost benefit curve is still very steep out to Option 5 indicating that each additional benefit cost effectively achieves additional benefits. Very small impacts on Greater TEER catchment nutrient and sediment loads are expected. Interestingly, full separation can be expected to increase TSS loads. This is both because of the high concentration of sediments in urban stormwater and because of the effectiveness of Ti Tree Bend STP at removing sediments. This has further water quality implications as sediment exports in urban areas generally carry other pollutants such as heavy metals and hydrocarbons, so increased sediment loads could also be expected to infer increased heavy metal and other pollutant loads to the Estuary.



App G Figure 16. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Impacts of these prioritised options on Tamar Estuary Zone 1 concentrations are shown in Figure 17. These results do not account for any impact of increased influent on treatment effectiveness at Ti Tree Bend STP. This figure shows that very large decreases in Enterococci concentrations can be expected from these investments. As was the case for loads, the majority of benefits in terms of Enterococci concentrations are achieved by investment to Option 5. Investment in Option 2 achieves over 50 per cent of the potential benefit at seven per cent of the cost. Little impact is expected on Tamar Estuary Zone 1 nutrient concentrations (remembering that no impact on treatment effectiveness is accounted for here. Increases in Tamar Estuary Zone 1 sediment concentrations can be expected (1.8%) for full separation. Investment Options 1 to 5 decrease TSS concentrations as greater volumes of stormwater reach Ti Tree Bend for screening and treatment.

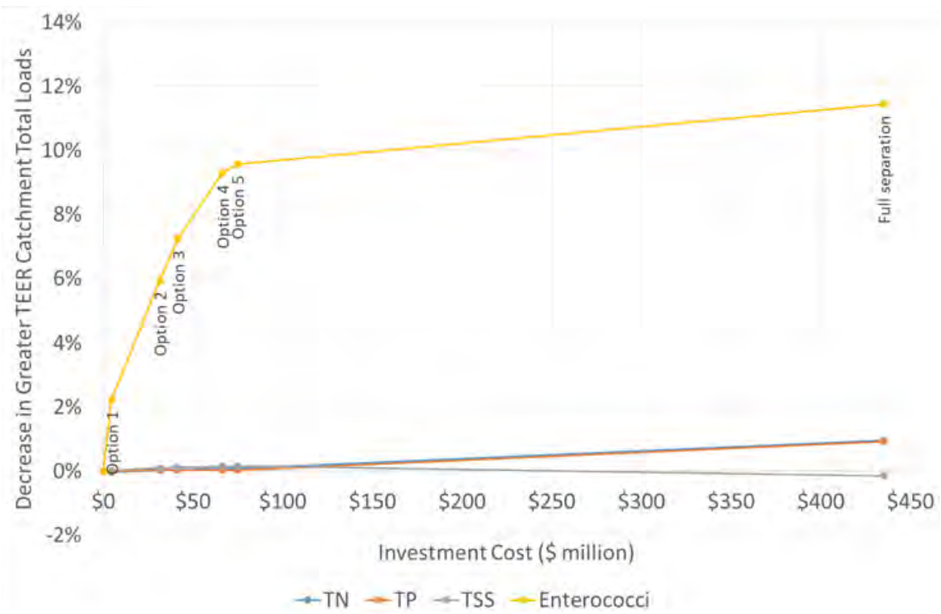


App G Figure 17. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

5.2 Impacts considering potential impacts on treatment at Ti Tree Bend

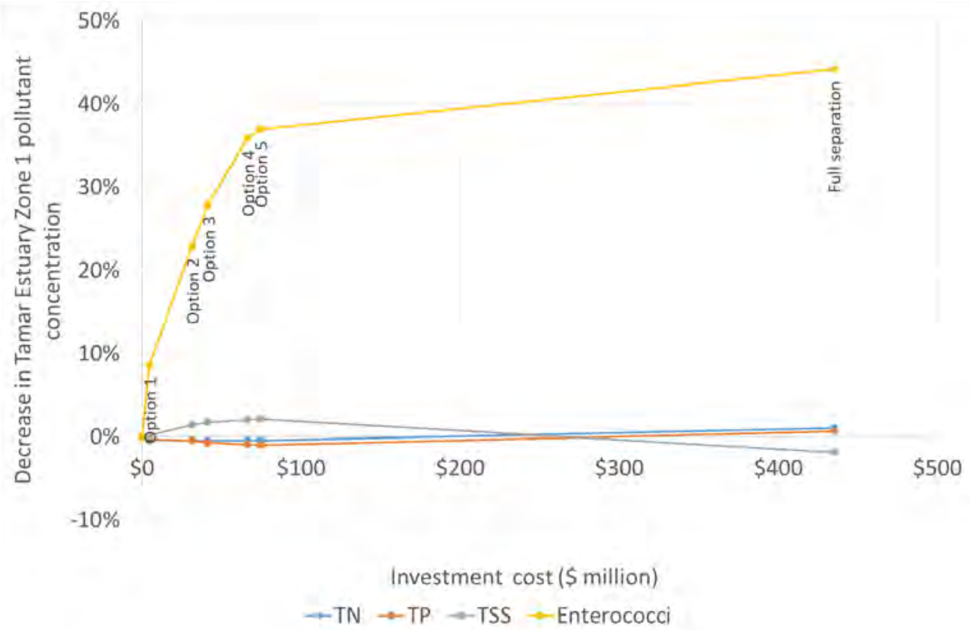
Section 4.2 demonstrated the potential effect of declining treatment effectiveness with increased influent volumes to Ti Tree Bend STP and showed that, with these accounted for, individual investment actions have the potential to increase both Greater TEER catchment total loads and Tamar Estuary Zone 1 concentrations. This section shows the results from prioritised investment options where these potential impacts on treatment effectiveness have been accounted for.

Figure 18 shows the decrease in Greater TEER catchment total loads when impacts of increased influent volumes on treatment effectiveness are accounted for. Note that impacts on Enterococci are identical to those shown in the previous section as Enterococci treatment effectiveness is assumed to be unaffected by increasing influent volumes. Impacts on nutrient loads vary from increases to decreases depending on the scale of the investment. This is affected by the assumption that the multiplier is capped at 100 per cent. If this is not the case then all investment options could be expected to lead to a net increase in nutrient loads, except full separation where nutrient loads decrease due to the greater treatment effectiveness of Ti Tree Bend STP at this lower influent level.



App G Figure 18. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Figure 19 shows the impact of these investment options on Tamar Estuary Zone 1 concentrations assuming treatment effectiveness is affected at Ti Tree Bend. As was the case with Greater TEER catchment total loads, decreases in Tamar Estuary Zone 1 concentrations are the same as for the previous section. In this case, nutrient concentrations can be expected to increase for all investment options (except full separation) as reduced treatment capacity increases the nutrient loads discharged from Ti Tree Bend STP. Note that the scale of this increase is larger and more consistent than for loads due to the effect of the spike in concentrations around Ti Tree Bend relative to the broader spread of changes in CSOs across the Zone. Option 5 is associated with a one per cent increase in TP concentrations and a 0.4% increase in TN concentrations. This estimated change in TN concentrations is strongly affected by capping the multiplier at 100 per cent (such that as investment increases progressively few design events are affected by declining treatment effectiveness). If treatment effectiveness is allowed to continue to decline past this point in the model, such that increased flows mobilise TN, then this increase in TN concentrations would be expected to be significantly greater than shown here. Analysis of this option with no cap on the impact on treatment effectiveness shows an increase in concentration of 2.7% for TN and 1.3% for TP is feasible.

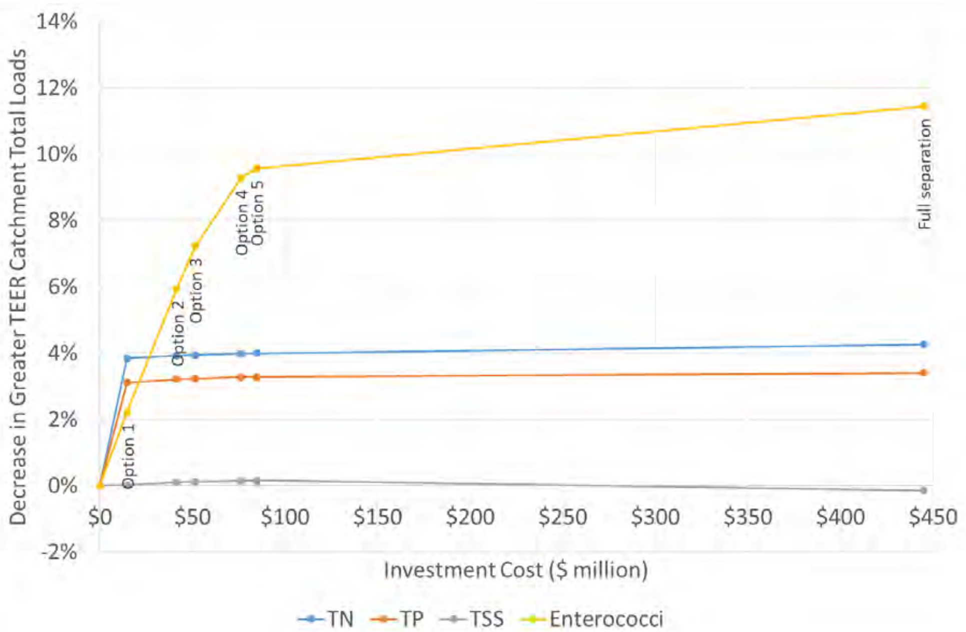


App G Figure 19. Cost versus estimated decrease in Tamar Estuary Zone 1 concentrations

5.3 Additional benefits of potential nutrient removal upgrades at Ti Tree Bend

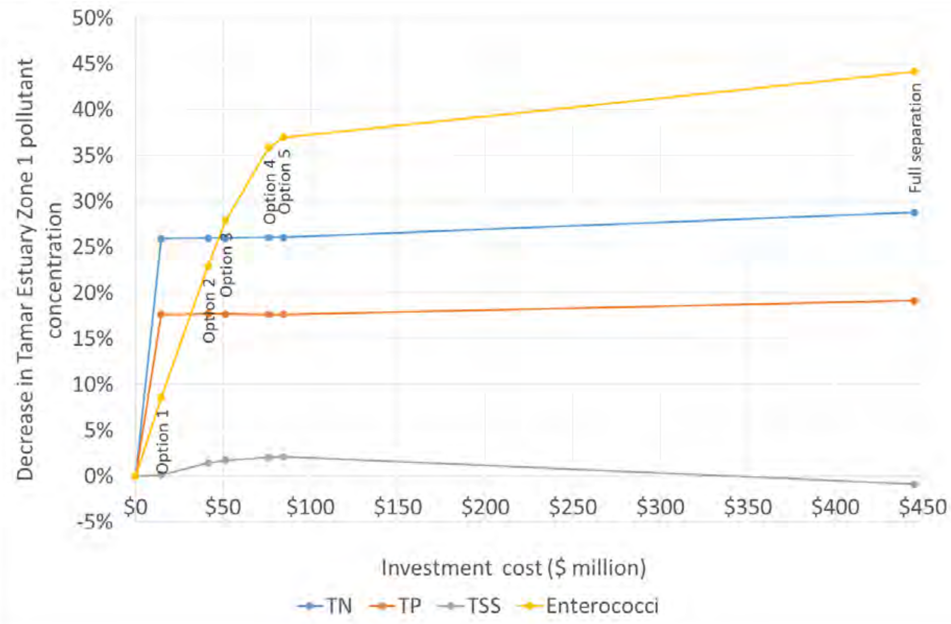
Given the potential for Tamar Estuary Zone 1 nutrient concentrations to increase as CSOs are avoided and more flows are sent to Ti Tree Bend, a scenario has been investigated which looks at the potential benefits of upgraded nutrient treatment at Ti Tree Bend in conjunction with these CSO options. This upgrade option uses analysis conducted by CH2M Australia Pty Ltd for TasWater looking at the costs and effectiveness of several potential upgrade options. The upgrade option considered here incorporates an intermittently aerated bioreactor, aerobic bioreactor and sidestream deammonification components. The cost of this option was estimated at roughly $10 million. CH2M Australia estimated TN effluent loads would decrease by roughly 53 per cent and TP by 72 per cent as a result of this upgrade. For the purposes of the analysis here these reductions were applied uniformly across all flow rates to the already estimated treatment effectiveness for each influent volume. Further investigation would be required to understand how the effectiveness of this upgrade might itself vary with influent volumes.

Figure 20 shows the impact of the preferred CSO investment options in conjunction with a treatment upgrade at Ti Tree Bend on Greater TEER catchment total loads. Note that loads and concentrations of TSS and Enterococci are assumed to be unaffected by this upgrade. This figure shows that with this upgrade included Greater TEER catchment nutrient loads can be expected to decrease by three to four per cent. Note that the cost axis has changed compared to results in the previous sections, reflecting the additional $10 million required to undertake the treatment upgrade at Ti Tree Bend.



App G Figure 20. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

Figure 21 shows the impacts of these investment options with the treatment upgrade at Ti Tree Bend on Tamar Estuary Zone 1 concentrations. This figure shows substantial benefits of the treatment upgrade in terms of decreased nutrient concentrations. It is estimated that TP concentrations would be expected to decrease by 18 per cent and TN by 26 per cent. This investment option allows the benefits of reduced CSOs in terms of Enterococci to be retained while substantially decreasing nutrient concentrations, avoiding the potential decline that could be expected without such an upgrade.



App G Figure 21. Cost versus estimated decrease in Greater TEER catchment diffuse and point source loads

6 Recommendations

This report provides a detailed analysis of the effects of a series of potential investment options for reducing CSOs which have been developed by City of Launceston. This analysis was undertaken using an improved version of the TEER CAPER DSS that was originally developed to support the TEER Water Quality Improvement Plan. In order to use these CSO options for analysis significant changes have been made to the DSS to allow results from the CoL hydraulic model to be incorporated, and to better represent connections between the combined system and Ti Tree Bend STP. This analysis first looked at the benefits of individual projects before developing preferred options. The potential for avoided CSOs to put additional pressures on treatment at Ti Tree Bend has also been explored. Based on this analysis:

- There is a clear pathway of investments in reduced CSOs that has the potential to provide large improvements in Enterococci (and other pathogen) concentrations in Zone 1. These investments could be undertaken using a staged approach, progressively capturing the benefits of full investment. Decreasing returns to the scale of investment mean that this approach captures most of the benefits in the early stages of the investment pathway. Investment in Option 5 is expected to lead to a 37 per cent decrease in Tamar Estuary Zone 1 Enterococci concentrations for a total cost of roughly $75 million. This represents 85 per cent of the total benefit that could be achieved by fully separating sewage and stormwater in the combined system, at 17 per cent of the cost. Full separation is considered to be infeasible given the enormous disruption it would cause over many years to businesses and residents in the combined system. These results demonstrate that this option is not needed to achieve very large decreases in pathogen concentrations in the upper estuary.

- Increased influent volumes to Ti Tree Bend STP from avoided CSOs have the potential to increase nutrient concentrations in the upper Estuary. Very little data are available to accurately estimate this impact but significant trends in treatment effectiveness with increased influent volume are observed in the data that is available. Ti Tree Bend was not designed to effectively reduce nutrient concentrations. It is recommended that nutrient treatment upgrades at Ti Tree Bend are considered as part of the investment pathway to reduce CSOs. TasWater already has some preliminary investigations of upgrade options which could be further developed in the design phase of any investment in CSOs. The analysis here shows this type of upgrade in conjunction with the CSO investment options could lead to significant water quality benefits in the upper estuary with concentrations of TN and TP decreasing by 26 per cent and 18 per cent respectively.

- More data on influent and effluent volumes and pollutant concentrations at Ti Tree Bend would significantly reduce the uncertainty of estimated impacts of increased influent volumes on treatment effectiveness. TasWater should continue to add to their understanding through continuation and refinement of their monitoring program.

7 References

Jessup, C. (2015). Launceston's Combined Sewage System – Investigation and Strategy Development, Dissertation towards completion of Bachelor of Engineering (Honours), University of Southern Queensland.

Kelly, R.A. (2017). *An Investment Plan for Improving Water Quality in the Tamar Estuary: Diffuse Source Management*. Technical Report, NRM North, Tasmania.

City of Launceston (2017). *Combined System Overflow Working Group Tamar Estuary and Esk Rivers: Water Quality Report.* November 2017.

Tamar Estuary and Esk Rivers Program. (2015). *Tamar Estuary and Esk Rivers Catchment Water Quality Improvement Plan*. NRM North, Tasmania.

.

Appendix 1 Approach to modelling Combined System Overflows

The TEER CAPER DSS was originally developed to support the TEER Water Quality Improvement Plan. Combined system overflows in this model were estimated using a fairly simple relationship between total flow and a threshold. A fixed volume of sewage was assumed to be present in the system every day with flow duration curves for urban land use areas in the combined system used to estimate frequency of various volumes of stormwater in the system. A fixed flow threshold was then used to simulate CSOs. There was no relationship in the original model between CSOs and effluent discharged at Ti Tree Bend, which was estimated based on historical flow and pollutant concentration data at this STP.

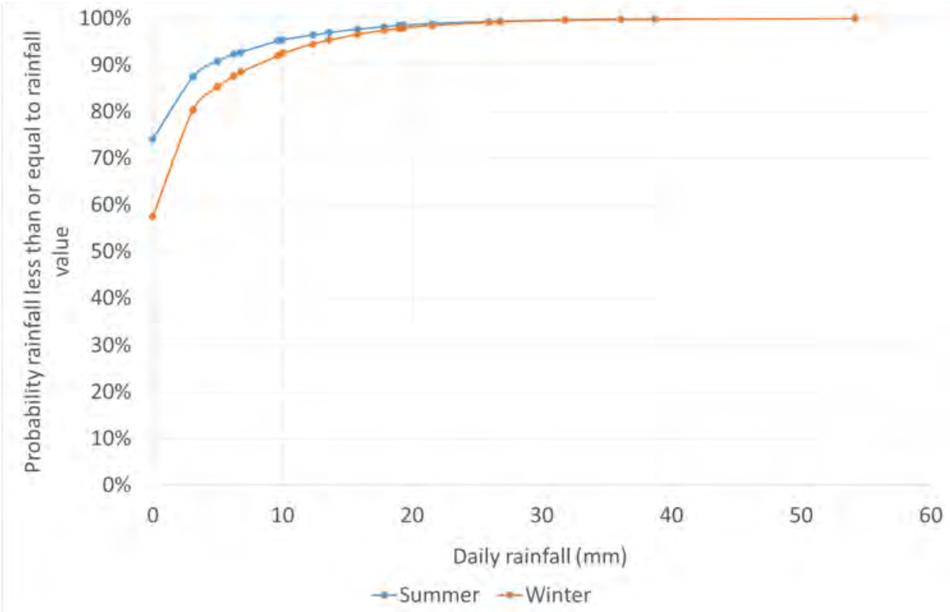
In order to properly account for the effect of CSOs on water quality in the Tamar Estuary and to allow for analysis of various investment options in the combined system on catchment pollutant loads and estuary concentrations, the TEER CAPER DSS has been redeveloped. The new version of the DSS contains a significantly improved representation of CSOs based on the hydraulic modelling undertaken by City of Launceston, as well as a new module for estimating discharges from Ti Tree Bend STP that represents the linkages between combined system flows and the STP. This appendix describes the new CSO and Ti Tree Bend modules in the TEER CAPER DSS. Appendix 2 provides a detailed description of the analysis undertaken to determine the impacts of influent volume on treatment effectiveness at Ti Tree Bend.

A1.1. Modelling CSOs

City of Launceston staff provided estimates of CSOs of sewage and total discharge for five points around the Estuary based on their hydraulic model for 20 different design events corresponding to different total volumes and intensities of rainfall. The location of discharge points used in the modelling is shown in Figure 22.

App G Figure 22. Location of discharge points used in CSO modelling in the DSS (Source: City of Launceston)

For CSO components of the DSS, total rainfall associated with each event was used as representative of the likelihood of each event. Ideally rainfall intensity would also have been used to determine this likelihood but long-term rainfall intensity data was not available. The CSO component model relates each event to the total rainfall for the event and maps these against the probability that rainfall is greater than or equal to this amount. These probabilities were based on analysis of the historic rainfall record from 1 January 1951 to 30 June 2017. Separate probabilities were determined for summer (October to March) and winter (April to September) in line with other modelling in the TEER CAPER DSS, as shown in Figure 23. Note that markers on this figure correspond to design events in the modelling provided by City of Launceston staff.



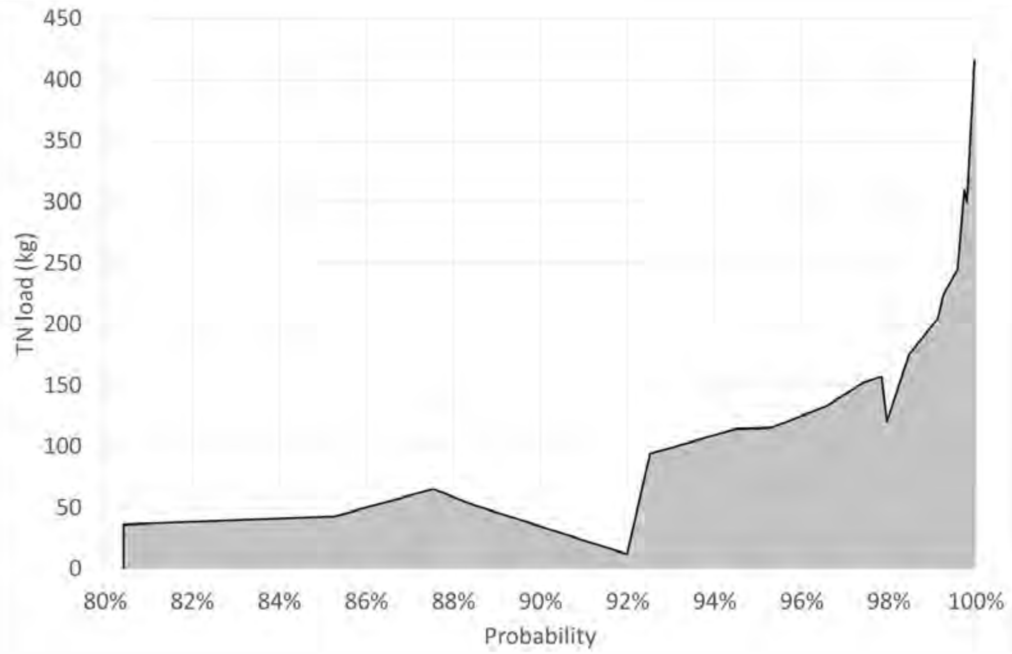
App G Figure 23. Probability of daily rainfall less than or equal to rainfall amount

The pollutant load for each design event is estimated as:

$$L_{p,r}=C_p\,(D-S)+Q_p\,S$$

where C_p is the concentration of pollutant p in urban stormwater (as calibrated in the source catchments model for the TEER catchment which underlies the TEER CAPER DSS), Q_p is the concentration of pollutant p in raw sewage, D and S are the total discharge and sewage discharge associated design event respectively based on the CoL hydraulic model.

Catchment loads were then estimated as the integral of the probability–load curve for each season estimated using the probability associated with each design event at each discharge point, as shown in Figure 24.



App G Figure 24. Example of calculation of winter TN load discharged as CSOs at Margaret St for the base case scenario

Loads are effectively weighted by the likelihood of each event to calculate an expected daily average load. This is then multiplied by the number of days in each season. So the total load from the discharge point is:

$$\bar{L} = \sum_{r=1}^{n} \frac{(L_{p,r} + L_{p,r-1}) \times (\alpha_r - \alpha_{r-1})}{2}$$

where αr is the probability associated with design event *r* and *Lp,r* is as calculated above.

A1.2. Modelling discharges at Ti Tree Bend STP

Discharges at Ti Tree Bend STP are modelled using the same basic approach, although in this case the minimum rainfall is 0mm. Total combined flows and sewage volume to Ti Tree Bend have been provided by CoL staff from the hydraulic model for each of the design events. Analysis of this data showed that the dry weather sewage component is an underestimate. Jessup (2015) estimates that dry weather flows to Ti Tree Bend STP are 12.2ML, consisting of raw sewage. This lines up well with an analysis of influent data measured at Ti Tree Bend that showed the minimum dry weather inflow to Ti Tree Bend STP is 11.1ML with a range of values above this on zero rainfall days. This compares with a weighted average sewage flow to the Estuary of 4.5 ML from the CoL hydraulic model. Given the uncertainty it was decided that Jessup's value should be adopted. Sewage and combined inflow was thus set to 12.2ML for periods of zero rainfall. A fixed additional sewage input of 8.5ML was found to provide an average daily sewage input (weighted by probability) of approximately 12.2ML.

Influent to Ti Tree Bend STP is then assumed to be the sum of base case influent and avoided CSOs under the scenario. As was the case with CSOs, pollutant loads are estimated using a combination of raw sewage concentrations and stormwater concentrations for each pollutant applied to the raw sewage and estimated stormwater component.

Total effluent for each design event is then:

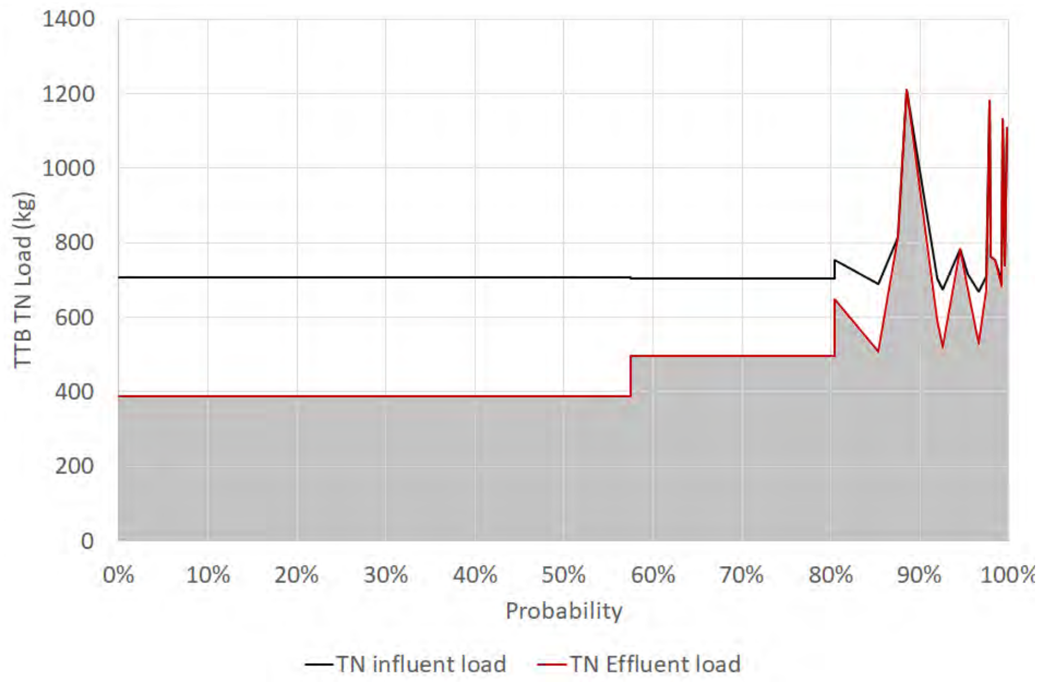
$$E_{p,r} = e_{p,i} I_{p,r}$$

Where $e_{p,r}$ is a multiplier reflecting treatment efficiency for the pollutant p and influent volume i for design event r, and Ip,r is the influent load of pollutant p for design event r. Derivation of the treatment efficiency multiplier used in the TEER CAPER DSS is described in Appendix 2.

Total effluent discharged from Ti Tree Bend is estimated in the same way as for CSOs as the sum of areas under the probability–load curve:

$$\bar{E} = \sum_{r=1}^{n} \frac{(E_{p,r} + E_{p,r-1}) \times (\alpha_r - \alpha_{r-1})}{2}$$

Note that unlike CSOs this curve extends to 0% probability. The dry weather value is assumed to remain constant while there is no rainfall. Load for events between zero and the minimum design threshold rainfall (3.12mm) is assumed to remain constant at the base case level given it is assumed that no CSOs occur below this rainfall threshold. Effluent loads are then the sum of the area below this curve as shown in Figure 25.



App G Figure *25*. Calculation of effluent loads discharged from Ti Tree Bend STP

Appendix 2 Estimating impacts of increased flow on treatment effectiveness at Ti Tree Bend

As was described in Appendix G Section 4, it is known that treatment efficiency is likely to increase at Ti Tree Bend STP as influent increases. This is in part due to progressive bypasses to parts of the treatment process as influent volumes increase, and partly due to less efficient treatment within those processes with increased flows. Given the potential for avoided CSOs to increase influent volumes and pollutant loads arriving at Ti Tree Bend STP for treatment it was felt that the potential effects of this should be tested in scenarios. This appendix describes the data analysis used to estimate the effects of increasing influent volumes on treatment efficiency at Ti Tree Bend STP.

A2.1. Data

Ideally data would be available (measuring influent and effluent volumes and concentrations) with which to calculate the proportion of influent load discharged to the Estuary. Unfortunately sufficient data of this form was not available from TasWater. Data that was available did allow for estimation of influent and effluent loads however. Data sets provided by TasWater were:

- daily influent volumes calculated as the sum of total flows from the City Rising Main and Hope St for 26/9/2015 to 22/10/2017 with some small gaps
- approximately 50 measurements of effluent concentrations of TN, TP, TSS and Enterococci measured between July 2016 and June 2017 (approximately weekly)
- approximately 38 influent concentration measurements for TN and TP from 1/9/2015 to 3/11/2017. These generally do not correspond to effluent concentration measurements.

A2.2. Estimating influent loads

Influent loads were estimated as:

$$I_t = C_p(F - S) + Q_pS$$

where *F* is the influent flow, *S* is the estimated sewage contained in the influent flow, C_p is the concentration of pollutant *p* in urban stormwater and Q_p is the concentration of pollutant p in raw sewage. In calculating influent load for these purposes, sewage volume was assumed to be the minimum of the influent flow value and the 12.2ML. Stormwater influent to Ti Tree Bend was then the difference between total influent flow and estimated sewage volume as described above.

The available influent concentration data was used to test the accuracy of this estimate of influent load for TN and TP. Table 3 shows the measured and estimated values of both event mean concentration for days rainfall means stormwater is included in the combined influent and the concentration of raw sewage estimated on dry days (ie, zero rainfall).

App G Table 3 Comparison of estimated and measured influent concentration parameters

Parameter	TN			TP		
	Based on measured data	Based on modelled data	Difference	Based on measured data	Based on modelled data	Difference
Event mean concentration (mg/L)	44.9	35.3	-21%	6.8	6.8	0%
Raw sewage (mg/L)	56.9	58.0	2%	8.9	11.2	26%

The values in Table 3 show that the approach is reasonably accurate in reproducing key influent concentration parameters. As such, given the paucity of influent concentration data it is deemed that this approach is appropriate for estimating the treatment effectiveness of Ti Tree Bend.

A2.3. Estimating effluent loads

Effluent loads were calculated using the measured effluent concentration data and assuming that effluent volume is equal to influent volume (in line with assumptions made by Jessup, 2015). This is likely to overestimate effluent volume to some degree as there will be some losses within the plant itself, such as evaporation.

A2.4. Relationships between the effective treatment and influent volume

Treatment effectiveness was then estimated as the proportion of influent that remains as effluent, that is:

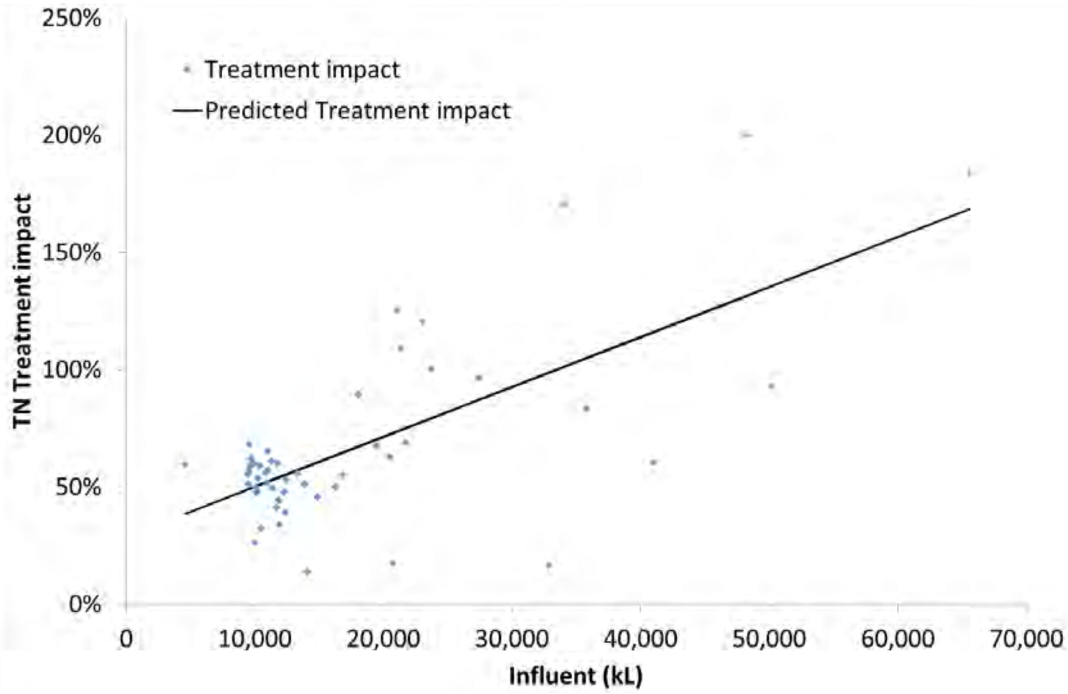
$$e_k = \frac{E_k}{I_k}$$

where E_k is the effluent load for observation k and I_k is the influent load. Note that as e_k increases, treatment effectiveness declines.

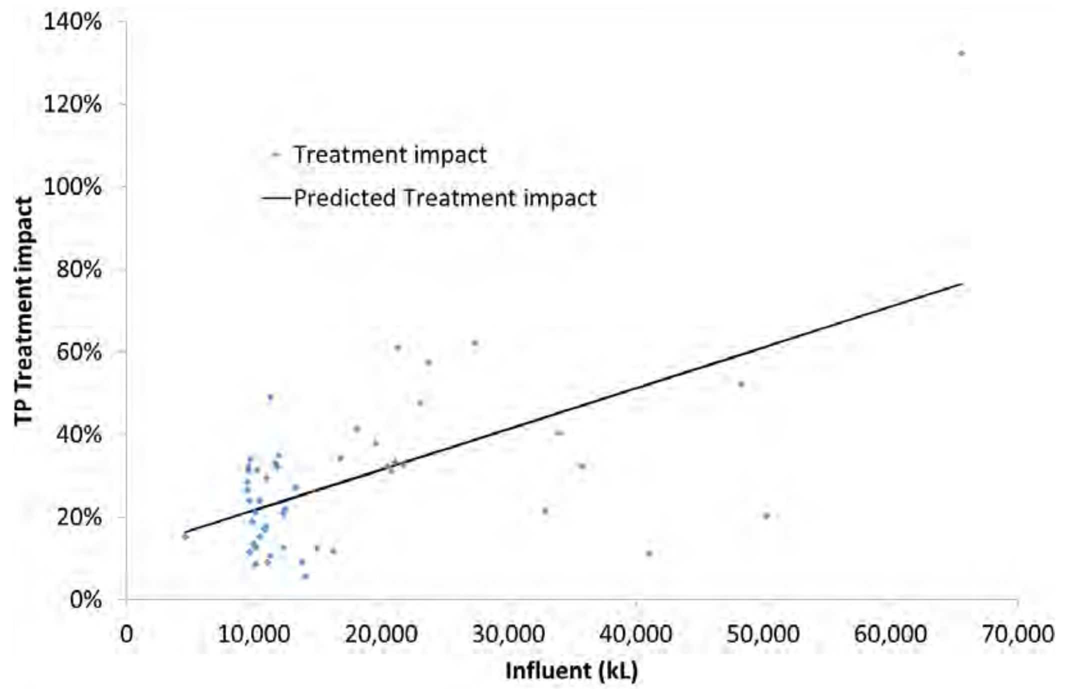
Influent volume and treatment effectiveness data were then analysed to look for a relationship for TN, TP, TSS and Enterococci. Table 4 provides a summary of the relationships found by this analysis. Figures 26 to 29 show fit of these empirical models.

App G Table 4 Statistics of fit for treatment effectiveness versus influent relationships at Ti Tree Bend

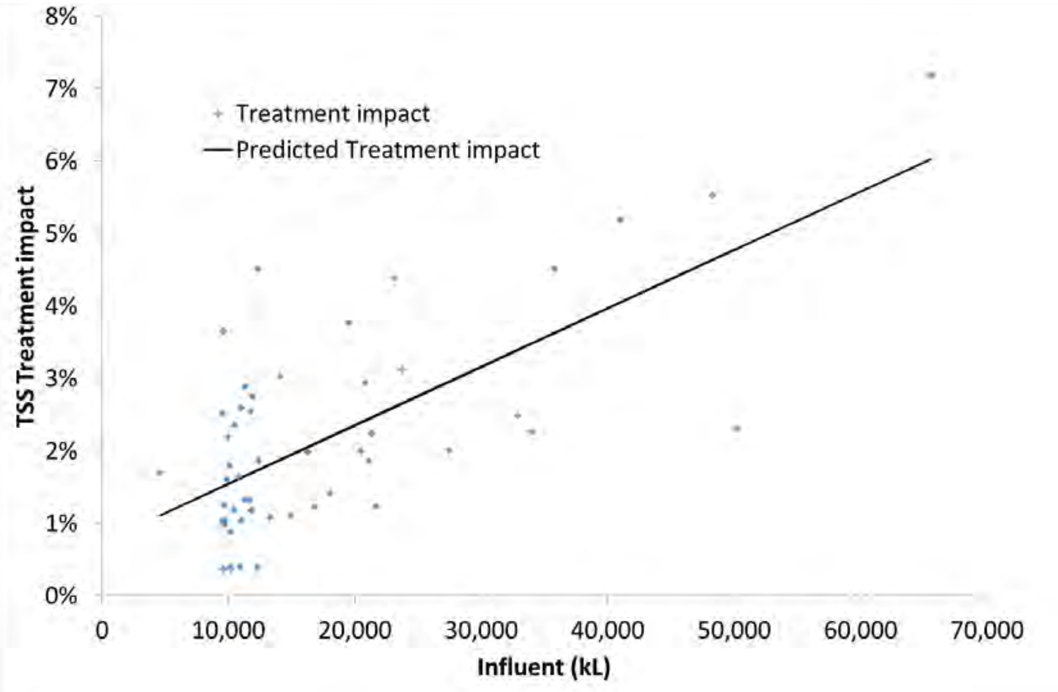
Parameter	TN	TP	TSS	Enterococci
Constant	0.28865	0.11750	0.00743	0.00077
Coeff Influent (kL)	2.128E-05	9.860E-06	8.070E-07	0
p-value on coeff influent	1.950E-08	3.405E-06	2.419E-08	NA
R^2	0.47	0.35	0.47	NA



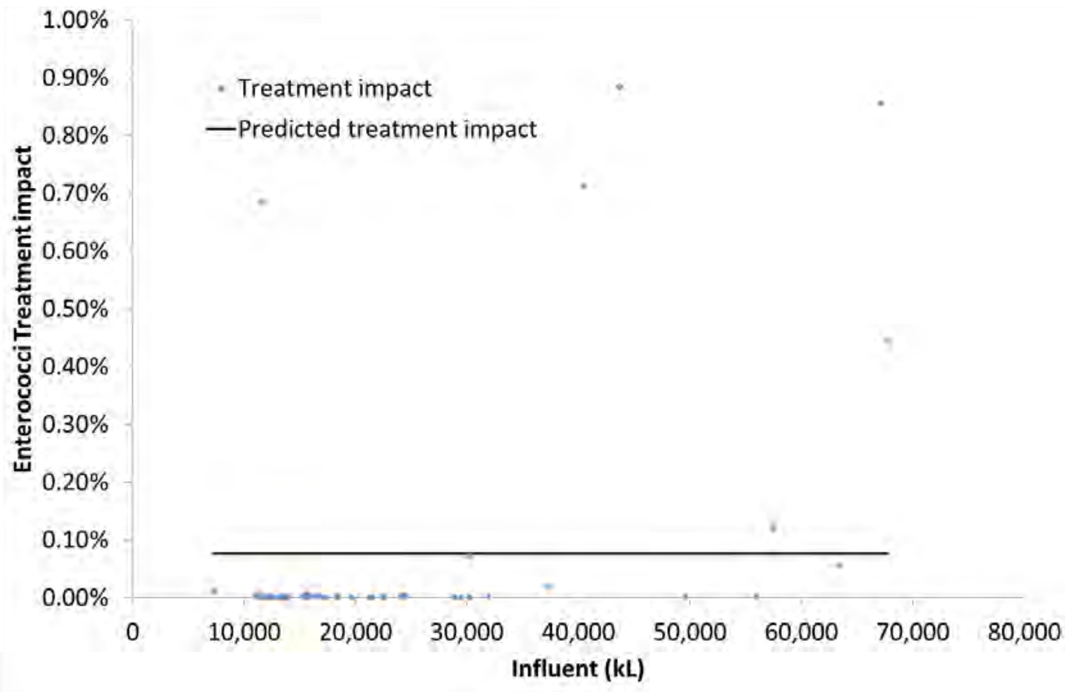
App G Figure 26. Fitted relationship between TN treatment impact multiplier and influent volume



App G Figure 27. Fitted relationship between TP treatment impact multiplier and influent volume



App G Figure 28. Fitted relationship between TSS treatment impact multiplier and influent volume



App G Figure 29. Fitted relationship between Enterococci treatment impact multiplier and influent volume (note average value used)

Table 4 and these figures indicate:

- There is a significant trend between the treatment impact multiplier and influent volume for TN, TP and TSS. In all cases p-values are very small (less than 0.00001) indicating a significant trend in the data.

- R^2 values for these relationships are fairly low (0.35 to 0.47). Inspection of the fits shown in the figures confirms that there is a significant variability of observations around the trend line demonstrating a high degree of uncertainty about the specific value of this multiplier.

- No real trend was observed for Enterococci. Treatment impact multipliers are generally very low (less than 0.1%) indicating very effective removal of Enterococci from influent to Ti Tree Bend. Given the lack of clear relationship with influent and the very low value of this multiplier a fixed average value has been used to model treatment impact of Ti Tree Bend on Enterococci loads.