Economics Work Package 11:
SRL1: The Urban Intervention Options Work Brief

Deliverable 1: Summary of potential solutions available for stormwater, wastewater and water supply provision

Prepared by Sue Ira, Koru Environmental Consultants Ltd on behalf of Greater Wellington Regional Council

Te Awarua-o-Porirua Collaborative Modelling Project

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Koru Environmental Consultants Ltd

Summary of potential solutions available for stormwater, wastewater and water supply provision

Report prepared for Greater Wellington Regional Council.

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1. Background

1.1 Introduction and Purpose of this Report

The purpose of the project is to collaboratively generate information and knowledge to support the Te Awarua-o-Porirua Whaitua Committee make recommendations for land and water management in the Whaitua. The project will produce modelling outputs and knowledge describing the current environmental, social, cultural and economic conditions in TAoP Whaitua, as well as potential future outcomes that might result under urban and rural land and water management scenarios.

This report forms part of the Urban Intervention Work Brief and is one component of the overall economics work brief that addresses the decision making needs of the Whaitua Committee. The focus of current stormwater and run-off management practice in the Porirua is largely on flood control and sedimentation, with the water transport aspect paramount. Alternative approaches to the uses of rainfall, the contaminants contained in stormwater and their sources have the potential to create diverse positive effects at multiple scales and across a number of dimensions. Changes to that focus may potentially impact the economic possibilities of water use, and urban-based effects on receiving waterbodies, which in turn may impact the extent of ecosystem services experienced by the community, with flow on effects for community wellbeing and liveability in the Porirua Whaitua.

A change in operational focus beyond water transport to intervention practices such as source control and treatment is needed, along with a wider vision as to how rainfall may be utilised to take account of community preferences for the condition of the receiving waterbodies and uses of water. This change will create costs over and above the existing flood control function currently funded as a collective good paid for by landowners as a way of targeted rates, levies and charges. The additional costs may be borne as private costs, or increases to rates, levies and charges where mitigation solutions are provided as part of the collective good.

This change in focus must be considered within the context of managing the three waters, i.e. water supply, wastewater and stormwater, as a holistic integrated system.

The purpose of this report is to document the potential solutions available to meet this change in operational focus towards water quality treatment, stormwater reuse and source control. Additionally, the report documents potential solutions available and currently being used to support water supply and wastewater infrastructure needs. A full range of solutions is presented, along with the applicability of their use and cost information as documented in national and international literature.

1.2 Problem Statement

1.2.1 Stormwater Management

Councils across New Zealand are currently facing a number of significant stormwater problems related to the continual growth, development and redevelopment of urban centres. These include issues such as:

- Increased flooding which stresses existing property owners as well as existing infrastructure.
- Increased volume and flow of stormwater which compromises existing levels of service as well as creates stressors on aquatic habitats through the process of accelerated stream channel erosion.
- Deterioration of the quality of receiving waters and sediments.
- Costs associated with long term maintenance of constructed stormwater practices built to mitigate the abovementioned effects.

At present, Wellington Water maintains nearly 650km of piped stormwater network. The stormwater network conveys approximately 80 million m^3 of rain from kerbs, channels, roofs and drains to streams and the marine environment each year (Wellington Water – Three Waters: Summary Asset Management Plan (AMP) 2011/12 – 2020/21). Within the Porirua Whaitua there is approximately 443km of piped network, 14387 manholes, inlets and outlets, and 3178 sumps. **Figure 1** illustrates the layout of the stormwater system within the Whaitua.

Key strategic issues identified for stormwater management through the AMP (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21) include:

- Flooding of land, properties, buildings and infrastructure
- Pollution of receiving waters and the environment from contaminants in stormwater or conveyed by the stormwater network.

These issues are consistent with those facing the majority of councils across New Zealand (as bulleted above), and pollution of the receiving waters from both stormwater discharges and wastewater overflows is a primary concern for the Porirua Whaitua Committee.

The AMP also acknowledges that the potential impacts of climate change on the stormwater network needs to be managed. No key tasks or projects are highlighted in the AMP with respect to the stormwater network, however it does acknowledge that little consideration has been afforded to the stormwater network in the past. The AMP states that catchment management plans need to be updated to indicate weaknesses in the network and the likely consequences of these failures (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21).

Historically, stormwater has been managed via dry detention basins or stormwater ponds. Whilst these devices are helpful for reducing flooding within urban areas, they provide limited water quality, ecological and social benefits. For a number of years now, water sensitive design (WSD) has been offered up as a solution to addressing the effects of stormwater discharges in a way which meets good urban design and ecological objectives. World-wide there has been much research undertaken to document the environmental protection and social benefits of WSD. The stormwater solutions presented in this report include both traditional stormwater management solutions as well as those advocated through a WSD approach. These are further discussed in Section 2.

1.2.2 Wastewater and Water Supply Provision

Robust, efficient and sustainable wastewater and water supply provision are critical infrastructure for any modern city. Water is vital to the health and well-being of residents, and is supplied for domestic and commercial needs, as well as firefighting and emergency needs. The collection, conveyance and treatment of wastewater prior to disposal is also essential for the public's health and well-being, and for protecting the environment (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21).

The Wellington region's wastewater network is separate from the stormwater system. Each year, 29 million m^3 of wastewater effluent needs to be collected and treated via disposal. This is done through a network of nearly 1000 km of wastewater pipes, over 60 pump stations and 3 wastewater treatment plants. Inflow and infiltration represents the greatest demand on the wastewater network, caused primarily by stormwater flowing into the network through illegal direct connections or flooded gully traps, and by groundwater infiltrating through poorly sealed joints and cracks in the pipework (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21). The Porirua Whaitua's wastewater network comprises approximately 596km of piped network supported by 15699 manholes, 76 pump stations and 72 other fittings (such as valves). **Figure 2** illustrates the wastewater network within the Porirua Whaitua.

With respect to water supply, Wellington Water currently collects, treats and delivers approximately 30 billion litres of water each year to meet the region's consumption requirements. This includes managing over 1000km of pipeline, 34 pumping stations and 81 reservoirs and pressure tanks (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21). Porirua's water supply is piped from the Lower Hutt Valley, and the network within the Whaitua comprises 547km of pipe, 23 pump stations, 39 storage units and 17983 "other network fittings" (such as valves, hydrants and meters). **Figure 3** illustrates the water supply network within the Porirua Whaitua.

Key strategic issues identified for water supply and wastewater through the AMP (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21) include:

<u>Water Supply</u>

- Water availability and supply limitations
- Responding to increased demand
- Reliability and security within current supply parameters.

<u>Wastewater</u>

- Wet-weather overflows (environmental and legislative concerns)
- Hydrogen sulphide creation within the network.

The AMP (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21) also acknowledges that the potential impacts of climate change on the three water activities needs to be managed. Disaster and emergency planning, water conservation and efficiency planning and the Messines Road reservoir upgrade are key projects highlighted in the AMP.

Solutions for the provision of water and management of wastewater are well documented. Due to the high level of public health risks associated with the provision of the infrastructure, as well as a 'user-pays' approach to funding, the traditional approaches used by councils across New Zealand tend to reflect best-practice. Despite this, better integration with the stormwater network and use of WSD approaches discussed in this report could have significant water supply and wastewater benefits. For example, the use of rain tanks for water re-use provides a sustainable water source and can reduce future pressures on the aging water supply system resulting from future growth. Similarly, the use of rain tanks and green roofs would assist in reducing stormwater discharges to the wastewater network, thereby reducing the impact of I&I on the wastewater network.

Figure 1 The stormwater system within the Porirua Whaitua

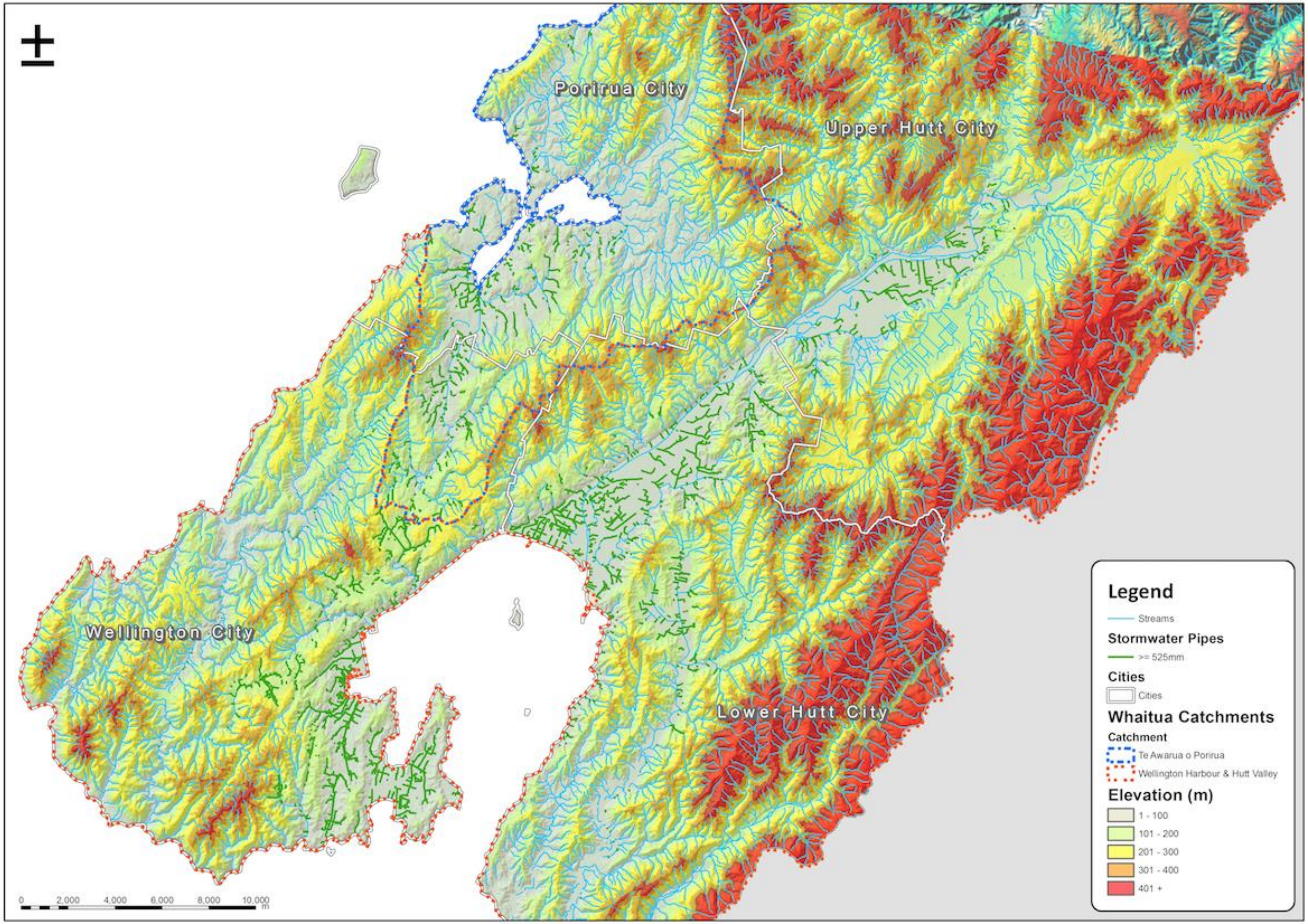


Figure 2 The wastewater system within the Porirua Whaitua

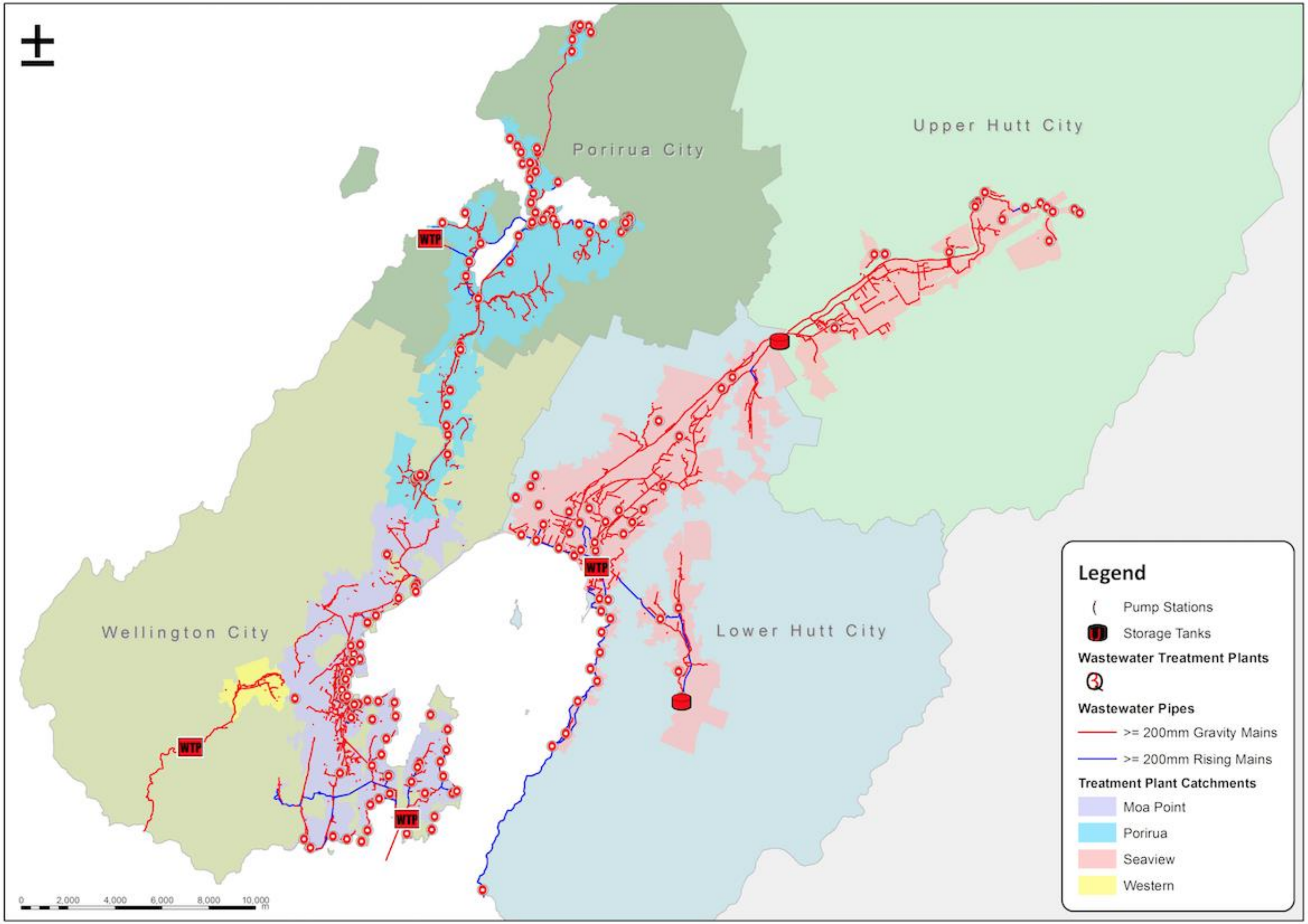
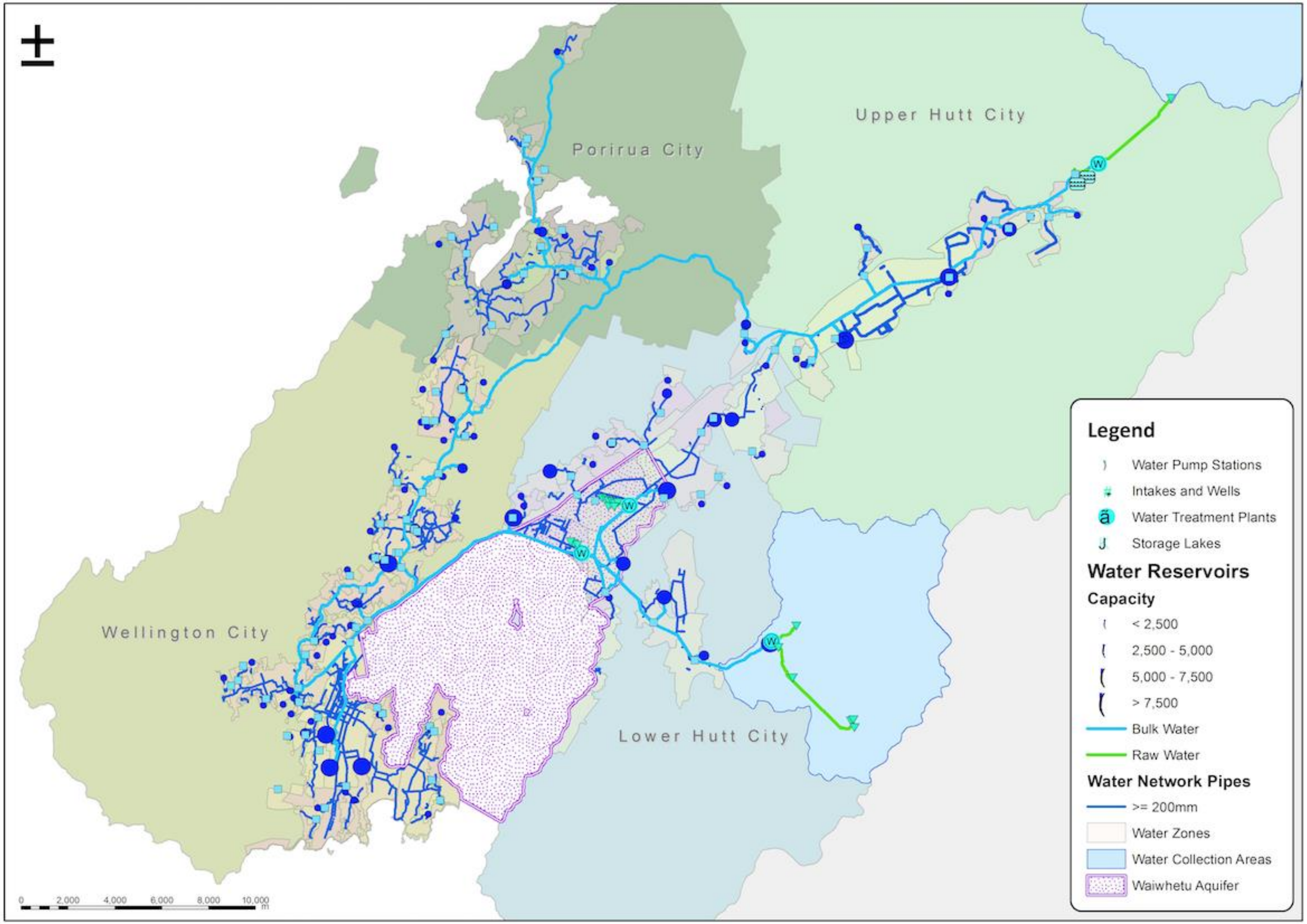


Figure 3 The water supply system within the Porirua Whaitua



1.2.3 Water Sensitive Design (WSD)

Before providing examples of the specific solutions incorporated within WSD, it is important to have a common understanding of the concept itself. The Auckland Council's Guidance Document 04 on WSD (Lewis, *et al*., 2013)[1] defines it as:

"An inter-disciplinary design approach to stormwater management that operates at complementary scales of the region, the catchment, and the site for planning and land development. Water Sensitive Design seeks to protect, enhance, and ultimately utilise natural systems and processes for enhanced stormwater management, ecosystem services, and community outcomes."

The Wellington City Council Water Sensitive Urban Design (WSUD) manual (undated) similarly defines WSD as:

"*WSUD is an approach to water management in towns and cities that addresses both water quantity and water quality issues. WSUD draws upon the processes of natural systems and adapts these to suit urban environments. It integrates the processes inherent in water systems with the 'built environment' – buildings, infrastructure and landscapes*."

Importantly, the Wellington City Council WSD manual (undated) acknowledges that the urban water system includes potable water, wastewater and stormwater which need to function as an integrated system.

The Wellington City Council WSD manual (undated) lists four overarching objectives of WSD, namely:

1. Protect or enhance the environmental, social and economic values of downstream environments
2. Reduce the frequency, duration and volume of stormwater runoff to mitigate the risks of nuisance flooding and moderate post-development flows to waterways
3. Reduce demand on potable water supply
4. Improve amenity in the urban environment.

WSD is additionally a philosophy about site design and development rather than just about managing stormwater at its source through vegetative practices such as swales or rain gardens. It requires that stormwater is considered up front as part of the design process, rather than being dealt with as an afterthought (which is so often the case with conventional approaches). By dealing with stormwater at this initial, concept design stage, one is able to create opportunities for the protection, remediation or enhancement of natural resources. In addition, WSD approaches are rarely used in isolation, but rather as a combination of integrated approaches that are most appropriate for the given development. Table 1 summarises some of the common WSD approaches used to achieve

1 Lewis, Mark; James, Jane; Shaver, Earl; Leahy, Allan; Wihongi, Phil; Sides, Eddie; Coste, Christine (2013). Water sensitive design for stormwater. Prepared by Boffa Miskell for Auckland Council. Auckland Council guideline document, GD2013/004 [DRAFT]

the broad objectives of WSD (Mainstream, 2012[2]). Additional WSD site design features not shown in Table 1 include:

- Reducing earthwork volumes;
- Reduced impervious areas (clustering, minimising road widths);
- Disconnecting impervious areas through site design and treatment approaches (eliminating kerbing);
- Using source control to reduce contaminants and the volume of water; and
- Using existing natural areas.

Table 1 Widely accepted WSD objectives and approaches (Mainstream, 2012[2])

Objective	Examples of typical WSUD approaches
Enhance environmental outcomes (waterway health and water quality)	Appropriate district and structure planning. Bioretention systems and sand filters. Stormwater wetlands. Grass or vegetated swales. Sedimentation basins. Gross pollution capture devices. Porous pavements.
Mitigate flood risk (particularly stromwater and overland flow)	Appropriate district and structure planning. Bioretention systems and sand filters. Stormwater wetlands. Grass or vegetated swales.
Enhance water supply outcomes (alternative water supplies)	Demand management and other behavioural change mechanisms Rainwater tanks. Stormwater harvesting (including third pipe systems). Recycled water.
Enhance social outcomes (visual and recreational amenity)	Bioretention systems. Stormwater wetlands. Grass or vegetated swales.

This report focusses on the structural stormwater management solutions shown in Table 1.

1.2.4 Understanding Cost

Provision of three waters infrastructure is exceptionally expensive. Not only are the capital costs of building new infrastructure high, but ongoing maintenance costs are a significant burden borne by councils. In general, the high costs surrounding water supply and wastewater infrastructure are generally more readily accepted than stormwater management costs due to the vital public health roles and benefits which they provide.

2 Mainstream Economics and Policy. 2012. Measuring the regulatory burden of Water Sensitive Urban Design in South East Queensland. A report for the Queensland Competition Authority.

Wastewater, Water Supply and Stormwater Infrastructure
Wastewater, water supply and stormwater management costs are very challenging to quantify and collect in a consistent, meaningful way which then facilitates economic analyses. This is mainly due to the high level of variability in design and construction, site variability and limitations, and lack of robust systems to monitor and record maintenance costs and activities. Cost information is also generally commercially sensitive and is therefore notoriously difficult to obtain. Furthermore, cost data generally differs from one region to another and, depending on inflation and growth levels, can become outdated within a few years. Stormwater treatment solution costs are particularly challenging to quantify. This is likely due to the large number of mitigation options (when compared with the other 2 waters), as well as the variability in design and construction. Internationally, there are three methods that are generally used to assess the economics of water infrastructure:

- Life cycle cost analysis,
- Cost comparisons, and
- Cost-benefit analysis.

Each of these methods is discussed in detail in Ira, 2009[3]. The approach used in this study, and the focus of this report, is a life cycle cost analysis. A life cycle costing (LCC) approach has previously been used to assess costs associated with stormwater devices in Australia, the United States of America (USA) and the United Kingdom (UK). The Australian/New Zealand Standard 4536:1999 defines LCC as the process of assessing the cost of a product over its life cycle or portion thereof. The life cycle cost is the sum of the acquisition and ownership costs of an asset over its life cycle from design, manufacturing, usage, and maintenance through to disposal. The consideration of revenue is excluded from LCC. A cradle-to-grave time frame is warranted because future costs associated with the use and ownership of an asset are often greater than the initial acquisition cost and may vary significantly between alternative solutions to a given operational need (Australian National Audit Office, 2001).

LCC has a number of benefits and supports a number of applications and analyses (Lampe *et al* 2005[4]):

- it allows for an improved understanding of long-term investment requirements;
- it helps decision-makers make more cost-effective choices at the project scoping phase;
- it reduces uncertainties and helps local authorities determine appropriate development contributions; and
- it assists local authorities in their budgeting, reporting and auditing processes.

Decision making on the use of water infrastructure needs quality data on the technical and financial performance of these devices. The financial performance will depend on the sum and distribution over the life cycle of the device of costs associated with design,

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3 Ira, S.J.T. 2009. Quantifying the Costs of Low Impact Design in New Zealand. Report prepared by Koru Environmental Consultants Ltd for Aqua Terra International Ltd and Tauranga City Council.

4 Lampe, L., Barrett, M., Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Hollon, M. (2005). Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems. WERF Report Number 01-CTS-21T.

construction, use, maintenance, and disposal. LCC can be used for structuring and analysing this financial information. The importance of a LCC analysis between differing water management scenario lies in its ability to make a relative comparison of costs between scenarios based on similar assumptions.

Available cost information, as collected from the asset management plans (AMPs), construction projects and suppliers/ contractors, is presented in Sections 2.1 and 2.2 of this report for water supply and wastewater infrastructure respectively. Available cost information, as collected from the literature, is presented in Section 2.3 of this report for stormwater infrastructure.

Further information and discussion is needed with Wellington Water in order to verify the suitability of this data for the Porirua Whaitua and to more accurately define the existing capital and ongoing infrastructure costs, as presented in the Wellington Water AMP (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21) (this information will be collected during the next phase of this project).

As discussed earlier, no key tasks or projects are highlighted in the AMP with respect to the stormwater network, however it does acknowledge that little consideration has been afforded to the stormwater network in the past. The AMP states that catchment management plans need to be updated to indicate weaknesses in the network and the likely consequences of these failures. Costs associated with these works would need to be investigated and quantified. With respect to the water supply network, further studies are likely needed to get a better understanding of how much money can be spent conserving water or introducing efficiencies before a new dam (or alternative water source) needs to be constructed. Similarly, the cost of alternative wastewater treatment methods could compared against the construction of a new or upgrading of an existing wastewater treatment plan (Wellington Water – Three Waters: Summary AMP 2011/12 – 2020/21). These types of cost analyses, however, are outside the scope of this study.

Water Sensitive Design (WSD)
Given that WSD is a relatively new concept much of the literature discusses and presents 'pilot' projects, thus there is little data on the long term maintenance aspects of WSD. Cost comparisons therefore tend to focus solely on differences in total acquisition costs (TAC) (see Section 3). In general, the types of costs quantified during these analyses include:

- design and planning,
- clearing and earthworks,
- pavement construction and concrete works,
- stormwater drainage,
- sanitary sewers, water reticulation and trenching, and
- general and day works.

These costs are generally compared for conventional and alternative site designs, and assessed to determine whether or not a developer's profit margin will be increased, or decreased, as a result of a WSD development. Whilst this report focusses mainly on literature which provides cost data resulting from a life cycle cost analysis, there have also

been a number of WSD cost comparison studies done here in New Zealand as well as in Australia, the United States and the United Kingdom.
Studies by South East Queensland in Australia[5], the US Environmental Protection Agency[6] and here in New Zealand have attempted to quantify cost comparisons of operation and maintenance costs and full life cycle costs (see Section 3).

These studies have highlighted that WSD both incurs costs and creates savings which need to be better understood. These costs include:

- Installation and maintenance of above ground stormwater treatment devices that utilise vegetative practices to remove contaminants (such as swales, rain gardens, wetlands).
- Landscaping and planting costs from incorporating natural systems and nature into an urban environment (these costs would be relevant if they perform a treatment function and could be considered "greening costs").
- Normal development costs (from activities such as site clearance, paving, piping, and conventional stormwater management such as ponds).
- Monitoring costs of private, at source systems.

Despite these costs, and due to the focus of WSD on the use of natural systems, there are a number of potential cost savings of WSD over a traditional approach to stormwater management. These savings include:

- reduced impervious surfaces leading to reduced paving costs;
- reduced pipe lengths leading to reduce infrastructure costs;
- reduced earthworks as well as clearing and grading leading to reduced costs associated with the construction activities; and
- realisation of potential "avoided" costs associated with remediation of streams and flood event "clean-up" programmes as a result of reduced stormwater effects.

In addition to cost savings, WSD also incurs a number of environmental and social benefits such as reduced downstream flooding, improved water quality, better integration with good urban design, building of sustainable communities, etc. (ECONorthwest, 2007[7]). In fact, when asked about needs for further research into WSD, many practitioners and researchers cite the need for measuring and quantifying WSD benefits in economic terms. This aspect whilst outside the scope of this literature review, is being investigated through the TAoP Whaitua project as a whole (Ira et al., 2012[8]).

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5 Water by Design. 2010. A Business Case for Best Practice Urban Stormwater Management Practice. Version 1.1 (SE Queensland)
Mainstream Economics and Policy. 2012. Measuring the Regulatory Burden of WSUD in SE Queensland. A report for the Queensland Competition Authority.

6 USEPA. 2013. Case Studies Analyzing Economic Benefits of Low Impact Development and Green Infrastructure Programs.
US EPA. Undated. Costs and Benefits of Stormwater BMPs. https://www3.epa.gov/npdes/pubs/usw_d.pdf accesssed on 10/01/2017

7 ECONorthwest. 2007. The Economics of Low Impact Development: A Literature Review. Eugene Oregon.

8 Ira, S J T, Batstone, C J, and Moores, J P. 2012. The incorporation of economic indicators within a spatial decision support system to evaluate the impacts of urban development on waterbodies in New Zealand. Melbourne Water Sensitive Urban Design Conference 2012.

Available cost information for WSD, as collected from the literature, is presented in Section 3 of this report.

1.2.5 Challenges and Caveats

Cost estimation plays a key role in all development activities. For developers, the bottom-line reality of cost usually outweighs marginally increasing environmental improvements that were gained from using alternative technologies. For councils, the cost burden of long term maintenance of three waters infrastructure is at the forefront of their minds throughout the development process.

Despite the costing studies mentioned in Section 1.2.4, a key impediment to the implementation of WSD and stormwater treatment solutions, both here in New Zealand as well as internationally, is still the perception that WSD costs more to implement both in the short term (i.e. construction and development costs) and long term (i.e. operating and maintenance costs)[3]. Understanding costs of WSD and green infrastructure presents a challenge to researchers, practitioners and decision-makers alike. Some of these challenges include:

- The difficulty in quantifying a cost differential between WSD and traditional developments due to the high number of variables which change for each individual situation. These variables relate mainly to the catchment size, impervious area to be treated, device type and the jurisdiction in which the works are located.
- This high level of variability in terms of catchment size, impervious area to be treated, soil and topographical conditions and the jurisdiction also present very real challenges when trying to quantify LCC for different types of stormwater treatment solutions.
- Maintenance cost data is difficult to collect due to the commercial sensitivity of cost information, and the relatively limited time that stormwater and WSD solutions have been in place. Actual cost data relating to long term operation and maintenance is scant.
- WSD incorporates a range of approaches relating to site design, earthwork volumes and solutions for managing stormwater discharges – these are dependent on the characteristics of the development, thus it is exceptionally difficult to estimate cost on a generic basis.
- WSD focusses on treating contaminants and reducing the volume of stormwater "at source". As a result, a large number of the stormwater management devices would be located on private property (e.g. using a rain garden and rain tank to manage stormwater from a residential dwelling or commercial property). Understanding the private and public split of costs can be a challenge.

Table 2 provides an indication of the likely public/ private split (as taken from Mainstream, 2012[2]) and this issue is further explored in Section 2.

A number of challenges also existing when attempting to quantify life cycle costs of water supply and wastewater infrastructure. Some of these challenges include:

- As with stormwater infrastructure, it is very difficult to determine the planning and consenting costs for each solution. Many network operator engineering/planning teams do not record and separate their cost information at such a small scale.
- Variations in cost arise as a result of differing site conditions and locations. For example, as the location changes, the delivery/transport costs might vary greatly, and local labour rates may be different. Most cost information obtain for this study has been acquired from network operators and contractors in the Auckland region. Prices may differ in each region of New Zealand.
- Although all the solutions are applicable to urban environments, many are also applicable to urban-rural and/or rural environments. In central urban areas, there may be many skilled contractors available to perform installations/ repairs/ maintenance, allowing both ease of access to contractors, as well as the potential to 'shop around' for the best price. However, in the urban-rural and rural areas, there may not be many trained contractors, which mean costs may increase due to market monopoly, or even require clients to pay for contractors to travel from urban areas. It is likely that this challenge will be discussed in more detail under the rural-urban and rural work briefs.

The inherent difficulty in collecting and quantifying water infrastructure cost data to allow for life cycle analysis has meant that existing life cycle models make a wide range of assumptions and have a number of inherent uncertainties built into them. These uncertainties are usually dealt with by providing a low to high range of likely costs. In addition, the models stress that their purpose is to provide a consistent platform for discussion around the relative difference in cost between different water solutions, rather than focussing on the actual cost itself.

Table 2 Allocation of WSD cost – understanding the public/ private split (adapted from Mainstream, 2012[2])

Cost item	Timing	Burden Initial	Burden Final
Substantive costs			
Planning and initial design of WSUD solution	Initial application via IDAS	Developer	Home purchaser (via land prices)
Detailed design of WSUD	Operational works and measures approvals	Developer	Home purchaser (via land prices)
Instillation of WSUD infrastructure	Post-development approval, pre-sale of land (except for rainwater tanks)	Developer	Home purchaser (via land prices)
Opportunity cost (reduction in sellable land)	Post-development approval, pre-sale of land	Developer	Home purchaser (via land prices)
WSUD (operations, maintenance and other management)	Ongoing during operational phase	Local government	Ratepayers
Training and capacity building	Ongoing	Developer, consultants, regulators	Home purchaser (via land prices), ratepayers, taxpayers
Administrative costs			
Development assessment processing costs	Upon lodgment of applications	Developer (local government where fees not cost reflective)	Home purchaser (via land prices)
WSUD asset handover costs	Upon completion of development	Developer, local government.	Home purchaser (via land prices), ratepayers

2. Summary of Mitigation Solutions and Cost Information

2.1 Water Supply

In order to build a summary of water supply solutions and cost information, a series of New Zealand network operator asset management plans were reviewed. Key reference sources are provided below, and where possible, multiple sources were used for the different solutions. Cost information was also obtained from development projects and Wellington Water.

Estimation of costs is very challenging to obtain for water supply solutions, as there is such a large difference between, for example, a dam that supplies water for irrigation for a farmer compared to a municipal water supply dam. Hence, where available cost information has been based on the Wellington Water and WaterCare AMPs. These plans provide a 'gross replacement cost' for each category of solution. To determine replacement costs, it was assumed that this cost was divided evenly amongst the listed asset, so for instance the total replacement costs for treated water reservoirs was divided evenly amongst the number of reservoirs listed in an AMP. It was not possible to obtain cost data on water dams, as these were not shown separately within the AMPs and the huge variations between dams meant contacting contractors for prices would not likely yield any useful information.

Based on the AMPs, the following solutions are presented and discussed in this section:

- Water supply dams
- Water treatment plants
- Treated water reservoirs
- Water pump stations
- Water pipes
- Valves and hydrants

For each solution a brief description is provided, following which information on the mitigation objectives, implementation and cost considerations are presented.

The information presented in Section 2.1 which relates to the different types of solutions for the urban situation is taken from the following key documents:

- Booysen,W., van Rensburg, J., Mathews, E. (2011). *Selection of Control Valves on Water Optimisation Projects.* Retrieved January 10, 2017, from http://www.eandcspoton.co.za/resources/docs/Valves/Choose_correct_valve_and_save.pdf
- Christchurch City Council. (2015). *Water Supply, Treatment, Pumping Station and Reservoir Design Standard*. Retrieved January 10, 2017, from https://www.ccc.govt.nz/assets/Documents/Consents-and-Licences/construction-requirements/IDS/Water-Supply-Pumping-Stations-and-Reservoirs-Design-Standard-Version-3.1.PDF
- Drainage NZ. (2014). *Manholes*. Auckland, New Zealand. Retrieved January 9, 2017, from http://www.drainage.nz/drainage-services/manholes

- Hamilton City Council. (Undated). *A Guide to Hamilton's Water Supply, River to the Tap.* Retrieved January 9, 2017, from http://www.hamilton.govt.nz/our-services/water/water/Documents/RIVER%20TO%20TAP%20FOR%20WEB.pdf
- Kapiti Coast District Council. (2016). *Water Supplies and Treatment*. Retrieved January 9, 2017, from http://www.kapiticoast.govt.nz/services/A---Z-Council-Services-and-Facilities/Water/Water-Treatment/
- Ministry of Health. (2016). *Guidelines for Drinking-water Quality Management for New Zealand (2nd edn).* Wellington: Ministry of Health. Retrieved January 9, 2017, from http://www.health.govt.nz/system/files/documents/publications/guidelines-drinking-water-quality-management-new-zealand-mar16.pdf
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- Watercare Services Limited. (2016). *Asset Management Plan 2016 to 2036*. Auckland, New Zealand. Retrieved January 10, 2017, from https://www.watercare.co.nz/SiteCollectionDocuments/AllPDFs/Watercare-Asset-Management-Plan-2016-2036.pdf
- Wellington City Council. (2011). *Three Waters Incorporating Water Supply, Wastewater and Stormwater.* Summary Asset Management Plan. Retrieved January 9, 2017, from http://wellington.govt.nz/~/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/threewaters/files/threewaters.pdf?la=en

2.1.1 Water Dams

Description
A structure made from compacted earth or concrete that provides water storage, as well as allowing sedimentation to occur.

Migitation Solution Objectives
Dams tend to:

- Allow water to be collected and used for a range of purposes, such as irrigation or potable water supply.
- Reduce flood effects by storing storm run-off.
- Provide both water quality and quantity control (mainly sediments which are able to settle out once trapped behind the dam, with a lower impact on metals).
- Provide peak flow and flood attenuation.

Implementation Considerations
Dams are a catchment-scale mitigation measure, and the recommended catchment size depends on the dam's purpose. An impermeable base is required, so a liner is required if the existing base is not rock or clay. As rainfall needs to be directed towards the dam and the surface water must be impounded, sufficient slope is required. To have maximum effect, the dam should be located in elevated areas exposed to high rainfall. Dams can have significant impacts on the environment which must be considered carefully. For instance, downstream erosion can be caused by the sediment retention of dams, and thermal effects can occur when discharging water to rivers. Local wildlife must also be considered, especially migratory fish.

Dams are generally owned and operated by public entities, including the council or network operators. As well as providing a water supply for potable water, dams can be a source of water for irrigation and an amenity for visitors.

Cost considerations and information
Cost information for water supply dams was particularly difficult to source since they are not included as separately costed items in the AMPs. In addition, due to the large variation between sizes of dams (which relate to their particular function as well as available space), contractors were not willing to price elements of dam construction and maintenance.

Some key issues to consider when understanding the cost elements of water supply dams include:

- The need for repairs
- Maintenance to ensure safety discharge measures to remain functional
- Land consumption and availability
- Inspections and safety audits
- Impact to the surrounding environment

2.1.2 Water Treatment Plants

Description
A facility used to remove suspended solids, damaging chemicals, or microbiological organisms in order to ensure water is suitable for its intended end use. A variety of processes are used to clean and treat the water, such as UV disinfection, pH control, chlorination, cartridge filtration and sedimentation.

Migitation Solution Objectives

- Provide high water quality treatments for sediments, metals, hydrocarbons and bacteria.

Implementation Considerations
Treatment plants generally provide catchment scale treatment, and as with any structure, the soil on which it is built must have the geotechnical capacity to support the weight of the structure. As water is being taken from natural water supplies, resource consents may be required, and these might limit the amount of water that can be taken from each site. They can supply water for hydrants, and by removing water-borne diseases, water treatment plants can lead to lower health-care costs. As fluoride can be added to the water supply at this stage, dental health can be improved.

Water treatment plants are generally publically built, owned and operated.

Cost considerations and information
Cost information for water treatment plants was obtained from AMPs (total acquisition costs) and maintenance contractor estimates. From the gross replacement costs within AMPs, costs of water treatment plants are in the order of $26 million per plant (only 1 data point was available). Maintenance costs include costs for monitoring and inspections of pumps (weekly), general maintenance (daily), servicing (every 3 months). Automated monitoring systems are often installed during the first maintenance cycle at a cost of $4,000 to $5,000 per plant.

Some key issues to consider when understanding the cost elements of water treatment plants include:

- Trained technicians are required to administer accurate chemical dosages
- Must be regularly serviced and de-sludged to ensure the water being treated remains clean and safe for consumption.

2.1.3 Treated Water Reservoirs

Description

Reservoirs are a storage space for treated water, which can provide extra water during peak demand periods, thus allowing the treatment plants to continue operating at their optimum rate, rather than running under pressure. The shape and size of reservoirs can vary greatly, and they can be located above or below the ground surface.

Mitigation Solution Objectives

- As the water comes directly from the treatment plant, its quality is high as all sediments, metals and bacteria have already been removed.
- Provide a water source when demands on the treatment plant water supply are high.
- Provide water for firefighting.

Implementation Considerations

Treated water reservoirs operate on a catchment-scale, however the size of the catchment can vary greatly between reservoirs. They are owned and operated by the council/ network operators and as such are public solutions.

If reservoirs are partially buried, it's important to ensure they are placed outside of the 100-year flood plain, and the bottom of the reservoir structure must be placed above the groundwater table. As with any large structure, it is imperative to confirm that the soil has the geotechnical capacity to support the weight of the water reservoir and the water it contains, and that it is placed on a geotechnically stable slope. In order to maintain the quality of the water, there must be measures to prevent surface runoff from entering the reservoir and to regulate circulation within the tank. In the interest of safety, overflow drainage must be provided, and adequate security is needed to prevent unauthorised access.

Treated water reservoirs are extremely useful, as they can be used to supply water when water mains break, or if maintenance requires distribution pipes to be shut. It is possible that due to their greater distance from treatment areas, coastal environments may require more reservoirs. These increasing distances from the distribution network may also influence the costs.

Cost considerations and information

Cost information for treated water reservoirs was sourced from the gross replacement costs in AMPs, and ranged from $620,000 - $3,600,000. No maintenance costs were available. Some key issues to consider when understanding the cost elements of treated water reservoirs include:

- A larger distance from the main distribution network will create higher costs
- Inspections must be carried out regularly on the hydraulic controls, security, cleanliness and structural components of the reservoirs.

2.1.4 Water Pump Stations

Description
Located near the potable water source, these pump stations provide the energy required to pump the water into the distribution network. Whilst the size and capacity of pumping stations can differ depending on local requirements, they are an essential component of the water supply distribution network.

Mitigation Solution Objectives

- By increasing pressure, the stations allow water to overcome unfavourable gravitational differences in order to enter the pipe network.

Implementation Considerations
As a public entity, these water pump stations are vested with the council and operated by the council and/or network operators.

As there are a range of pump types and sizes available, the required water level and the required discharge volume are the key factors to consider when determining which pumps need to be installed. Any lubrication used to keep the pumps operating efficiently must meet NZMAF Food Assurance Authority C15, in order to prevent it causing any contamination to the water supply. The soil and slope that the pump station is located on must be geotechnically safe for the structure.

Cost considerations and information
Cost information for water pump stations was sourced from the gross replacement costs in AMPs, and ranged from $74,300 - $345,000 per pump station. Maintenance costs include costs for general inspections of pumps (fortnightly), general maintenance and servicing (every 6 – 10 years), chamber lid replacement (approx. $3,000) and chamber repairs (every 25 years).

Some key issues to consider when understanding the cost elements of water pump stations include:

- Energy costs can be extremely significant so ensuring optimal efficiency is obtained from the installed pumps is crucial.
- As with any major water supply machinery, regular inspections and maintenance are required, as well as cleaning of the pump station chamber. These works need to be carried out by appropriately trained technicians.
- If confined space entry is present, this can greatly increase the cost of inspection, maintenance, and repairs.
- Automatic monitoring systems may be a large upfront cost, but they can reduce the costs of inspections in the long term.

2.1.5 Water pipes

Description
As a method of conveying water between its source and its destination, water pipes provide a hollow cylindrical medium through which water is conveyed. There is a large range of pipe sizes, diameters and lengths, the use of which are determined by the scale of conveyance required.

Mitigation Solution Objectives

- Provide a network for raw water to be taken from its source to the treatment plant
- Once this water has been treated, the pipes convey it to the end-use location.

Implementation Considerations
The scale of pipes can vary immensely, from site scale to catchment scale. As such, pipes can be both privately and publicly owned, operated and maintained. Whilst the only soil constraint is the requirement of a geotechnically stable subgrade, the slope of the pipes is considered a key limitation. As pipes can be damaged easily, it is imperative to ensure the slope of the pipes is not so steep so as to result in excessively high velocities. Velocities over 2.0 m/s can cause water hammers which are detrimental to the pipe. However, if the pipes are not being used in conjunction with a pump, the slope, pipe dimeter and pipe material must be combined in a way that allows gravity to ensure flow of water is maintained. This flow rate will be determined by the daily consumption, peak day demand, peak day demand peaking factor, the number of residents and the daily consumption of each resident.

Cost considerations and information
Construction and installation costs for water pipes have been sourced from construction projects and AMPs. Water main pipes ranging from 50 – 150mm can vary from $280 to $546 per linear metre. Maintenance costs were sourced from contractors undertaking this type of maintenance work. Initial CCTV inspections can cost from $240 - $370 per hour, and thereafter CCTV is undertaken on about a 6 yearly basis. If traffic management is needed during maintenance, this can range from $140 - $450 per hour (or service depending on the contractor). Flushing debris and clearing pipes generally incurs an establishment fee of approximately $80 and then $180 per hour as needed. This rate is comparable to costs incurred if pipes are vacuumed. The level of maintenance needed is dependent on the condition and contaminant levels in the pipes.

Some key issues to consider when understanding the cost elements of water pipes include:

- Initial CCTV inspections are required, and from there maintenance schedules are created which must be adhered to.
- The depth at which the pipe must be buried, and the diameter of the pipe are the two limitations most likely to impact the upfront cost.
- Leaks or cracks must be dealt with quickly and efficiently to ensure water supply is maintained.

2.1.6 Valves and Hydrants

Description

Valves are widely used devices which alter water passages in order to increase or decrease flow as required. Hydrants are points at which firefighters can connect equipment to gain rapid access to water supply, allowing them to effectively combat fire damage.

Mitigation Solution Objectives

- To control water direction and quantity by adjusting flow direction, volume or pressure.
- Can control water supply for both potable and irrigation uses.
- Can ensure adequate pressures are achieved for household requirements such as washing machines.
- Can prevent/reduce deaths due to increased efficiency of firefighting .

Implementation Considerations

The scale of implementation for both valves and hydrants is very small, as many valves are required in each water system and hydrants must be placed at frequent intervals for safety reasons. As such, they are implemented both publicly (owned by the council) and privately (by homeowners and businesses).

In regards to hydrants, it is necessary to take steps to prevent members of the public being able to access and steal the water for personal use. It is also important to ensure any back-flow of water into the hydrant is prevented, as this can contaminate the water supply contained within the mains pipes. Rapid opening or closing of valves and hydrants can cause damaging water hammers, and thus this must be avoided. When selecting an appropriate valve to be used, flow characteristics, control range, cavitation, flashing, valve body size, actuator type, safety rating, control speed and water pressure are all key factors to be considered.

Cost considerations and information

Construction and installation costs for valves and hydrants have been sourced from construction projects and AMPs. Valves range in cost from $1,340 - $4,630, with a gross replacement cost of around $2,100 per valve. Hydrants range from $1,850 to $2,860, with a gross replacement cost of $1,000 to $3,100 per hydrant.

Some key issues to consider when understanding the cost elements of valves and hydrants include:

- As fire hydrants are a safety measure, they must meet strict NZ Fire Service Hydrant standards, including annual testing for leaks and valve operation.
- If the system is boosted by pump sets, the diesel engine must be serviced in accordance with NZS4510.
- Valve failure can render a whole system inoperable, thus care must be taken to provide regular testing and replacement when required.

2.2 Wastewater

In order to build a summary of wastewater solutions and cost information, a series of New Zealand network operator AMPs were reviewed. Key reference sources are provided below, and where possible, multiple sources were used for the different solutions. Cost information was also obtained from development projects and Wellington Water.

"Ballpark" estimation of costs is very challenging to obtain for wastewater solutions, as there is such a large difference between a wastewater pump station that connects a few houses to the local sewer main and a station that services an entire suburb of Porirua. Hence, where available, cost information has been based on the Wellington Water and WaterCare AMPs. These plans provide a 'gross replacement cost' for each category of solution. As with the water supply costs, replacement costs were divided evenly amongst the identified asset.

Based on the AMPs, the following solutions are presented and discussed in this section:

- Wastewater treatment plants
- On-site wastewater treatment systems (septic tanks/ irrigation fields)
- Hydrocarbon interceptor units
- Grease traps
- Wastewater pump stations
- Wastewater pipes
- Manholes/ chambers

For each solution a brief description is provided, following which information on the mitigation objectives, implementation and cost considerations are presented.

The information presented in Section 2.1 which relates to the different types of solutions for the urban situation is taken from the following key documents:

- Wellington City Council. (2011). *Three Waters Incorporating Water Supply, Wastewater and Stormwater.* Summary Asset Management Plan. Retrieved January 9, 2017, from
- http://wellington.govt.nz/~/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/threewaters/files/threewaters.pdf?la=en
- Drainage NZ. (2014). *Manholes*. Auckland, New Zealand. Retrieved January 9, 2017, from http://www.drainage.nz/drainage-services/manholes
- Watercare Services Limited. (2016). *Asset Management Plan 2016 to 2036*. Auckland, New Zealand. Retrieved January 10, 2017, from
- https://www.watercare.co.nz/SiteCollectionDocuments/AllPDFs/Watercare-Asset-Management-Plan-2016-2036.pdf
- Level. (Undated). *Land-application Disposal System*. Retrieved January 19, 2017, from
- http://www.level.org.nz/water/wastewater/on-site-wastewater-treatment/land-application-disposal-systems/
- Wellington Regional Council. (2000). *Guidelines for On-Site Sewage Systems in the Wellington Region.* Retrieved January 19, 2017, from

- http://www.gw.govt.nz/assets/council-publications/Environment%20Management_20010223_154203.pdf
- Auckland City Council. (Undated). *On-Site Wastewater Management.* Factsheet based on Auckland Council Technical Publication 58 (TP58). Retrieved January 19, 2017, from
- Drainage NZ. (2014). *Manholes*. Auckland, New Zealand. Retrieved January 9, 2017, from http://www.drainage.nz/drainage-services/manholes
- http://www.aucklandcouncil.govt.nz/EN/ratesbuildingproperty/consents/buildingstructures/Documents/onsitewastewatermanagementintro.pdf
- Marlborough District Council. (2012). *Tradewaste Petrol and Oil Interceptor*. Blenheim, New Zealand. Retrieved January 20, 2017, from http://www.marlborough.govt.nz/sitecore/shell/Controls/Rich%20Text%20Editor/~/media/Files/MDC/Home/Services/Utilities/Tradewaste_Petrol_Oil_Interceptor.ashx
- Hugo Plastics. (2015). *Petrol and Oil Interceptor*. Wellington, New Zealand. Retrieved January 20, 2017, from
- http://hugoplastics.nz/wp-content/uploads/2015/10/Hugo-Plastics-HP-9BG-Petrol-and-Oil-Interceptor.pdf
- Placentia Municipal Code. (2016). *General Limitations, Prohibitions, and Requirements on Fats, Oils, and Grease ("FOG") Discharges*. Retrieved January 20, 2017, from
- http://qcode.us/codes/placentia/view.php?topic=16-16_24-16_24_020

2.2.1 Wastewater Treatment Plants (WWTPs)

Description
WWTPs are large scale facilities which treat wastewater in order to remove harmful contaminants such as suspended solids, chemicals and micro-organisms. It is necessary to remove these from the wastewater that is processed by the plant as it is discharged into the environment.

Mitigation Solution Objectives

- Water quality is improved by removing sediments, metals, organic pollutants, hydrocarbons and bacteria.
- Minimises the impacts the discharged wastewater has on the ocean it is released into (and thus the marine life).

Implementation Considerations
The site must be located on flat ground (with the geotechnical capacity to support the structure), and for optimal gravitational feed of the wastewater, it should be placed at the bottom of the catchment.

There are many benefits of using WWTPs. Firstly, the waste solids that are removed from the wastewater can be used as fertiliser, while gas can be harvested from the plant and used to generate power. As well as this, the large ponds required for UV treatment can provide a habitat for local wildlife such as birds, and an amenity for people.

As treatment plants discharge into the oceans, they must be located close to the coast, and they must be continually assessed to ensure they impose no health or environmental risks, or impact on recreational activities that take place in the harbour. It is also necessary to ensure that maintenance workers avoid exposure to health-hazards when working in the plant by ensuring all wastewater is correctly contained. WWTPs are a public facility and are therefore are owned and operated by the council/ network operators.

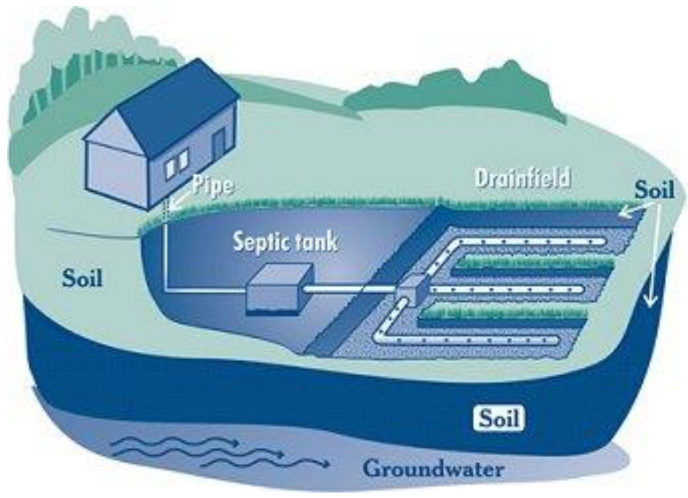
Cost considerations and information
Cost information for WWTPs is highly variable. The gross replacement cost of a WWTP, as determined from WaterCare's AMP, is estimated to be around $54 million. Wellington Water estimate the gross replacement cost to range from $690 to $710 per person treated. Maintenance costs include costs for monitoring and inspections of pumps (weekly), general maintenance (daily), servicing (every 3 months). Automated monitoring systems are often installed during the first maintenance cycle at a cost of $4,000 to $5,000 per plant. Some key issues to consider when understanding the cost elements of WWTPs include:

- Land consumption
- Water quality tests must regularly be conducted and presented to the council
- Regular condition inspections, maintenance and desludging must be carried out
- Distance from the coast will increase the pipe costs required for discharge into the ocean.

2.2.2 On-site wastewater treatment systems/sceptic tanks and irrigation fields

Description

When no connection to the sewer main is available, or as a way to save on water costs, these systems collect wastewater from a household and either discharge this effluent directly into permeable soil or through irrigation measures to water crops.



Mitigation Solution Objectives

- Provide high sediment, organic pollutant and bacterial treatment through bacterial action that occurs in the soil.
- Disposes of effluent that cannot be sent to wastewater treatment plants.
- Reduce water consumption.

Implementation Considerations

These devices are private implementations, so homeowners are responsible for installation and maintenance. They are generally used in rural or rural-urban areas, but may be present in older low density residential subdivisions.

The position of the water table and the area available for land application both need to be considered before installing any on-site treatment systems, as well as the effects on local ecology and near-by properties. In order to avoid contaminating the stormwater network and causing any health risk to the public, overloading the irrigation field must be avoided. Any plants being irrigated by wastewater must not be used for human consumption, and animals must not graze in affected areas.

The soil permeability must be assessed, as impermeable soil will result in effluent surface runoff. There must be a minimum depth of 600mm of soil underneath the soakage area prior to reaching the groundwater level. The slope must be under 20 degrees, or a system must be specifically designed for the site. If a slope is present, the drip irrigation lines might require pressure compensation. It is essential that the treatment tank is placed on a level base.

By using onsite wastewater treatment systems/sceptic tanks and irrigation fields, the pressure placed on wastewater treatment plants is reduced, and less wastewater is discharged into the sea. In areas where water supply is limited (eg relying on rain tanks), using effluent for non-potable uses such as irrigation can lead to water savings.

Cost considerations and Information

Costs of on-site wastewater systems vary greatly between irrigation systems (such as buried, drip fed, low pressure pipelines). Cost information was sought from suppliers, contractors and owners of similar systems. On average, the construction and installation costs of these systems can range from $8,500 - $15,000. On average ,on-site systems should be inspected and serviced on a 6 monthly basis, and can lead to annualised maintenance costs of $500 - $550. Daily running costs result from energy usage of the system. Data on corrective maintenance costs is still being investigated.

Some key issues to consider when understanding the cost elements of on-site systems include:

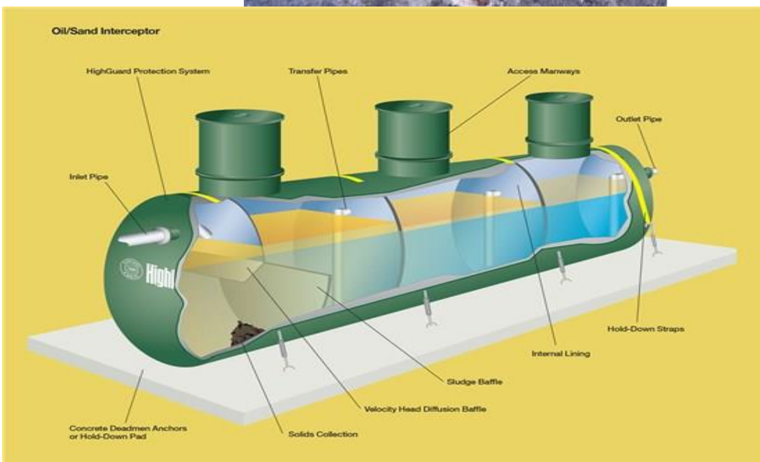
- Adequate land must be provided for effluent absorption.
- Tanks must be regularly de-sludged to ensure they operate efficiently.
- If gravity feeds cannot be used, pumps are required.
- Diversion methods may be required to prevent surface runoff from entering the soakage treatment area.

2.2.3 Hydrocarbon Interceptor Units

Description
A hydrocarbon interceptor unit comprises 3 connected units which result in hydrocarbons separating from wastewater due to their different respective densities and being removed from the surface of the water entering the pipe network. They are often installed in petrol forecourts, large carparks and vehicle maintenance areas.

Mitigation Solution Objectives

- High water quality benefits in regards to hydrocarbon removal.
- Prevent contaminants from entering the wastewater network and causing damage.



Implementation Considerations
As a solution that is implemented on a site scale, they are privately implemented and maintained. The size of the unit will be dictated by the portion of the catchment which is discharging through it.
Whilst there are no slope constraints, the soil in which the interceptor unit is placed must have sufficient strength and stability to support the buried structure. In order for servicing to be carried out, an access cover to the interceptor unit must be provided.

An effective hydrocarbon interceptor unit can reduce the occurrence of blockages, overflow or oil accumulation in pipes, thus is an essential element in maintaining the efficiency of the entire wastewater treatment network.

Cost considerations and information
Cost information for interceptor units is still being investigated, with some initial unit costs being obtained from suppliers. The cost of a 2000 litre unit ranges from $1,800 - $2,200 plus installation and an additional $1,500 - $2,800 for the lid.

Some key issues to consider when understanding the cost elements of interceptor systems include:

- To prevent build-up of hydrocarbons, regular cleaning (using products with a pH of 6-10) must be carried out, while all sludge is removed and taken to an appropriate disposal facility.

2.2.4 Grease Traps

Description
Similar to hydrocarbon interceptors, grease traps aim to prevent harmful materials from entering the wastewater network. These are predominantly fats, oil and grease. Grease traps should be installed in all restaurants and many other commercial food services, and thus can vary greatly in size and price according to the location in which it is installed, and whether it is above ground or buried.

Mitigation Solution Objectives
- Provide high water quality treatment in regards to sediments and oils.
- Reduce or prevent blockages or damage to drains by preventing excess grease build up in pipes, thus avoiding costly maintenance and repair bills.

Implementation Considerations
Whilst the grease trap itself has no slope constraints, its size is determined by the slope and volume of the wastewater pipe which feeds into the trap.

In order to avoid emulsification of the grease, it is important to ensure wastewater coming from dishwashers or with temperatures greater than 60 degrees Celsius does not discharge into the traps. Regardless of whether the traps are above ground or buried, they must be installed in a location which allows access for cleaning and maintenance.

The contaminants which become trapped on the grease trap can be turned into garden mulch or biodiesel which has strong environmental benefits. Other environmental benefits are created through the reduction of environmental damage that can be caused be fat blockage induced dry weather overflows from the wastewater network.

Cost considerations and information
Costs vary greatly with differing sizes and locations, but costs which have been obtained from suppliers indicate that a 1,200 litre to 3,600 litre trap can vary from $2,200 to $3,800 plus installation. This cost is for a surface mounted grease trap – underground grease traps are more expensive. In terms of maintenance, grease traps should be cleaned every 3 – 6 months, depending on the level of build-up. A clean and service can cost around $400 - $500.

Some key issues to consider when understanding the cost elements of grease traps include:
- Regular cleaning is required as full grease traps can cause overflows.
- Buried grease traps may have higher costs associated with them due to difficulty in access and the requirement for a pump truck when being cleaned.

2.2.5 Wastewater Manholes/Chambers

Description

Wastewater manholes/ chambers are openings provided at regular intervals (usually 90-150m) which allow technicians to inspect, repair or adjust buried wastewater services.

Mitigation Solution Objectives

- Allow for joining of wastewater pipes, and the maintenance associated with this.
- Ease of inspection allows potential future malfunctions to be identified and prevented before they occur.

Implementation Considerations

As the manhole chamber is buried, the bearing capacity of the soil must be sufficient for the manhole foundation, whilst steep grade pipelines of greater than 7% should be avoided unless precautions have been taken.

Manholes and chambers act on a small scale, and are both publicly and privately owned and operated. Wastewater manholes must be provided at sites where pipes change direction, gradient or size, and must be located at least 1.0m from boundaries and structures.

Communication with the relevant transport authority may be required if the manhole is to be located on the road to ensure vehicles are unable to push manholes open, and the manhole covers required on roads differ to those on pavements and other non-trafficked areas. Contractors who perform maintenance on the manholes and chamber are working in a confined, underground environment, and thus measures must be put in place to ensure their safety (including providing a traffic management plan if working on a manhole placed in a trafficked area).

Cost considerations and information

Costs for manholes and chambers have been investigated and based on actual construction projects, network operator AMPs, discussions with contractors and Wellington Water. Construction and installation costs range from $4,400 - $6,600 per manhole. The gross replacement cost for a manhole can be in the order of $8,000. Manholes and chambers should be flushed annually at a cost of around $400.

Some key issues to consider when understanding the cost elements of manholes/ chambers include:

- Regular flushing must take place.
- Additional services/connections may need to be installed into existing manholes which can increase costs.

2.2.6 Wastewater Pump Stations

Description
Wastewater pump stations provide the energy necessary to transport wastewater across the wastewater pipe networks to the treatment plants where it can be processed and discharged into the environment.

Mitigation Solution Objectives

- Provide the pressure required to transport wastewater across unfavourable gravitational differences
- Reduce the need for additional satellite treatment plants or waste water discharges to freshwater and marine environments.

Implementation Considerations
As a public entity, these water pump stations are vested with the council and are operated by council and/or network operators. However, in some cases, privately owned pump stations can be used to connect private households to the public wastewater network if they are downhill from the network, and in these cases the installation, operation and maintenance responsibilities lie with the private household owner.

Whilst there is a range of pump types and sizes available, the water level that the wastewater is to be pumped to and the required discharge volume are the key factors to take into account when determining which pumps need to be installed.

The soil and slope that the pump station is situated on must be geotechnically safe for the structure. Maintenance workers must be protected from any potential health hazards by ensuring wastewater is properly contained.

Cost considerations and information
Construction of wastewater pump stations can vary widely depending of the size and scale of the pump station. Wellington Water's AMP estimates the gross replacement cost of a pump station to range from $154,600 - $694,000. Construction of pump stations in the Auckland Region have ranged from $325,000 - $750,000. Pump stations are generally inspected monthly at a cost of $340 (based on a 4 hour inspection per month). Moving pumps are inspected every 3 months at a cost of $850 per station. General maintenance is likely to occur every 6 – 10 years, and chamber repairs/ replacement of parts every 25 years.

Some key issues to consider when understanding the cost elements of wastewater pump stations include:

- Energy costs can be significant so ensuring optimal efficiency is obtained from the installed pumps is crucial.
- As with any major pump, regular inspections and maintenance are required, as well as cleaning of the pump station chamber, which must be carried out by

appropriately trained technicians. Wet-well washing is required to remove fat build-up.

- If confined space entry is present, this can greatly increase the cost of inspection, maintenance and repairs.
- Automatic monitoring systems may be a large upfront cost, but they can reduce the costs of inspections.
- Wastewater pump stations near schools, day-cares or restaurants experience higher demand and more wear, thus require more frequent servicing and have a shorter design life.

2.2.7 Wastewater Pipes

Description

Wastewater pipes are hollow cylindrical units made from various materials that transport wastewater through the network until it eventually reaches the treatment plant. These pipes can come in a large range of sizes, diameters and lengths, which are determined by the scale of transportation required.

Mitigation Solution Objectives

- Allow unwanted wastewater to be removed from a wide variety of locations, which is then transported to appropriate treatment stations.

Implementation Considerations

The scale of pipes can vary immensely, from site scale to catchment scale. As such, pipes can be both privately and publicly owned, operated and maintained.

Whilst the only soil constraint is the requirement of a geotechnically stable subgrade, the slope of the pipes is considered a key limitation. As pipes can be damaged easily, it is imperative to ensure the slope of the pipes it not too steep as this could result in excessively high velocities. Velocities over 2.0 m/s can cause water hammers which could be detrimental to the pipe. However, if the pipes are not being used in conjunction with a pump, the slope, pipe dimeter and pipe material must be combined in a way that allows gravity to ensure flow of wastewater is maintained.

In order to determine the design flow required of the pipe, the number of residents, dry weather flows, dry weather peaking factor and peak wet weather flows need to be analysed. There must be an adequate number of manholes provided along the wastewater pipe networks, and there must be sufficient spacing between the ground surface and the pipes.

Cost considerations and information

Construction and installation costs of wastewater pipes can range from $110 - $2,407 per linear metre (110mm dia – 900mm dia pipes). Gross replacement costs of pipes, as taken from the WaterCare and Wellington Water AMP, range from $194,000 - $694,000. Maintenance costs were sourced from contractors undertaking this type of maintenance work. Initial CCTV inspections can cost from $240 - $370 per hour, and thereafter CCTV is undertaken on an “as-required” basis. If traffic management is needed during maintenance, this can range from $140 - $450 per hour (or service depending on the contractor). Flushing debris and clearing pipes generally incurs an establishment fee of approximately $80 and then $180 per hour as needed. This is similar to costs incurred if pipes are vacuumed. Confined space entry is sometime required at a cost of $170 per hour. The level of maintenance, clean and repair needed is dependent on the condition and contaminant levels in the pipes, and is generally based on CCTV footage.

Some key issues to consider when understanding the cost elements of wastewater pipes include:

- Initial CCTV inspections are required, and from there maintenance schedules are created which must be adhered to.
- The depth at which the pipe must be buried, and the diameter of the pipe are the two limitations most likely to impact the upfront cost.
- Selecting the right diameter is essential as undersized pipes have reduced capacities, while oversized pipes are economically inefficient.

2.3 Stormwater

Stormwater management practices tend to be less well defined in the network AMPs, and some of the 'at source' solutions tend to be privately owned and operated. As a result, a number of national and international manuals have been reviewed in order to develop a suite of key solutions which could be used in Porirua. Some of these solutions are already being implemented in the Wellington region. The following solutions are presented and discussed in this section:

- Dry detention basins
- Ponds
- Wetlands
- Rain gardens and tree pits
- Swales and filter strips
- Infiltration trenches and permeable paving
- Sand filters
- Rain tanks
- Green roofs and green walls
- Riparian buffer strips
- Source control (roofs)
- Catchpits, manholes and pipes
- Proprietary devices

For each solution a brief description is provided, following which information on the mitigation objectives, implementation considerations and cost is presented.

The information presented in Section 2.3 which relates to the different types of solutions for the urban situation is taken from the following key documents:

- Auckland Regional Council. 2000. *Low Impact Design Manual for the Auckland Region*. TP124.
- Auckland Regional Council. 2003. *Stormwater Management Devices – Design Guideline Manual*. TP10.
- Centre for Neighborhood Technology and American Rivers. 2010. *The Value of Green Infrastructure. A Guide to Recognising it's Economic, Environmental and Social Benefits*.
- COSTnz: http://www.costnz.co.nz
- Dillon Consulting. 2006. *Stormwater Management Guidelines*. Prepared for the Halifax Regional Municipality (Canada). 05-4680-0400
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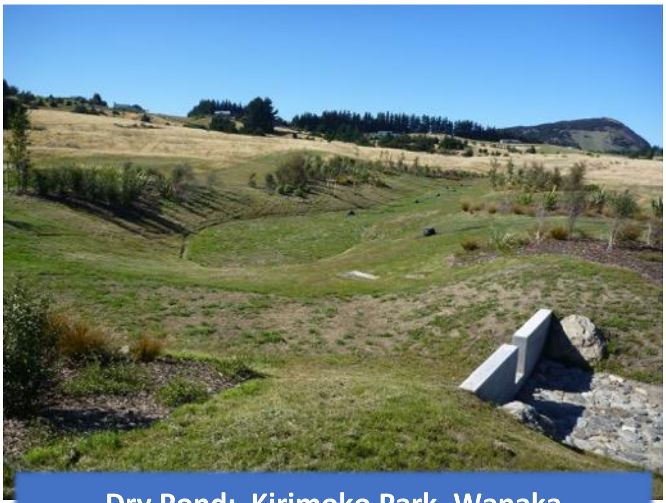
More detailed references relating to cost information are provided within the "Cost Considerations" section for each solution.

2.3.1 Dry Detention Basins

Description

Dry detention basins are also referred to as dry ponds. It is a permanent depression or pond area that temporarily stores stormwater runoff to reduce the peak rate of stormwater discharge and to reduce flooding. They assist with peak flow and flooding control by detaining runoff and reducing it at a specified design rate. They are normally dry between rain events and are generally grassed areas that can be used for other activities between rain events.



Dry Pond: Kirimoko Park, Wanaka

Mitigation Solution Objectives

In general, dry detention basins provide for:

- peak flow reduction
- flood control

They are generally not used for water quality treatment, but can assist with the removal of sediments, and contaminants attached to sediments, through extended detention.

Implementation Considerations

Dry detention basins are catchment-scale devices and are general suitable for catchments which are greater than 6ha. They can be used on any type of soil. Key limitations of the practice relate to slope (the steeper the slope the more difficult it is to obtain the necessary storage area) and land availability.

As they are generally implemented on a catchment scale, they are usually owned and operated by a public entity such as a council or network operator. Regular mowing and care (potentially on a quarterly basis) is needed and, depending on the sediment load, removal and disposal of sediments to a contaminated landfill may be necessary.

Dry detention basins can be used as recreational/ amenity areas during inter-event dry periods.

Cost considerations and information

As part of the UPSW DSS Economic costing project[9], costs of dry detention ponds were investigated. Pond sizings were obtained from consultancies in Auckland, and 10 ponds, designed to attenuate the 2 year average recurrence interval event storm were analysed in order to determine an average dry pond surface area. The low cost values within COSTnz

9 Ira, S. (2011). The development of catchment scale life cycle costing methods for stormwater management. Prepared for NIWA. Cawthron Report No. 2082

were then used to model costs. On average, for a 60% impervious 1 ha catchment, the TAC of the dry pond was $8,000. Annualised maintenance costs were around $85/ha.

With respect to cost, land availability and value is a key consideration. Land costs are not included in the COSTnz models. Through the UPSW study[9] a land cost factor was used to account for land costs, and this was based on a cost of $\$80/m^2$ for greenfield areas and $\$140/m^2$ for developed catchments (in 2011). The land cost factor for dry ponds was 0.04 and 0.06 of the $/ha LCC for greenfields and developed catchments respectively.

2.3.2 Ponds

Description
An open body of water which provides treatment through the process of sedimentation. Wet ponds also temporarily store stormwater runoff to reduce the peak rate of stormwater discharge and to reduce flooding. They have been used for many years by network operations to provide water quantity and quality mitigation of stormwater runoff.

Pond: North Shore, Auckland

Mitigation Solution Objectives
In general, ponds provide for:

- water quality treatment (mainly sediments and to a lesser extent metals)
- peak flow reduction
- flood control
- stream channel erosion protection

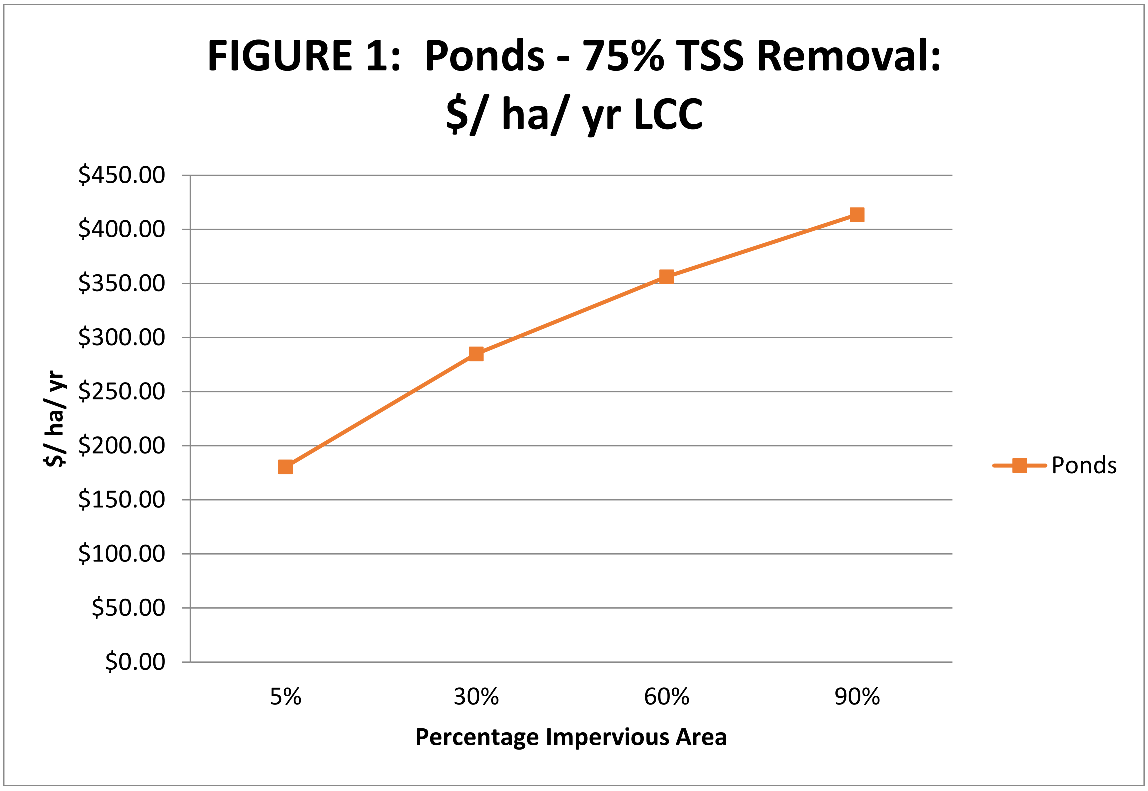
Implementation Considerations
Ponds are catchment-scale devices and are generally suitable for catchments which are greater than 4ha. They are primarily used on clay soils, however, with the inclusion of an impermeable liner they can be used on any type of soil. Key limitations of the practice relate to slope (the steeper the slope the more difficult it is to obtain the necessary storage area); land availability and they would be very expensive to use in areas of bedrock. In addition, ponds can cause thermal affects when discharging directly to streams.

As they are generally implemented on a catchment scale, they are usually owned and operated by a public entity such as a council or network operator. Regular inspections are needed to ensure pond spillways, embankments, inlets, outlets, grates and other mechanical parts are functioning as designed. In addition, regular mowing of embankments and care of vegetation is needed (on average on a quarterly basis). Over the long terms, desludging of the forebay and main body of the pond may be required and the sediments disposed of at a contaminated land fill.

Ponds can be used as water storage reservoirs (e.g. water for fire fighting, stock watering, etc). Ponds can enhance property values for those properties which abut the pond. Ponds can be aesthetically pleasing and provide amenity value to surrounding communities.

Cost considerations and information
Cost considerations relate to the size of the pond and landscaped area, associated cost of the land, and the maintenance issues discussed above. As part of the UPSW DSS Economic costing project[9], costs of dry detention ponds were investigated. Pond sizings were obtained from consultancies in Auckland, and theoretical treatment scenarios were costed using COSTnz. Life cycle costs for ponds are presented in Figure 1 and are shown for a range of impervious areas assuming 75% total suspended solids removal. Figure 1 highlights that

LCC for ponds with 60% impervious area draining to them costs, on average $350/ha/yr. The discounted NPV for the same data point is approximately $290/ha/yr (50 year life span and 3.8% discount rate).



Source: Ira, S J T. 2011. Report No. 2082 by the Cawthron Institute entitled: "*The Development of a Catchment Scale Life Cycle Costing Method for Stormwater Management*".

As discussed in Section 2.3.1 (Dry Detention Ponds), a land cost factor was developed. This factor was determined to be 0.08 and 0.14 for greenfields and developed areas respectively, and based on land needed to remove 75% total suspended solids.

2.3.3 Wetlands

Waitangi Park Wetland, Wellington

Description

Constructed wetlands are designed to mimic natural wetland systems which use processes involving wetland vegetation, soils, microbes and sedimentation to improve water quality. Due to the complex mix of physical, chemical and biogeochemical processes, wetlands are very effective at treating a wide-range of contaminants in stormwater.

Mitigation Solution Objectives

In general, wetlands provide for:

- water quality treatment: sediments, metals, TPHs, PAHs, bacterial, nutrients
- peak flow reduction
- flood control
- stream channel erosion protection

Implementation Considerations

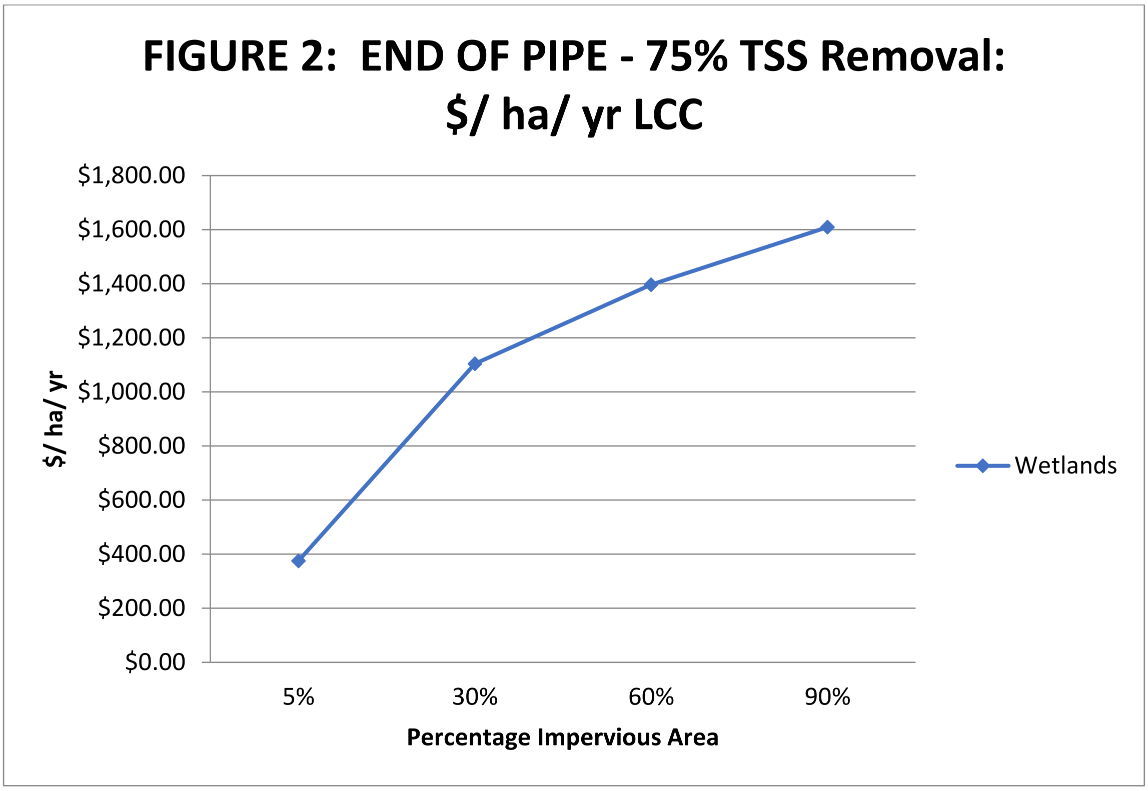
Wetlands are catchment-scale devices and are general suitable for catchments which are greater than 1 -2ha. They are primarily used on clay soils, however, with the inclusion of an impermeable liner they can be used on any type of soil. Key limitations of the practice relate to slope (the steeper the slope the more difficult it is to obtain the necessary storage area); land availability and they would be very expensive to use in areas of bedrock.

As they are generally implemented on a catchment scale, they are usually owned and operated by a public entity such as a council or network operator.

Wetlands can provide attractive open space areas and add amenity value to surrounding communities. In addition they provide habitat for a variety wildlife and plant communities. Wetlands require regular maintenance, especially in the first few years to ensure the plants grow well and survive. Weeding, watering and replanting may be needed. Thereafter, maintenance requirements reduce dramatically as the wetland plants establish and thrive. Regular inspections are needed to ensure spillways, embankments, inlets, outlets, grates and other mechanical parts are functioning as designed. Over the long term, desludging of the forebay of the wetland may be required and the sediments disposed of at a contaminated land fill.

Cost considerations and information

Cost considerations relate to the size of the wetland and landscaped area, associated cost of the land, landscaping, and the maintenance issues discussed above. As part of the UPSW DSS Economic costing project[9], costs of wetlands were investigated. Wetland sizings were obtained from consultancies in Auckland, and theoretical treatment scenarios were costed using COSTnz. Life cycle costs for wetlands are presented in Figure 2 and are shown for a range of impervious areas assuming 75% total suspended solids removal. Figure 2 highlights that LCC for wetlands with 60% impervious area draining to them costs, on average $1,400/ha/yr. The discounted NPV for the same data point is approximately $1,320/ha/yr (50 year life span and 3.8% discount rate).



Source: Ira, S J T. 2011. Report No. 2082 by the Cawthron Institute entitled: "*The Development of a Catchment Scale Life Cycle Costing Method for Stormwater Management*".

As discussed in Section 2.3.1 (Dry Detention Ponds), a land cost factor was developed. This factor was determined to be 0.16 and 0.29 for greenfields and developed areas respectively, and based on land needed to remove 75% total suspended solids.

2.3.4 Rain Gardens and Tree Pits

Description
A rain garden is an attractive, landscaped shallow depression that captures, absorbs and treats stormwater runoff from impervious areas such as car parks, roads, driveways and roofs. There are two types of rain gardens. A bioretention rain garden infiltrates stormwater back into the ground (no piped system). A biodetention rain garden detains water and releases it into a piped system. A tree pit is a small rain garden that captures rain water from sidewalk pavements or roadways.

Rain gardens: New Lynn, Auckland

Tree Pit (source: http://www.aucklandcouncil.govt.nz/EN/environmentwaste/stormwater/Documents/treepitsconstructionguide.pdf)

Mitigation Solution Objectives
In general, rain gardens provide for:

- water quality treatment: sediments, metals, TPHs, nutrients (if designed specifically for nutrient removal)
- stream erosion control
- volume reduction (i.e. if they are bioretention rain gardens/ tree pits)

Implementation Considerations
Rain gardens can be used to treat relatively small impervious areas ("lot scale" treatment) up to areas of 3 - 4ha. There are very few limitations to the application of rain gardens, and careful design can overcome most issues such as high sedimentation inputs or steep slopes.

Given their small size, it is important to ensure that tree pits have sufficient quantity of soil media to be able to support tree growth. Careful design consideration is required to ensure the root zone does not remain saturated.

Because rain gardens and tree pits have a variety of scales at which they can be implemented, they can be built, owned and operated either publically or privately. Public rain garden and tree pit assets are generally associated with treatment of roading infrastructure, whilst private devices are associated with house and driveway treatment. Rain gardens and tree pits require regular maintenance, especially in the first few years to ensure the plants grow well and survive. In areas of high contaminant loading, clogging of the filter media media may become a problem and over time the filter media may need to be replaced and the rain garden/ tree pit replanted.

Rain gardens and tree pits assist with "bringing nature back into an urban environment". They can provide refuge areas for birds, lizards and insects, assist with disconnecting impervious areas and reducing the temperature of urban stormwater.

Cost considerations and information

With respect to construction costs of rain gardens, the Conservation Research Institute (2005[10]) states that lot level costs can be decreased by 25% – 30% when using rain gardens rather than a conventional detention pond and pipe system. The study, however, discusses bioretention rain gardens (i.e. where the water will infiltrate into the ground), as opposed to biodetention rain gardens, which still require a piped system to discharge stormwater. The Stormwater Center factsheet on bioretention (http://www.stormwatercenter.net/ : accessed on 22 August 2009) states that bioretention is relatively expensive. This is mainly due to the fact that rain gardens consume a fair amount of land for the catchment area treated (approximately 5% surface area to catchment area).

In New Zealand, COSTnz has been used to develop unit dollar per hectare costs as part of the UPSW DSS economic model[9]. Over a life cycle analysis period of 50 years and at a discount rate of 3.8%, life cycle costs for rain gardens equated to approximately NPV$3,880 /ha/yr for an area comprising 60% imperviousness and to a treatment level of 75% total suspended solids removal. The undiscounted LCC equated to $8,054/ha/yr. It is interesting to note that the NPV LCC is substantially lower than the undiscounted LCC and is reflective of the potentially relatively high maintenance cost of rain gardens. Further research is needed to fully understand these maintenance costs.

As discussed in Section 2.3.1 (Dry Detention Ponds), a land cost factor was developed for the UPSW DSS economic model[9]. This factor was determined to be 0.052 and 0.092 for a combination of at source devices (rain gardens, infiltration trenches, sand filters and swales) for greenfields and developed areas respectively, and based on land needed to remove 75% total suspended solids. When comparing this land cost factor to those provided for ponds (Section 2.3.2) and wetlands (2.3.3), land costs of at source solutions make up a far smaller portion of the total life cycle costs than they do for end of pipe solutions.

Kumar and Kettle, 2013[11] used COSTnz, as well as data from recent Auckland developments and research undertaken in Queensland, Australia to determine costs associated with rain gardens. The TAC “low cost” formula provided in Kumar and Kettle, 2013[11] aligned well with the UPSW modelling work[9], and was adopted in subsequent updates to the UPSW cost modelling. The formula is

$$Low\ Cost\ =\ \$2000\ +\ \$300/m2\ rain\ garden\ area \qquad (1)$$

Through a sensitivity analysis and iterative process it was discovered that the routine maintenance and corrective maintenance costs used within the Kumar and Kettle, 2013[11] lead to higher maintenance costs for medium to large size rain gardens than what was modelled using COSTnz for the UPSW work. Very little actual rain garden maintenance cost data is available and therefore a unit costing approach to determining maintenance costs (as provided in COSTnz) is a good approach.

2.3.5 Swales and Filter Strips

Swales & Filter Strips: Goodland Estates, Auckland

Description

Swales and filter strips are vegetated tracts of land which have been designed to filter contaminants and increase infiltration. As stormwater flows through the vegetation (often grasses) contaminants are removed by filtration, infiltration, biological uptake and adsorption. Swales tend to have a trapezoidal or "V" shape and can accept concentrated flow, whilst filter strips can only accept sheet or distributed flow.

Mitigation Solution Objectives

In general, swales and filter strips provide for:

- Water quality treatment: sediments, metals, and TPHs
- Volume reduction (if designed for infiltration)

Implementation Considerations

A key factor in the performance of swales and filter strips is the residence time (i.e. the time that it takes the water to travel through the swale/ filter strip). The residence time is dependent on slope, area and velocity of flow (which can only be slowed down through the frictional resistance of the vegetation). As a result, these solutions are only suitable for small catchment areas of <4ha and should only be used on slopes of <5% unless check dams are used. Ensuring a dense cover of native or introduced grasses is important.

Swales and filter strips are particularly effective in treating linear impervious areas such as roads. As a result, many swales are owned and operated by public road network operators. They need to be mowed regularly (unless native grasses are used) and should be inspected annually for signs of erosion or preferential flow paths. Minor repairs may be needed to the inlets or outlets of swales.

As with rain gardens, swales and filter strips assist in disconnecting impervious areas and when vegetated with native grasses can provide green links/ refuges for birds, lizards and insects.

Cost considerations and information

Overseas studies (Conservation Research Institute, 2005[10]) generally state that swales and filter strips allow for reduced stormwater infrastructure costs, as they will often reduce the need for piped reticulation systems. Swales can replace piped systems, and can be used as conveyance channels whilst providing for a degree of water quality treatment. The Conservation Research Institute (2005[10]) reported the following figures in US dollars (construction costs):

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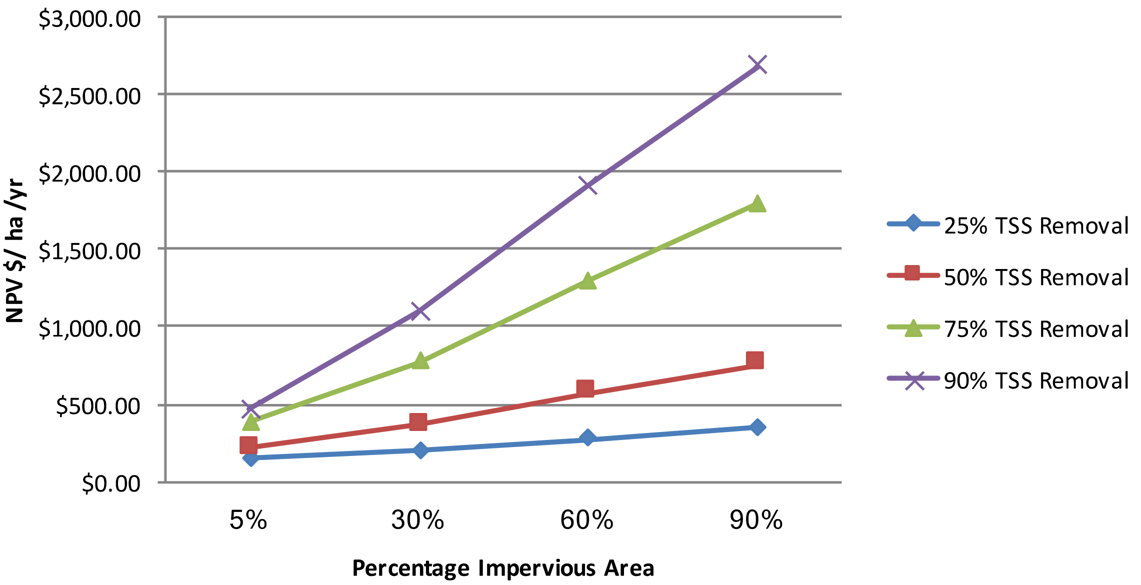
10 Conservation Research Institute. 2005. Changing Cost Perceptions: An Analysis of Conservation Development. Report prepared for the Illinois Conservation Foundation and Chicago Wilderness.

- pipe system (previously undeveloped area) – US$79/m
- pipe system (replacing another pipe) – US$106/m
- swale system (poor soils) - US$59/m
- swale system (good soils) - US$17/m

The study was originally undertaken by Backstrom *et al*. (cited in Conservation Research Institute, 2005[10]) for swale and pipe systems in Europe, and they showed that piped systems tended to be 34% to 80% more expensive than swales. However, it should also be noted that where swales require driveway crossings, the cost differential shown above would be reduced (the more crossings required, the higher the cost of the swale).

In New Zealand, COSTnz has been used to develop unit dollar per hectare costs as part of the UPSW DSS economic model[9]. Over a life cycle analysis period of 50 years and at a discount rate of 3.8%, life cycle costs for swales equated to approximately NPV/ha/yr $1,300 for an area comprising 60% imperviousness and to a treatment level of 75% total suspended solids removal (Figure 3).

Figure 3: NPV $/ha/yr LCC of Swales



Source: Ira, S J T. 2014. Addendum to Report No. 2082 by the Cawthron Institute entitled: "*The Development of a Catchment Scale Life Cycle Costing Method for Stormwater Management*".

There is scant data available relating to the cost of filter strips. It is generally accepted that filter strips have comparable costs to swales. The COSTnz swale and filter strip model can be used in New Zealand to cost filter strips, however, the model is data intensive and requires significant knowledge about the local site conditions and construction materials.

2.3.6 Infiltration Trenches and Permeable Paving


Permeable Paving: New Lynn, Auckland

Description
Infiltration trenches capture water from impervious areas and discharge it into the underlying soils and groundwater. Permeable paving also infiltrates water through the permeable gaps into either the ground or an underground storage area before being piped into a stormwater system.

Mitigation Solution Objectives
In general, infiltration trenches and permeable paving provides for:

- Water quality treatment (to a very limited degree as they are prone to clogging)
- stream channel erosion protection
- volume reduction

Implementation Considerations
Infiltration trenches and permeable paving can only be used on flatter slopes and in areas of low contaminant levels as they are prone to clogging by sediments and debris. They provide mitigation for small catchment areas (<4ha). Infiltration trenches should not be used in clay soils or areas of geotechnical instability. If paired with an underground storage piped system, permeable paving may be used in areas with clay soils.

Give the topography, geology and soils of the Porirua Whaitua, it is likely that infiltration trenches will not be a viable stormwater solution. Permeable paving, with an underground storage and drainage system, could be used for driveway, parking and low trafficked road areas.

Permeable paving can be built, owned and operated either publically or privately. Public paved assets are generally associated with surfacing of public roads or parking areas, whilst private pavers are associated with house and driveway paving.

In higher contaminant areas, infiltration trenches and permeable paving solutions are prone to clogging. Regular inspections and general maintenance (on approximately a quarterly basis) is needed to ensure they continue functioning. Replacement of pavers and disposal of sediment may be required in the longer term.

Cost considerations and information
Costs of infiltration solutions are very dependent on the type of solution being constructed. In addition, cost variability can be related to the condition of the subgrade, structural

thickness of the paving system required, need for an impermeable lining and structural elements such as lateral restraints (Kumar and Kettle, 2013[11]).
The Auckland Council Unitary Plan Costing Report (Kumar and Kettle, 2013[11]) investigated the costs of permeable paving based on the Tamahere Retirement Village. For a basecourse of 350mm and paved area of 1,000m^2 they found that the estimated TAC would be approximately \$150/m^2. In comparison, a similar area under conventional tar-seal equated to approximately \$80/m^2. Costs of paving driveways with permeable paving (as opposed to parking or low use road areas) were estimated to be around \$135/m^2.

Based on studies undertaken in the United Kingdom, Kumar and Kettle, 2013[11] and Auckland Council paving surface sweeping costs, the average annualized maintenance for parking areas varied between \$8.80 - \$11.00 per m^2 for parking areas and \$2.50 to \$3.12 per m^2.

Costs associated with the the purchase and installation of permeable paving can therefore be quite high (depending on the product) when compared with conventional driveway and parking areas. With respect to maintenance, the real concern with infiltration practices is with their long term functioning. The majority of maintenance expenditure relates to unclogging and re-establishing the surface of the infiltration practice (Ira, 2009[12]). The Stormwater Centre factsheet on infiltration (http://www.stormwatercenter.net/ : accessed on 22 August 2009) states that infiltration practices have a fairly high failure rate and, therefore, will have a shorter life span than other types of stormwater practices. They estimate that maintenance costs of infiltration practices are between 5% and 10% of the construction cost. Costing scenarios using COSTnz, here in New Zealand, found comparable results, with annual maintenance costs being around 5% - 6% of the total acquisition cost (Ira, 2009[12]). This equates well to the maintenance costs determined by Kumar and Kettle, 2013[11].

11 Kettle, David and Kumar, Priya (2013). Auckland Unitary Plan stormwater management provisions: cost and benefit assessment. Auckland Council technical report, TR2013/043

12 Ira, S J T. 2009. *Quantifying the Costs of Low Impact Design in New Zealand*. Report prepared for Aqua Terra International Ltd on behalf of Tauranga City Council.

2.3.7 Sand Filters

Sand filter (source: http://www.hyndsenv.co.nz/product/hynds-sand-filter/)

Description

Sand filters are similar to other biofiltration devices such as rain gardens, except that they use sand (or an organic-sand mix) to provide filtration. Whilst they can be built above ground, they are often built below ground in highly urbanised areas where space is limited. They are effective at removing hydrocarbons and finer sediments and have been used for many years to treat runoff from motorways.

Mitigation Solution Objectives

In general, sand filters provide for:

- Water quality treatment: sediments, metals and hydrocarbons

Implementation Considerations

Sand filters are efficient at treating small catchment areas of <6ha. They are highly engineered devices and are therefore generally not constrained by topography or soils. There does, however, need to be enough grade to allow the sand filter to function hydraulically.

As with other filtration solutions, they can be prone to clogging. They therefore need to be inspected regularly and the filtration chamber may need to be skimmed to re-establish permeability. Sediment/ debris also needs to be periodically removed from the sedimentation chamber. The traffic impacts of sand filter maintenance need to be carefully considered during the design phase.

Sand filters are often used to treat roads in highly urbanized areas, and would therefore be built, owned and operated by a public entity. However, due to their efficiency at treating hydrocarbons, as well as metals, they are also frequently used to provide treatment of industrialised areas. These sand filters would be privately built and maintained.

Cost considerations and information

Costing scenarios undertaken using COSTnz for the UPSW DSS Economic model project[9] has shown that sand filter costs can be quite high in comparison to vegetated devices such as swales and rain gardens. This cost generally relates to concreting and excavation costs incurred during construction. Sand filter costs are generally dependent on the size of the sand filter (excavation, manufacture and backfill costs vary, whilst there is usually a fixed cost for establishment, connection to services, outlets/ inlets) and site conditions.

Kumar and Kettle, 2013[11] used COSTnz to estimate $/m^2 rates for sand filters and determined that there are significant cost efficiencies of sand filters with increasing area of treatment. Total present costs were presented for sand filters which treat 1,000 and 3,000 m^2 (Table 3).

Table 3 Recommended sand filter costs (source: Kumar and Kettle, 2013[11])

SAND FILTER	Low	High
Treating 1,000m²		
Construction	$ 40,000	$ 77,000
Maintenance		
Average Annualised	$ 2,040	$ 2,912
TOTAL PRESENT COST	$ 85,300	$ 141,749
Treating 3,000m²		
Construction	$ 60,000	$ 91,000
Maintenance		
Average annualised	$ 2,520	$ 3,492
TOTAL PRESENT COST	$ 115,324	$ 167,862

2.3. 8 Rain Tanks

Description
A rain tank collects and stores rain water from an impervious area and then either facilitates the reuse of that water or discharges into the stormwater system. Rain tanks serve individual properties and are usually used to collect water from roof areas. Underground water tanks can also be used to collect and store water from car parking areas.


Rain tanks: Rising Way, Auckland

Mitigation Solution Objectives
In general, rain tanks provide for:

- peak flow reduction/ attenuation
- volume reduction (if the tank is designed for water reuse)

Implementation Considerations
Rain tanks can come in many shapes and sizes, and can be placed adjacent to or under a house, or even within the cavity walls! They only provide mitigation for small, site-scale areas. Water should only be reused if it is collected from a relatively inert roofing material such as coloursteel, zincalume, concrete, slate or ceramic tiles.

They are generally privately built, owned and maintained by a homeowner or private entity. They require annual inspections of the tank orifice outlet, pipe network, screens and other working parts, along with annual cleanout of the tank itself to remove any sediment/ debris from the tank. Over the long term, filters, screens, pumps and associated electrical parts would need to be replaced.

There are many benefits of rain tanks, the most notable of which is that it encourages the reuse of rain water, thereby reducing the volume of water which is discharged to freshwater streams. It assists in reducing the demand for potable water use and the modular nature of these systems assist in building resilience during and after disasters.

Cost considerations and information
In general, in New Zealand, a 25,000 litre rain tank can cost between $3,000 and $3,500 (2007 cost data). Additional costs are incurred if the rain tank is installed underground, or requires concrete bedding. Costs for pumps, piping, connections, electrical work and filters can add an additional $3,800 to $5,000 to the cost of installation (2007 cost data). The cost of the tank is, however, highly variable depending on the size and type of tank, access constraints and amount of site preparation required (Kumar and Kettle, 2013[11]). Kumar and Kettle, 2013[11] assumed that a minimum size of 5,000 litres would be needed for a dual-purpose system and showed that the average recommended rain water tank unit costs ranged from $7,500 - $10,500 and had an average annualised maintenance cost of between $425 and $645 per household. Over a 60 year period with a 4% discount rate this equates to a total present cost of between $16,250 - $24,150 per household.

It is difficult to quantify the cost differences to home owners of constructing and maintaining water tanks for reuse purposes. Vesely *et al*. (2005[13]) noted that due to the low value of water within New Zealand, savings gained from using water tanks for non-potable water within cities, are often very small. The study (Vesely *et al*., 2005[13]) examined retrofitting a small residential subdivision (Glencourt Place in Auckland) with rain water tanks in order to investigate the environmental benefits of, and costs associated with, water reuse. Twenty new rain tanks were installed and the water was then utilized for gardening, laundry and toilet flushing purposes. A life cycle costing analysis was undertaken to compare the cost of the tanks versus a conventional piped system. The report found that retrofitting the tanks incurred similar costs to that of upgrading the downstream pipe. Over the life cycle, the rain tanks cost between 4% and 18% more than the conventional approach, depending on the level of the discount rate that was used in the analysis. However, the inclusion of water savings benefits to each household did diminish this difference (the maximum difference between options being 6%). For both approaches the total acquisition costs (i.e. design and construction costs) dominated the analysis.

Boubli and Kassim (2003[14]) investigated the costs of installing rain tanks in two separate subdivisions in Sydney, Australia, and compared them with the costs of a conventional subdivision. They found that, for the Pioneer Street subdivision, the rain tanks were cost neutral when compared with the conventional design. However, at Heritage Mews, the rain tanks option offered significant savings (approximately 25%). The authors found that the larger the site and the larger the capacity of the rain tanks, the greater the opportunity for savings. The study only examined the construction costs of rain tanks.

Coombes *et al*. (undated[15]) also investigated the cost of rain water tanks in the Lower Hunter region of Australia. They found that the installation of rain tanks was a more economically viable solution than conventional piped infrastructure which was connected to mains water supply. They quantified that, at a household level, the tanks were 0.9% more economically efficient that traditional water supply.

From these studies it can be inferred that water is more highly valued as a commodity in Australia, than in New Zealand.

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13 Vesely, E.-T., J. Heijs, C. Stumbles, and D. Kettle. 2005. The Economics of Low Impact Stormwater Management in Practice – Glencourt Place. NZWWA Conference. Auckland, New Zealand.

14 Boubli, D. and Kassim, F. 2003. Comparison of Construction Costs for Water Sensitive Urban Design and Conventional Stormwater Design.

15 Coombes, P.J., Kuczera, G., Argue, J.R., and Kalma, J.D. Undated. Costing of Water Cycle Infrastructure savings arising from Water Sensitive Urban Design Source Control.

2.3.9 Green Walls and Roofs

Description
A green or living roof is a roof of a building which is completely or partly covered by vegetation. It includes special lightweight soils to support plant growth, a drainage layer, and a waterproofing layer to protect the building from leaks. Many countries are also now promoting the use of green walls as well as green roofs.

Source: Wellington WSUD Guideline Manual

Mitigation Solution Objectives
In general, green roofs and walls provide for:
- Water quality treatment via filtration and microbial activity (airborne contaminants)
- Volume reduction via storage in the drainage layer, take up by plants and evapotranspiration

Implementation Considerations
Green roofs and walls are not limited by topography or soils since they are constructed in place of conventional roofs. The key considerations relating to green roofs include the structural loading and water proofing requirements. Careful choice of plants is important to ensure that they survive in the chosen depth of filter media and the low level of organic content. Green roofs cannot be used in areas where rain tanks are needed for potable water supply.

Green roofs and walls are privately owned and maintained by the building owner. Access is also needed for maintenance. They require regular maintenance, especially in the first few years to ensure the plants grow well and survive. Irrigation may be required during dry periods, and they need to be routinely inspected to check on the plants, integrity of the water proofing and drainage media, and to ensure there are no blockages to drainage.

Green walls and roofs have a significant number of stormwater and other environmental benefits. They help to reduce pollution entering our waters, reduce local flooding potential, they act as an insulator for a building therefore reducing energy usage, reduce the "urban heat island" effect and beautify our cities and attract native birds and insects to our urban landscapes.

Cost considerations and information
Living roofs are relatively new stormwater solutions, especially in New Zealand, and therefore there is relatively limited cost data. According to the "Low Impact Development (LID) Center" (Low Impact Development Urban Design Tools Website: http://www.lid-stormwater.net/greenroofs_cost.htm ; accessed on 24/01/2017) the highest cost associated with green roof creation is the soil substrate/ media and plants associated with it. In addition, increased costs may result from additional structural support (Kumar and Kettle, 2013[11]).

The LID Centre (http://www.lid-stormwater.net/greenroofs_cost.htm ; accessed on 24/01/2017) stated that installation costs for green roofs in the USA are on average between US$15 to US$20 per square foot. This equates to NZ$220 - $300 /m^2. They report that costs of green roofs in European countries such as Germany are far cheaper due to a modulated approach to installation (on average US$8 to US$15 per square foot). A proposal by Climate CoLab (http://climatecolab.org/plans/-/plans/contests/2012/building-efficiency/c/proposal/1304142; accessed on 24/01/2017) showed higher costs of approximately US$35 per square foot (approximately NZ$520/ m^2) and highlighted that the cost of a green roof is about double that of a conventional roof. This increased cost could be offset, however, if a life cycle cost analysis is undertaken as the study states that green roofs have longer life spans than traditional roofs (75 years instead of 30 years for a conventional roof).

Due to green roofs being relatively new there is little information on actual maintenance cost data. As discussed above, green roofs require regular maintenance, especially in the first few years to ensure the plants grow well and survive. Irrigation may be required during dry periods, and they need to be routinely inspected to check on the plants, integrity of the water proofing and drainage media, and to ensure there are no blockages to drainage. Climate CoLab state that annual maintenance for green roofs is in the order of US$2 per square foot (this equates to approximately NZ$30/ m^2).

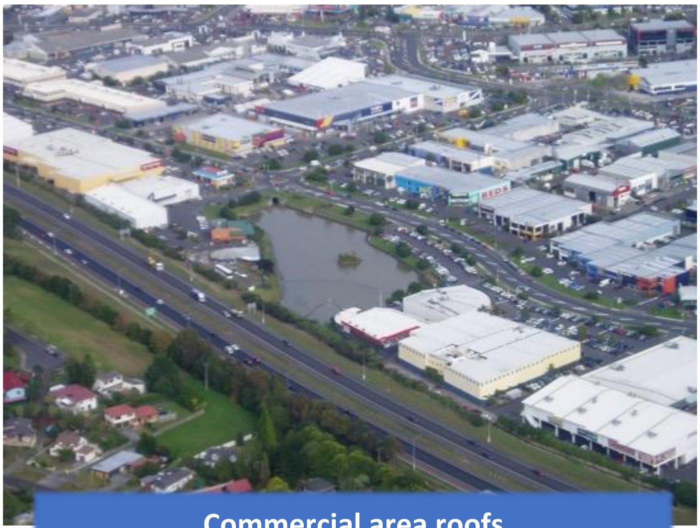
Kumar and Kettle, 2013[11] report that, based on a 200m^2 roof, green roof construction costs range between $335 - $595/m^2. Average annualised maintenance costs range from $12.35 - $16.25/m^2. Total present costs per house lie between $540 - $855/m^2. These costs are higher than those reported above in the USA and Germany, but are likely to be representative of the relatively new implementation of green roofs in New Zealand.

The New Zealand company "Greenroofs Ltd" (http://www.greenroofs.co.nz/faq.html, accessed on 11 January 2017) give the following installation costs for a 200m^2 roof:

- a sedum plug roof = $150/m^2;
- native plug roofs = $230/m^2; and
- sedum mats = from $200/m^2.

They note that these prices do not include craneage, delivery, edge details, GST or travel costs.

2.3.10 Source Control (Roofs)



Commercial area roofs

Description

Impervious surfaces themselves can leach contaminants. For example, galvanized metal roofs and copper roofs are significant sources of zinc and copper respectively in urban environments. By using inert roofing materials, these contaminants will not enter the stormwater system (avoidance rather than treatment). Inert roofing materials include clay or concrete tile roofs, colour-bonded roofs, low-lead painted roofs and the like.

Mitigation Solution Objectives

Source control of roofs for:

- Avoidance of roofs as a source of contamination by metals such as zinc, copper and lead.

Implementation Considerations

There are no limitations to installing alternative inert roofing materials to those that leach contaminants such as zinc, copper and lead. The roof would be privately owned and maintained by the building owner, and maintenance would be as per the manufacturer's recommendations.

The key benefit of using an inert roofing material is that it eliminates the need to treat roof water with a stormwater management device. In industrial and commercial areas, especially, this can lead to significant construction and ongoing maintenance cost savings.

Cost considerations and information

There are many different types of roofing materials and costs of roof types materials are still being investigated. Maintenance of roofs should be as per the manufacturer's recommendations.

2.3.11 Riparian Buffer Strips


Riparian Buffer Strips: Goodland Estates, Auckland

Description
A riparian buffer strip is a well vegetated strip of land (usually bush/ forest vegetation) adjacent to a stream which assists in protecting the stream from stormwater impacts. In low density residential areas which abut streams, planted native riparian buffer strips assist in providing treatment for diffuse discharges and helps to reduce the total volume and peak rate of stormwater runoff via evapotranspiration and plant uptake.

Mitigation Solution Objectives
In general, riparian buffer strips provide for:

- Water quality treatment of diffuse runoff only (they provide no water quality treatment for piped discharges)
- peak flow reduction
- flood control
- stream channel erosion protection
- volume reduction

Implementation Considerations
The biggest limitation in terms of riparian buffer strips is land and space availability. In the urban context, it is generally only used as a mitigation solution in low density residential developments. It is not limited by topography or soils so long as the vegetation planted can cope with the local climatic conditions. It is estimated that approximately 3500m^2 of bush revegetation would mitigate 600m^2 of impervious area.

Riparian buffer strips can either be privately or publically planted and maintained. Some developers will vest these strips with councils as part of the reserve/ green space requirements. Native bush planting has moderately high maintenance needs during the first 3 or so years of growth. These relate to weed and predator control, and possible watering of small plants. However, once the bush has established, maintenance requirements are reduced. Riparian strips of less than 20m wide can have problems relating to weed infestation.

In addition to their stormwater benefits, native bush riparian buffer strips can provide shading of waterways and habitat for diverse wildlife populations and plant communities.

Cost considerations and information
As part of the UPSW DSS Economic costing project[9], costs of riparian planting were determined. A brief literature review was undertaken as part of that project in order to supplement cost data which was available within the COSTnz models. The literature review was a web-based review and those sources which provided cost data included:

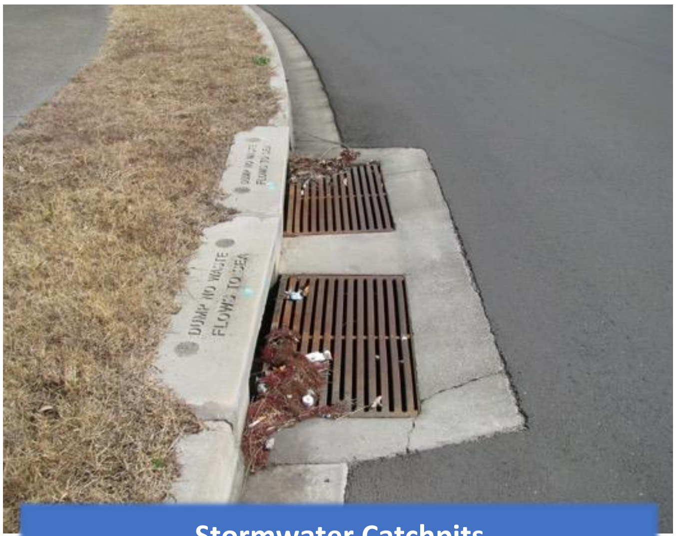
- Waihora Ellesmere Trust
- Waikato Regional Council
- COSTnz
- Full Bloom Nursery Ltd
- Rodney District Council

Two levels of riparian planting efforts were costed: a low quality costing option and a high quality costing option which allowed for a greater density of plants, increased resources (such as fertilisers) and a more intensive level of initial maintenance. Costs are shown in Table 4 below.

Table 4 Low and high effort riparian planting costs (source: UPSW DSS Economic costing project[9])

	Low Effort (per m2)	**High Effort (per m2)**
TAC	$118	$136
Initial MC	$9	$15
Long Term MC	$0.5	$0.5
Undiscounted Total LCC	$127	$151

2.3.12 Catchpits, pipes and manholes



Stormwater Catchpits

Description
Catchpits, pipes and manholes provide for the safe collection and underground conveyance of stormwater away from urban areas.

Mitigation Solution Objectives
The main objective of these systems are to collect stormwater and convey it to the receiving environment with the minimum of nuisance and damage to the public and the urban environment.

Implementation Considerations
The majority of catchpits, pipes and manholes are generally publically owned and operated, however, landowners are generally responsible for maintaining pipes which are on their property before they connect to the public stormwater system.

Depending on sediment loads entering the public stormwater network, pipes and catchpits may require regular cleaning and flushing. In addition, network operators generally will conduct CCTV inspections to determine if network upgrades of maintenance is needed.

Cost considerations and information
Construction and installation costs of stormwater pipes have been estimated from actual construction projects and can range from approximately $470 - $1,590 per linear metre for 300 – 600mm diameter pipes. Maintenance costs were sourced from contractors undertaking this type of maintenance work. Initial CCTV inspections can cost from $240 - $370 per hour, and thereafter CCTV is undertaken on an “as-required” basis. If traffic management is needed during maintenance, this can range from $140 - $450 per hour (or service depending on the contractor). Flushing debris and clearing pipes generally incurs an establishment fee of approximately $80 and then $180 per hour as needed. This is similar to costs incurred if pipes are vacuumed. Confined space entry is sometime required at a cost of $170 per hour. The level of maintenance, clean and repair needed is dependent on the condition and contaminant levels in the pipes, and is generally based on CCTV footage.

Some key issues to consider when understanding the cost elements of stormwater pipes include:

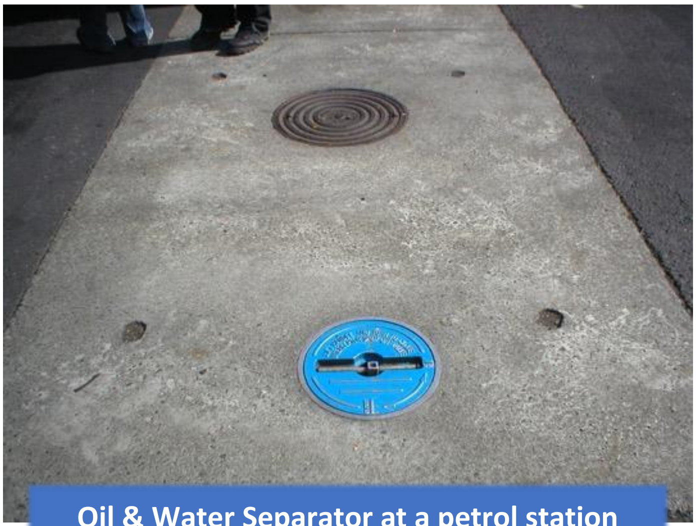
- Initial CCTV inspections are required, and from there maintenance schedules are created which must be adhered to.
- The depth at which the pipe must be buried, and the diameter of the pipe are the two limitations most likely to impact the upfront cost.
- Selecting the right diameter is essential as undersized pipes have reduced capacities, while oversized pipes are economically inefficient.

2.3.12 Proprietary Devices

Description

There are a significant number of different proprietary devices on the market in New Zealand, such as gross pollutant traps, downstream defenders, catchpit inserts, super catchpits, stormfilters, up-flo filters, oil and water separators, etc.

These devices all have different purposes and mitigation objectives. Whilst they are an important part of stormwater management, especially in ultra-urban areas where space is limited, there are too many to discuss here and are outside the scope of this study.



Oil & Water Separator at a petrol station

2.4 Summary

Section 2 has provided a summary of the range of water supply, wastewater and stormwater infrastructure solutions which are available for use within urban areas of the Porirua Whaitua. This information has been formatted and summarized into an excel spreadsheet in order to assist the Porirua Whaitua Committee develop future development and mitigation scenarios for modelling. This "solutions matrix" is included in Appendix A.

Sections 2.1 – 2.3 demonstrate that whilst the management solutions for each type of water infrastructure are relatively well understood, the cost information for many of them still needs further investigation. Costs shown in the literature and collected in New Zealand vary widely and this is likely due to:

- the high level of variability in terms of catchment size, impervious area to be treated, soil and topographical conditions and the jurisdiction; and
- the lack of maintenance cost data that is available in a usable and comparable format – in general actual cost data relating to long term operation and maintenance of the three waters is scant.

An additional point to note about the cost information presented is that much of the TAC information actually only relates to construction and installation costs. The US EPA recommend (unnamed and undated report: https://www3.epa.gov/npdes/pubs/usw_d.pdf , accessed on 11 January 2017) adding an additional 30% onto this cost in order to calculate the TAC. This issue will be further investigated during the data collection phase of this project.

3. WSUD – Cost Comparisons and Considerations

3.1 Cost Comparisons

As discussed in Section 1, councils across New Zealand face a number of significant stormwater problems arising from the growth, development and redevelopment of urban centres. Water sensitive design (WSD) has been offered up as a solution to addressing the effects of stormwater discharges. Additional benefits to the WSD approach is that it can assist with reducing demands on potable water supply and reduce effects of wet weather wastewater overflows by disconnecting impervious areas and reducing the effect of infiltration and inflow on the wastewater network. There has been much research undertaken to document the environmental protection and social benefits of WSD. However, a key impediment to its implementation is the perception that WSD costs more than conventional stormwater management approaches in both implementation and operation.

An international literature review of comparative case studies was undertaken (Ira, 2014[16]) for the Cawthron Institute and NIWA in an attempt to quantify the cost differential between WSD and conventional developments. Approximately 41 reports/ papers were sourced and reviewed.

The majority of available cost information from actual case studies related to design and construction costs (i.e. TAC), and actual long term maintenance costing of WSD devices was generally not available.

Table 5 provides a general overview of the cost differential from 4 countries comprising 53 case studies. According to research undertaken by the USEPA, and based on 3 case studies, total life cycle costs of WSD are on average 24% cheaper than conventional developments (Jaffe, et al, 2010[17]). However, when examining the case studies more closely, it is clear that there is a difference between the northern hemisphere studies and those undertaken in Australia and New Zealand. The Australasian case studies tend to indicate increased costs associated with WSD, namely:

- TAC of WSD incur 16.9% increased costs,
- MC of WSD incur 26.8% increased costs (another study found them to be 7 – 15x greater than traditional costs), and
- LCC incur 33.2% increased costs.

This difference could be due to a number of different reasons, one of which is economies of scale. On-site stormwater management is relatively new in New Zealand, and it is anticipated that as the use of WSD becomes more common, the market will mature, and innovation and competition may reduce pricing. However, it is difficult to quantify exactly how directly comparable the different case studies are with New Zealand's approach to

16 Ira, S J T. (2014). *Quantifying the cost differential between conventional and water sensitive design developments – a literature review*. Report prepared for NIWA and the Cawthron Institute.

17 Jaffe, M., Zellner, M., Minor, E., Ahmed, H., Elberts, M., Sprague, H., Wise, S. and Miller, B. 2010. *Using Green Infrastructure to Manage Urban Stormwater Quality: A Review of Selected Practices and State Programmes*. Report to the Illinois EPA

WSD. In many of the UK and USA studies, the purpose for implementing WSD relates to the reduction of combined sewer overflows. Comparison of WSD with the costs of wastewater infrastructure (as opposed to stormwater infrastructure) would yield a very different cost differential. It is also noted that in many studies, landscaping and on-going landscaping maintenance costs were assumed to be the same for both conventional and WSD subdivision (i.e. costs relating to landscaping a flowerbed are the same as for landscaping a rain garden). Finally, many of the case studies in the UK and USA assumed that no piped network was necessary if permeable paving or infiltration practices are used. With some of New Zealand's clay soils and steep slopes, as is the case in Porirua, this may not always be a viable scenario. It is noted that in New Zealand's most detailed WSD case study (Long Bay), a 12% increase in TAC, on a per lot basis, was predicted for the WSD scenario (Auckland Council WSD Case Studies - Long Bay Structure Plan, Auckland. Accessed at http://www.acwsd.org/ on 8 October 2013).

Table 5 Summary of cost differentials from international and national literature (source: Ira, 2014[16])

Case Study Locality	WSUD Type	Objectives for WSD	Percentage Difference (Ave)	Cost Type
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-55.5%	LCC
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-27.7%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	-13.5%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	7 - 15x greater	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-9.6%	TAC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-26.8%	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-11.0%	LCC
United Kingdom	Open storage	Reduce WW overflows	15.0%	TAC
United Kingdom	Open storage	Reduce WW overflows	-23.0%	MC
USA	Rain gardens, swales, porous paving, wetlands	Treatment, attenuation, reducing WW overflows	23.0%	TAC
USA	Rain gardens, bush trees, swales, green roof, wetlands	Treatment, attenuation, reducing WW overflows	24.0%	LCC
INTERNATIONAL AVERAGE*			**-2.6%**	**TAC**
INTERNATIONAL AVERAGE*			**-24.9%**	**MC**
INTERNATIONAL AVERAGE*			**-15.7%**	**LCC**

*Average derived from 53 case studies across 4 countries

The literature review highlighted the difficulty in quantifying a cost differential between WSD and traditional developments due to the high number of variables which change for each individual situation. These variables related mainly to the catchment size, impervious area to be treated, device type and the jurisdiction in which the works are located.

As mentioned previously, many of the studies provided within the USA and UK show large cost savings associated with WSD. In addition to this, some New Zealand theoretical case studies (ARC, 2000[18]), show a clear saving of TACs for WSD over traditional developments.

18 Auckland Regional Council. (2000). *Low Impact Design Guidelines Manual.* Technical Publication 124

On closer inspection of the literature this saving is related to the "***avoided costs***" of site earthworking, preparation, concreting and reduced piping rather than the costs of the stormwater management devices themselves. As discussed in Section 1.2.4, these savings or avoided costs more specifically include:

- Reduced impervious surfaces can lead to reduced paving costs.
- Reduced pipe lengths can lead to reduce infrastructure costs.
- Reducing the amount of earthworks as well as clearing and grading leads to reduced costs associated with the construction activities.
- Potential "avoided" costs associated with remediation of streams and flood event "clean-up" programmes as a result of reduced stormwater effects.

The literature review highlighted that there is little actual data available regarding maintenance costs. Much of the work undertaken in New Zealand with respect to maintenance costs is based on the COSTnz model (including the Auckland Council Unitary Plan Costing Report - Kettle and Kumar, 2013[19] and modelling undertaken for the UPSW DSS economic cost model – Ira, 2011[20]). This work has demonstrated that WSD maintenance costs are higher than traditional "end of pipe" solution costs. On average, WSD "at source" infrastructure costs tend to be approximately 59% – 70% more expensive that end of pipe infrastructure costs (NPV LCC over 50 years). This difference is, on average, generally consistent with the Australasian literature which suggests an increased cost range of, on average 55% in Australia.

3.2 Costing of WSD for the Porirua Whaitua study

WSD is an approach to site design and development, as well as mitigation for the 3 waters. However, as Section 3.1 highlights, determining the actual costs of WSD is problematic and a cost differential variable will not be able to be used for this study. For the three waters cost scenario reference library it is recommended that costs of WSD be broken down into two separate facets which can be costed separately depending on the nature of the scenario, namely:

1. Costing of structural and at-source solutions, as identified in Section 2.1 – 2.3
2. Costing of site design/ construction components as identified in Section 1.2.4.

It is further recommended that other modellers in the study consider quantifying the benefits and potential cost savings to the water supply and wastewater network which result from a WSD approach (it is noted that this is outside the scope of this study).

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19 Kettle, David and Kumar, Priya (2013). *Auckland Unitary Plan stormwater management provisions: cost and benefit assessment*. Auckland Council technical report, TR2013/043

20 Ira, S. (2011). The development of catchment scale life cycle costing methods for stormwater management. Prepared for NIWA. Cawthron Report No. 2082

4. Conclusions and Next Steps

4.1 Final Thoughts

The purpose of this report has been to document a summary of the available solutions for the provision of three waters infrastructure within the urban environment. Section 1 provides a background and context to the study, as well as an explanation of the proposed costing methodology that will be used in the Porirua Whaitua Collaborative Modelling Process. Section 2 provides a selection of the most common water supply, wastewater and stormwater solutions available for use within the Porirua Whaitua. In addition, available cost information relating to each of the solutions is presented and discussed. This section is supported by a "solutions matrix" which is included in Appendix A. Section 3 focusses specifically on costing of WSD and presents a proposed approach for developing cost information for WSD for the scenario reference library.

Overall, a wide range of solutions and mitigation options are available for use in the Porirua Whaitua. Each option has a series of limitations as well as benefits which need to be considered carefully prior to recommending their use as part of any future modelling scenario. Importantly, many of the solutions can be used in combination with each other, and the Whaitua Committee will need to consider how well each of those solutions interact together. For example, for stormwater infrastructure, a "treatment train approach" is often recommended to fully meet the stormwater objectives for a particular catchment. The treatment train approach is a concept where a number of different solutions operate in series and in an integrated manner, and it can apply to the stormwater network as well as the water supply and wastewater networks. The NZTA Stormwater Treatment Standard[21] provides some recommendations on the application of this approach:

- do not use solutions which have the same function within in a treatment train – each solution should have a different function;
- when considering contaminant removal – decide on solutions which will remove key contaminants of concern rather than just thinking about contaminant removal in general;
- whilst any two elements of the system should be considered separately, how they interact with each other to provide a benefit needs to be considered; and
- the additional expected cost of an additional solution should be compared to the expected benefits of the added element solution.

As an example, and as can be seen from Figure 4, ideally the approach could include source control as well as treatment (and if necessary attenuation) as part of the overall stormwater management system.

The interactions between and limitations of different solutions, objectives of each solution and the practicality of solutions operating in series with each other will need careful consideration by the Whaitua Committee in order to ensure sensibility and practicality of future water management modelling scenarios.

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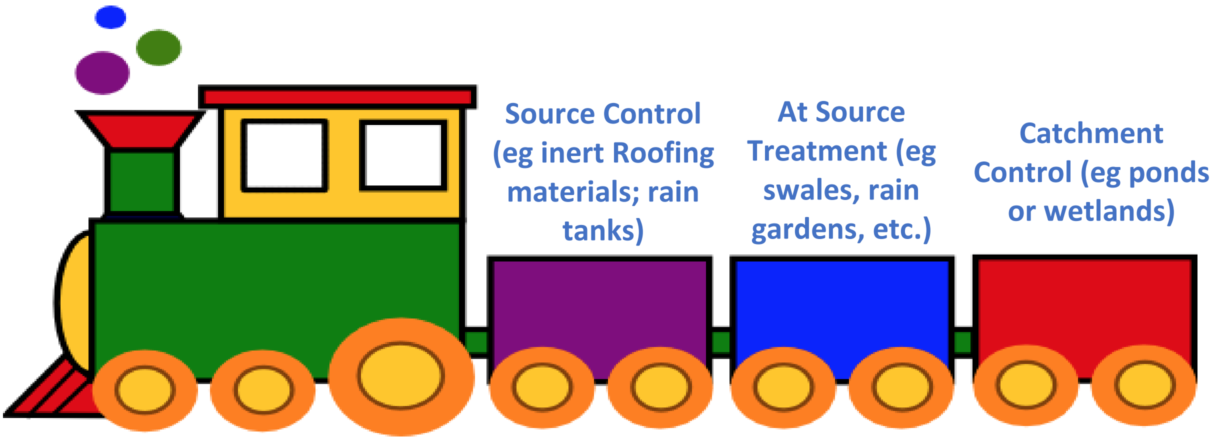
21 NZTA. 2010. *Stormwater Treatment Standard for State Highway Infrastructure*.

Figure 4 Schematic of a treatment train approach for stormwater management



4.2 Next Steps

This "Solutions Summary" document is Deliverable 1 of the urban interventions work brief. The next steps in this project include:

- workshopping and discussing the information contained within this report with Wellington Water in order to ensure that Section 1 accurately reflects the current "Business as Usual" infrastructure network in the Porirua Whaitua;
- collection of cost data from Wellington Water;
- modelling and reporting on life cycle costs for the identified solutions;
- updating of this report following the completion of the life cycle costing analysis for urban solutions so that the recommended cost data can be included within the excel solutions matrix; and
- researching and completing the alternative funding pathways for stormwater report.

APPENDIX A

SOLUTIONS SUMMARY MATRIX