The Wastewater Specialists
Optimising your assets

Department of Internal Affairs

Three Waters Review

Cost Estimates for upgrading Wastewater Treatment Plants to meet Objectives of the NPS Freshwater

Final Report

September 2018

Executive summary

Boffa Miskell Ltd (Boffa Miskell) and GHD Ltd (GHD) were commissioned by the Department of Internal Affairs to scope the national level compliance cost for local authority wastewater treatment plants (WWTPs) to meet National Policy Statement (NPS) water quality criteria for Freshwater Management (NPS Freshwater). The Wastewater Specialists (TWWS) provided technical support and localised knowledge of WWTP operation around New Zealand.

The project is one part of the Three Waters Review, which the Department of Internal Affairs is undertaking to gain a better understanding of the challenges facing three water services. The project specifically considers discharges from WWTPs to freshwater receiving environments, and reviews the benefits and associated costs of upgrading these to achieve improved receiving water quality.

There are 321 publicly owned WWTPs operating in New Zealand identified in the study and of these 152 (47 percent) discharge to freshwater, serving a total estimated population of 644,900 (13 percent of New Zealand's total population).

At the time of writing this document, Regional Councils across the country are in varying stages of implementing the NPS Freshwater. To provide a consistent approach and an aspirational target, the study assumes that NPS Freshwater B Attribute states for Escherichia coli (*E. coli*), total nitrates and ammonia are the target to be met in receiving waters. This is consistent with the NPS Freshwater requirements that regional councils improve water quality over time in relation to human health, and must maintain or improve water quality over time in relation to ecosystem health. It is also consistent with community expectations for high water quality requirements to be applied to discharges of sewage effluent.

The majority of centralised WWTPs in New Zealand were constructed over the past 60 years and approximately 60% of WWTPs discharging to freshwater use waste stabilisation pond technology. In general, the effluent quality from a waste stabilisation pond based WWTP is relatively poor in comparison to more modern treatment technologies, in particular with regard to ammonia.

To achieve the requirements of the NPS Freshwater in the key attributes, a number of possible treatment processes were assessed. This assessment looked at the ability of each type of process upgrade to understand if it could achieve the outcomes required to meet the Attribute B state at the point of discharge. The study assessment of all relevant WWTPs showed that only upgrades to a Biological Nutrient Removal (BNR) – Activated Sludge Plant with Ultra Violet (UV) disinfection would reliably give the outcomes required in all parameters. This outcome was carried forward into an overall cost assessment and used to develop numbers for a national cost envelope.

The assessment process has a focus on receiving water quality impacts and ignores a range of other typical and site specific WWTP upgrade considerations (e.g. asset condition and population growth potential).

Table ES-1 following summarises the costs associated with upgrading all WWTP discharges to meet the Attribute B state in the WWTP discharge; the total capital cost for New Zealand is estimated at $1.4 to $2.1 Billion.

Of the WWTPs discharging to freshwater that require upgrading, 82% are servicing minor (<5001 people) or small populations (<501 people). The annual cost impact of the WWTP upgrades is greatest for the small communities (<501 people) at approximately $3,576 for each affected household. The average annual cost impact is $1,138 per affected household. The higher cost for the small communities represents the impact that sharing the cost of upgrades has on a smaller number of affected households. The annual cost impact is based on an interest rate of 6% per annum and repayment term of 25 years, plus the increase in annual operation expense associated with the upgrades[1]. The annual cost impact per household affected assumes that the costs associated with a WWTP upgrade will be met by the households contributing to that plant.

Table ES-1 Estimate of capital cost to upgrade WWTPs discharging to freshwater to meet NPS Freshwater Attribute B state in the discharge

Region	No. WWTPs affected	Pop affected	Estimate of probable capital cost ($ Million)	Estimate of probable operating cost ($ Million per annum)
Auckland	4	10,030	$32 - $48	$0.59 - $0.89
Bay of Plenty	6	20,320	$55 - $83	$1.2 - $1.8
Canterbury	12	5,270	$31 - $46	$0.28 - $0.41
Gisborne	1	640	$3.5 - $5.2	$0.034 - $0.05
Hawke's Bay	5	7,960	$34 - $52	$0.63 - $0.94
Manawatu-Wanganui	24	132,940	$330 - $500	$13 - $20
Marlborough	1	690	$2.7 - $4.1	$0.021 - $0.032
Nelson	0	0	-	-
Northland	11	26,560	$100 - $150	$2.1 - $3.2
Otago	20	23,590	$120 - $180	$2.1 - $3.1
Southland	14	20,150	$84 - $130	$1.6 - $2.4
Taranaki	5	9,620	$74 - $110	$2.6 - $3.8
Tasman	3	2,580	$16 - $24	$0.22 - $0.32
Waikato	23	117,340	$240 - $360	$6.5 - $9.7
Wellington	6	39,630	$130 - $200	$4.8 - $7.2
West Coast	10	18,060	$120 - $180	$3.1 - $4.7
Total	**145**	**435,370**	**$1,400 - $2,100**	**$39 - $59**

Receiving water quality is influenced by both diffuse and point source contaminant contributions from other activities and land uses within the catchments where there are WWTP discharges.

The study also reviewed the likely contribution of WWTP discharges to receiving water quality, based on other potential sources of nutrients within each catchment, and the relative flow contribution of each WWTP to its receiving environment (determined by considering mean discharge rates and mean river flow rates). This assessment was used to allocate a likely small/moderate/large contribution rating to

[1] Amortisation rates and terms are taken for consistency with BECA 2018, *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards*.

each WWTP as a means of assessing the relative worth of investing in a WWTP upgrade. Table ES-2 shows the national capital investment estimate when a contribution based approach is applied:

Table ES-2 Contribution based estimate of capital cost to upgrade WWTPs discharging to freshwater to meet NPS Freshwater Attribute B state

Region	Estimate of probable capital cost ($ Million)			
	Small	Moderate	Large	Total
Auckland	$14 - $20	$18 - $28	-	$32 - $48
Bay of Plenty	$4.1 - $6.1	$29 - $44	$22 - $33	$55 - $83
Canterbury	$22 - $33	$8.7 - $13	-	$31 - $46
Gisborne	$3.5 - $5.2	-	-	$3.5 - $5.2
Hawke's Bay	$30 - $44	$4.9 - $7.4	-	$34 - $52
Manawatu-Wanganui	$240 - $360	$73 - $110	$18 - $27	$330 - $500
Marlborough	$2.7 - $4.1	-	-	$2.7 - $4.1
Nelson	-	-	-	-
Northland	$41 - $62	$45 - $67	$17 - $25	$100 - $150
Otago	$59 - $89	$52 - $78	$7.4 - $11	$120 - $180
Southland	$52 - $77	$18 - $28	$13 - $20	$84 - $130
Taranaki	$2.2 - $3.2	$72 - $110	-	$74 - $110
Tasman	-	$16 - $24	-	$16 - $24
Waikato	$110 - $160	$92 - $140	$41 - $62	$240 - $360
Wellington	$4.7 - $7.1	$110 - $160	$20 - $30	$130 - $200
West Coast	-	$94 - $140	$24 - $36	$120 - $180
Total	**$580 - $880**	**$630 - $950**	**$160 - $240**	**$1,400 - $2,100**

The assessment shows that the smallest investment (total capital cost in the range of $160 Million to $240 Million) is necessary to upgrade WWTPs that have a "large" contribution to the water quality of their receiving environment. However a much larger investment (total capital cost in the range of $630 Million to $950 Million) is necessary to upgrade WWTPs that are having a "moderate" contribution to their receiving environment.

Case studies

Three case studies are included within the report (Cambridge, Ngatea, and Wellsford) to assist with providing context. These case studies were used to increase the accuracy of national level cost estimates by benchmarking assumption based costings against the upgrade cost for specific WWTPs.

The case studies also provided useful additional information about other challenges facing councils – for example, resource consenting issues and timeframes, and the potential benefits to receiving environments from proposed upgrades.

Resource consenting issues

The study reviewed the level of compliance WWTPs are achieving with current consent conditions. Collated compliance information on WWTPs is reported in the [2]Water New Zealand National Performance Review. This shows that the number of reported abatement notices, infringement notices, enforcement orders or successful prosecutions related to WWTP consents is consistently low. The 2016/17 report notes that this may be related to the approach used to enforce consents, rather than non compliance per se. Other evidence suggests consent non compliance issues are more wide spread and there are other issues, for example, 20 WWTPs included in the report were operating on expired consents.

A detailed review of consent compliance in the Waikato region undertaken in conjunction with the Waikato Regional Council showed variable compliance across a number of plants. It was identified that up to 50% of all WWTP's in the Waikato Region that discharge into a freshwater environment fail to meet consent conditions, and that the cost upgrades needed to meet consent compliance were within a range of $63 Million - $94 Million. While this review outcome cannot necessarily be applied nationally, it can be inferred that localised compliance challenges apply to WWTPs across all of New Zealand.

The Cambridge and Wellsford case studies provided information about the challenges being faced by councils and their communities where WWTPs are operating under expired consents. In the case of Wellsford, the WWTP operated on an expired consent from 1999 until November 2017, and the Cambridge WWTP has been in this situation since 2016. This reflects the difficulty that councils and communities face in reaching agreement on a WWTP upgrade that meets the community aspirations and is also affordable. The discharge from the WWTP must also meet requirements set in regional plans since the original consents were granted. For all three case studies, the upgrade costs that are currently planned to meet resource consent conditions are significant for the communities involved.

Wet weather overflows

The study included a high level review of the contribution of wastewater network overflows to receiving water quality and examples of different approaches to wastewater network overflow management are appended. Cost estimates for reducing or removing wastewater network overflows were not included in the study due to the variable performance targets that apply across the regions, and differing levels of data available from network owners on overflow frequency and planned improvement works. The level of variability in all of these factors made it difficult to develop a national cost estimate with a consistent basis.

The impact of wet weather wastewater overflows on receiving water quality is in most cases very short term due to the periodic nature of overflows, and in wet weather conditions wastewater overflows may be only a small contributor to the contaminant load when compared to other diffuse sources. Removal or reduction in wastewater network overflows will often not contribute significantly to achieving NPS Freshwater quality targets in a water body with investment better targeted at reducing contaminants in stormwater runoff.

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[2] https://www.waternz.org.nz/NationalPerformanceReview

Meeting NPS Freshwater objectives related to public health and iwi concerns are more pressing drivers for improved wet weather overflow management; specifically the NPS Freshwater objective, A1; to safe-guard the health of people and communities, as affected by contact with freshwater; and objective D1; to ensure that tangata whenua values and interests are identified and reflected in the management of freshwater. Iwi generally view raw sewage entering freshwater bodies as disrupting Te Mana o te Wai, making wastewater overflow issues especially significant in this context.

Given the frequency of overflows identified in the case studies and the level of investment identified at the case study sites ($10 Million in Christchurch, $48 Million in Dunedin, $77 Million in Porirua) a more specific analysis of wet weather overflows is required, if upgrades to wastewater systems required by the NPS Freshwater are to be fully costed.

Key assumptions

Key assumptions that apply to this study include:

- WWTP improvements were assessed based on meeting the NPS Freshwater Attribute B values for *E. coli*, nitrates and ammonia at the point of discharge. This is consistent with the NPS Freshwater requirements that regional councils are expected to improve water quality over time in relation to human health, and must at least maintain water quality over time in relation to ecosystem health. It is also consistent with community expectations for high water quality requirements to be applied to discharges of sewage effluent.
- BNR-Activated sludge processes, with UV treatment will be necessary to achieve the NPS-Freshwater objectives in all instances. It is recognised that there may be individual cases where pond upgrades and use of emerging technologies (such as that being tested for the Wellsford case study) will achieve the required outcomes. However for the purposes of developing a national level cost this assumption is appropriate.
- There are a range of other freshwater values (such as fisheries and electricity generation) covered by the NPS Freshwater that are not considered as part of this study. In addition, attributes which relate to ecosystem health such as sediment and dissolved oxygen that are likely to be influenced by wastewater discharges are not included in this study.
- The level of treatment provided by some WWTPs may be required to be improved so that freshwater objectives set in regional plans can be achieved within timeframes specified in the plan. The Freshwater NPS requires councils to set these freshwater objectives by 2025 (or 2030 in some limited cases). In some cases, the regional plan could require resource consents to be reviewed to allow minimum standards set in the plan to be achieved.
- While there is no attribute listed for phosphorus in the NPS Freshwater, it does contain a requirement on councils to manage phosphorus as part of periphyton management in freshwater bodies. The consequent phosphorous limits in regional plans will have a bearing on wastewater treatment.
- Analysis of the contribution of WWTP discharges to receiving water quality was made based on broad assumptions that certain types of land uses are nutrient generating. It is acknowledged that localised land management practices can either reduce or increase nutrient loads; however, this study's scope did not cover detailed review of all receiving water catchment practices.
- The study has assessed the status of WWTPs as they are in 2018 and cost estimates do not account for future growth as this was outside the study scope. It is acknowledged that when considering upgrades to their wastewater networks, that the asset owners will

in most cases provide for future growth to optimise the investment, and upgrades to account for this will increase cost.

- The cost estimates presented in this report were developed solely for the purpose of evaluating potential order of magnitude capital costs for widespread treatment augmentation. They are sufficiently accurate to serve this purpose. They cannot be used for budget setting purposes as site specific considerations have not been investigated and the works have not been fully scoped.
- Data available from the nearest Land, Air, Water, Aotearoa (LAWA) monitoring point accurately reflects the receiving environment of the WWTP discharge.

Other matters raised through focus groups

This study has required the collaboration and input from a number of wastewater network owners and operators across New Zealand. The open discussions, ready sharing of information and assistance with focus group discussions is appreciated and acknowledged.

A number of key issues were raised through discussion including the following:

- Upgrade costs for WWTPs have been calculated assuming that individual WWTPs are upgraded and that the point of discharge remains the same. In some cases upgrading the discharge to a land based discharge or amalgamating existing WWTPs and wastewater networks may provide the optimal solution for capital and operational expense. These options would require individual case-by-case feasibility studies which have not been carried out in this report.
- Workforce capability is a significant issue should a transition from non-mechanical, low input WWTP's to higher input, more mechanical plants be considered. An industry focus group discussion carried out as part of this project raised the ability for the sector to attract, retain and train staff as a significant barrier to progress.
- Phosphorus is typically measured and managed through treatment plant consents. There is no attribute listed for phosphorus in the NPS Freshwater, but councils must manage phosphorus as part of periphyton management.
- Consenting plants under the RMA is a significant process and one that should not be under estimated. WWTP consenting processes can take both significant time (between 2 and 4 years) and cost (an average consent process would be in the order of $500,000 to secure).
- A key aspect of any transition from waste stabilisation pond technology to BNR-Activated Sludge type processes is solids treatment and handling. Waste stabilisation ponds typically store solids within the ponds and are periodically cleaned out, on an as required basis. BNR-Activated Sludge plants produce sludge as part of the treatment process. This sludge needs to be managed on a day to day basis and disposed of in an environmentally sustainable and culturally acceptable fashion. This handling and disposal of sludge can be difficult and expensive.

Table of contents

Table index

Figure index

Appendices

1. Introduction

1.1 Purpose

Boffa Miskell Ltd (Boffa Miskell) and GHD Ltd (GHD) were commissioned by the Department of Internal Affairs to scope the national-level compliance cost for local authority wastewater treatment plants (WWTPs) to meet National Policy Statement (NPS) water quality criteria for Freshwater Management (NPS Freshwater). The Wastewater Specialists (TWWS) provided technical support and local knowledge of WWTP operation around New Zealand; particularly in relation to oxidation ponds.

The project is one part of the Three Waters Review, which the Department of Internal Affairs is undertaking to gain a better understanding of the challenges facing three waters services.

The project specifically considers discharges from WWTPs to freshwater receiving environments, and reviews the benefits and associated costs of upgrading these to achieve improved receiving water quality.

Receiving water quality is influenced by both diffuse and point source contaminant contributions from other activities and land uses within the catchments where there are WWTP discharges and wastewater network overflows. This report has focussed on assessing the contribution of treated wastewater discharges to freshwater quality, estimating costs to improve discharge water quality and providing a high level evaluation of whether investment in improvements will materially assist with meeting NPS Freshwater objectives.

It is important to note that the study has assessed the status of WWTPs as they are in 2018 and cost estimates do not account for future growth as this was outside the study scope. It is acknowledged that when considering upgrades to their wastewater networks, that asset owners will in most cases provide for future growth to optimise the investment, and upgrades to account for this will increase cost.

The study included a high-level review of the contribution of wastewater network overflows to receiving water quality and examples of different approaches to wastewater network overflow management are appended. Cost estimates for reducing or removing wastewater network overflows were not included in the study due to the to the variability and often absence of performance targets that apply across the regions, and differing levels of data available from network owners on overflow frequency and planned improvement works. The level of variability in all of these factors made it difficult to develop a national cost estimate with a consistent basis.

1.2 Scope

The study scope and background on the NPS Freshwater objectives as outlined by the Department of Internal Affairs is reproduced following:

- *Assessment of the potential cost for local government to upgrade wastewater infrastructure to meet increasing standards under the NPS for Freshwater Management. The assessment is to consider the potential costs both for current form of the NPS and any associated standards or targets set under it, and if standards or targets continue to increase in the future.*
- *The assessment will need to identify the environmental attributes that will be the key cost drivers in this area, and estimate the potential national cost to upgrade wastewater infrastructure.*

- *Provide a breakdown of how cost drivers differ across profiles, such as types of wastewater systems, components within the system (such as reticulated or plant infrastructure), or factors such as network age or condition.*
- *Provide commentary on how different attributes (such as E. coli, nitrates, or phosphorous) are currently treated by wastewater plants, and what the cost will be if standards or targets increase, or requirements for attributes change over time.*

The NPS Freshwater sets an overarching methodology for management of freshwater bodies, along with national targets and national bottom lines. Implementation however occurs at a regional level through regional plans, and regional councils are currently at different stages of implementation. Many regional councils are still in the process of making decisions that will affect any potential upgrades to wastewater infrastructure that might be required, such as:

- *The objectives and values for freshwater bodies;*
- *The levels and targets for attribute states (including whether levels will be set above national bottom lines);*
- *The proportionate impact that wastewater systems will have on a freshwater body, set through resource consent conditions and limits, relative to other activities that contribute to freshwater quality;*
- *Timeframes over which improvements to freshwater quality will occur.*

1.3 NPS Freshwater Management implementation

The NPS Freshwater came into effect on 1 August 2014 with amendments made in August 2017. The document acknowledges that freshwater is important for New Zealand's economic, environmental, cultural and social well-being and there are a number of increasing threats (i.e. water quality degradation, climate change, over allocation) to this vital resource.

The NPS Freshwater provides for a National Objective Framework that establishes freshwater objectives for national, and other, values for freshwater. Attributes, or measures of the environmental state (parameters) relating to ecosystem health and human health for recreation national values have been developed in the NPS Freshwater. The attribute tables provide different states against which water quality is measured, as well as a national bottom line standard. The NPS Freshwater makes it clear that the national bottom line is not a standard to aim for. Rather, its purpose is for freshwater systems below this bottom line to improve to at least this state or better over time. The relevant attribute standards used in this project are provided in Appendix B.

Regional (and unitary) councils are required to fully implement the NPS Freshwater within their respective policies and plans no later than the end of 2025 (although this may be extended to the end of 2030 in some circumstances. Each region will be divided up into separate freshwater management units with specific limits for water quality based on consultation with the community and other stakeholders. Water quality limits will vary between and within freshwater management units.

At the time of writing this document, councils were in varying stages of implementing the NPS Freshwater. Some councils (i.e. Environment Canterbury) have already been through the required planning processes and implemented policies and objectives and set limits for water quality for some freshwater management units.

1.4 Overview of wastewater treatment plants in New Zealand

Most cities and towns in New Zealand are serviced by centralised WWTPs. This means that wastewater is conveyed from individual dwellings, through reticulation, to a centralised location for treatment and disposal. Some small towns are serviced by de-centralised systems in which each individual house, or cluster of houses, is serviced by its own on-site WWTP and disposal field. In general, decentralised systems are becoming less common as councils provide reticulation and centralised treatment for their communities due to higher failure rates of on-site systems.

The majority of centralised WWTPs in New Zealand were constructed over the past 60 years. Approximately 60% of the municipal WWTPs in New Zealand use waste stabilisation pond technology. Waste stabilisation ponds are passive, large footprint treatment processes that require minimal operation and maintenance.

The performance of waste stabilisation ponds is highly seasonal, generally providing a better level of treatment during summer due to the warmer temperatures, but poorer effluent quality in winter. In general, the effluent quality from a pond based WWTP is relatively poor in comparison to more modern treatment technologies, in particular with regard to ammonia.

Where basic pond based WWTPs cannot provide the level of treatment required to meet increasingly stringent resource consent conditions, WWTPs are being upgraded. Upgrades of WWTPs in New Zealand can be broadly divided into two categories.

– **Approach 1 -** Upgrades using more modern technology which is generally a variation of an activated sludge process. This includes sequencing batch reactors, membrane bioreactors, and biological nutrient removal processes such as Bardenpho reactors. Activated sludge based WWTPs can provide consistent, year round treatment of wastewater to a higher level than generally achievable through waste stabilisation pond based processes, including reliable nitrification (conversion of ammonia to nitrate). However, activated sludge treatment comes with a higher cost, both capital and operational, and increased complexity requiring more skilled operators. The majority of larger towns and cities in New Zealand are now serviced by activated sludge based WWTPs.

– **Approach 2** - The second category of WWTP upgrades involves modification to waste stabilisation ponds. This has provided a major challenge to New Zealand over the past 15 years, and continues to do so. Council's often undertake such modifications because the cost of upgrading to an activated sludge process is perceived to be unaffordable, particularly for smaller communities. Waste stabilisation pond modifications are fuelled by the plethora of suppliers who actively promote their treatment solutions in New Zealand.

Modifications to waste stabilisation ponds come with a significant risk of failure, and there have been many examples of such upgrades failing to meet expectations. A review of the performance of a number of different upgrade options was completed in 2016 and reported in a paper prepared for the Water NZ annual conference titled "Upgrading waste stabilisation ponds: reviewing the upgrade options" (Ratsey, 2016). Case studies from across New Zealand were used by TWWS to assess the performance of a wide range of technologies added to pond based WWTPs. Treatment technologies reviewed included AquaMats, floating wetlands, partitioned ponds, baffles, Actiflo, BioFiltro, wetlands, filtration, and ultra-violet disinfection (refer Appendix A for an explanation of these technologies).

The key findings of this review indicate that upgrades of waste stabilisation ponds that rely on natural treatment processes invariably retain one major disadvantage of pond based treatment i.e. inconsistent and unpredictable performance. In particular, if reliable year round nitrification is required, waste stabilisation pond upgrading is considered to be a high risk option.

Where waste stabilisation ponds are upgraded using physical or chemical treatment processes the level of treatment attainable is more predictable. However, it is important that the process selected aligns with required discharge water quality targets since there is variability in contaminant removal efficiency with different processes.

WWTPs typically evolve as populations increase and resource consent conditions become more stringent. This has resulted in non-standardised WWTPs throughout New Zealand, particularly those servicing small to medium towns.

1.5 Overview of wastewater networks

Wastewater networks are designed to convey wastewater to a WWTP. The complexity and scale of the networks operating in New Zealand varies across communities. Many networks include a combination of both old and new sections. While the majority of networks operate using gravity, there is a steady increase in the installation of pressurised systems being retrofitted to older areas of networks or being installed to service new developments.

For most networks, the wastewater conveyed is derived from a combination of residential, commercial and industrial sources. In addition, water commonly enters networks from either infiltration of groundwater or rainfall and also via illegal stormwater connections. The load from rainfall derived inflow and infiltration often causes total inflows to exceed the capacity of the network; and for this reason many systems incorporate engineered overflow points. These are designed overflow points that have been located to minimise the impacts of an overflow on the public (e.g. avoiding private property). These overflows are often termed wet weather overflows.

In some parts of New Zealand, wastewater networks are specifically designed to overflow to the stormwater system in rainfall events. In other situations the wastewater and stormwater networks are combined and incorporate designed overflow points to receiving waters when it rains. Overflows from combined networks are called a combined sewer overflow. Combined systems are no longer constructed and in cases where they exist the network owners are working to eliminate them over time.

Wastewater networks are not designed for discharge of dry weather flow, which is wastewater plus any groundwater within the system flowing in dry conditions. However overflows of networks can occur due to various failures within a system such as a pump failing or more commonly system blockage. This type of overflow is called a dry weather overflow.

The rate and frequency of overflows from wastewater networks varies across New Zealand. In many municipalities network owners are operating systems that were constructed more than 50 years ago and are managing associated issues with degradation (causing infiltration) and lack of capacity to deal with population growth.

Another complexity is that the approach to consenting of wastewater overflows varies across the regions, as does the approach being taken by networks owners to managing overflows. Appendix C provides examples of different management approaches being applied across New Zealand.

1.6 Acknowledgements

This study has required the collaboration and input from a number of wastewater network owners and operators across New Zealand. The open discussions, ready sharing of information and assistance with a focus group discussion is appreciated and acknowledged.

Specific thanks are given to the following organisations for their participation in meetings and the project industry focus group:

Christchurch City Council	Queenstown Lakes District Council
Dunedin City Council	Waikato Regional Council
Hamilton City Council	Watercare Services Ltd
Hauraki District Council	Wellington Water
Waipa District Council	Water New Zealand
Western Bay Of Plenty District Council	Water Services Managers Group

2. Methodology

2.1 Approach

A key focus for the study has been to align the impacts of WWTP discharges on receiving water quality. This has involved comparing the contribution of WWTP discharges to inputs from the wider catchment that also influence the potential for a watercourse to meet NPS Freshwater quality standards (refer section 3.4.3). The study also included reviewing whether WWTPs comply with their current discharge consent conditions based on available data.

Where improvements to WWTPs are identified by the study to be beneficial, a high-level cost estimate to enhance treatment has been developed.

The nature of the study is that it has involved collation and review of a large dataset covering WWTP characteristics and receiving environment values. There were gaps in the available data and these have been filled using a combination of assumptions and information drawn from case studies (refer section 5). The general approach taken to the study is outlined in Table 1.

Table 1 Summary of study methodology

Step	Description	Primary Data Sources
Step 1- Locate and characterise WWTP	Identify the locations and characteristics of all WWTP discharges in New Zealand to freshwater (discharge location, consent compliance, plant age and type, population served etc.)	New Zealand wastewater treatment plant inventory (Water NZ) Water NZ 2016/17 Benchmarking results
Step 2 –provide overview of wastewater network overflows	Provide description of network overflows and strategies to reduce in major centres and representative medium and small centres	Direct approach to asset owners and operators refer section 3.3 and Appendix C
Step 3 - Mapping	Map all WWTP location data in GIS and overlay available info on the receiving environment, land use etc. to provide catchment context.	[3]Land, Air, Water, Aotearoa (LAWA) website Ministry for the Environment overlays (flow rates, land cover)
Step 4 – Assess receiving environment	Assessment of the receiving environments (stream order, land use, specific values etc.) and the relative contribution of WWTP discharges to freshwater quality and to meeting NPS freshwater targets.	GIS maps and LAWA data refer section 3.4
Step 5 – Upgrade assessment based on current consent compliance and receiving environment	Review of WWTP current compliance position where information is available. High level assessment of whether upgrades to the WWTP are material to meeting NPS values for freshwater.	Water NZ 2016/17 Benchmarking results
Step 6 – WWTP upgrade definition	Grouping of WWTP into categories for upgrade cost estimation based on proposed process addition and treatment rate	
Step 7- Cost estimation	Cost estimate for upgrade of all WWTPs in NZ based on Step 6 outcomes	GHD cost curves for WWTP process addition (refer 6.3).
Step 8 – Case studies	Three case studies were used to understand resource consent challenges, validate cost estimates and review the relative contribution of WWTPs to receiving environments.	Information received from Watercare Services, Hauraki District Council and Waipa District Council

[3] https://www.lawa.org.nz/

The upgrade assessment in Step 5 is shown graphically in Figure 1 and explained in following text.

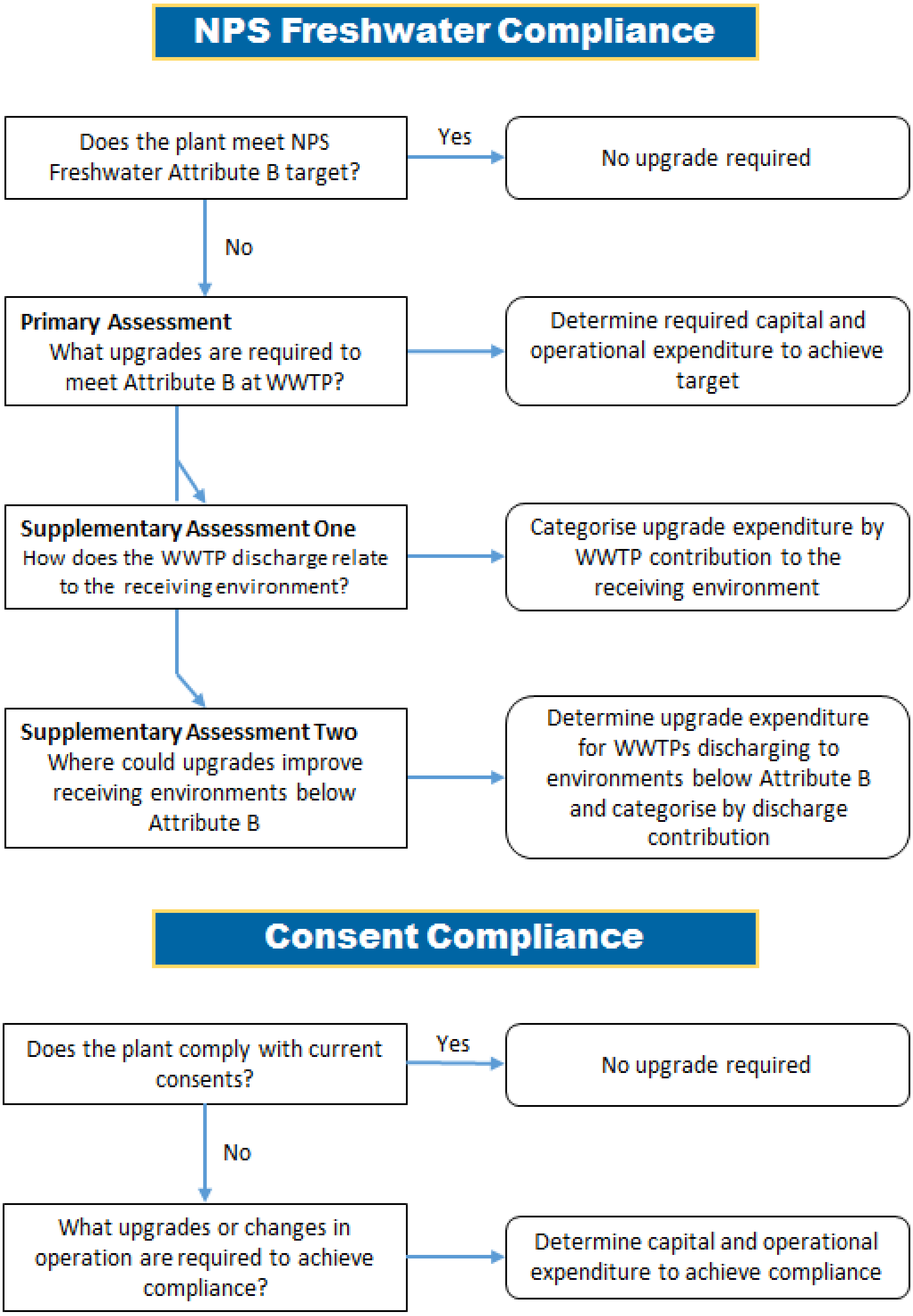


Figure 1 Assessment process to identify WWTP upgrades

The following key queries were analysed for Step 5:

- **Does the WWTP comply with current consent conditions?.** If a WWTP is not meeting its current discharge consent conditions there is a compliance issue to be addressed and potentially an upgrade required to meet full compliance. Based on available data in the Water NZ National benchmarking database very little enforcement action related to non-compliance is reported at a national level. However based on information provided by our study participants, the benchmarking database does not necessarily reflect performance. Part of the complexity is that “non-compliance” can be very minor and addressed through improved operations and maintenance works rather than a significant plant upgrade. As discussed in section 6.3.2 with little data readily available at a national level the Waikato region was used as an example to explain the issues and potential cost involved with meeting compliance.
- **Does the plant meet the B Attribute Level?** The NPS Freshwater Attribute B values were chosen as the target to be achieved in receiving waters (refer section 3.4.3 for an explanation). If a plant discharge is already meeting Attribute B levels for *E.coli*, total nitrates and ammonia no upgrade is assumed to be required.
- **Would an upgrade improve the receiving environment water quality?**. If the answer to query 2 is “No” the question then relates to what the likely existing nutrient and *E. coli* contribution (small, moderate, or large) is from the WWTP to the receiving environment. Of particular interest is the query “*if investment is made in a WWTP upgrade to meet Attribute B at the end of pipe, what would be the likely magnitude of change to the receiving environment?*”. Key considerations in making this assessment included what other land uses within the catchment generate nutrients and what proportion of flow and contaminant is sourced from the WWTP in comparison.

The assessment process has a focus on receiving water quality impacts and ignores a range of other typical and site specific WWTP upgrade considerations (e.g. asset condition, plant load versus current capacity, population growth).

Where a plant upgrade is deemed unlikely to noticeably improve receiving water quality, alternatives such as offset mitigation (e.g. native planting) or improvements to upstream landuse management practises could be considered. These wider catchment initiatives to improve receiving water quality are not specifically assessed in this report.

3. Study Data Sources

3.1 Overview of Data Sources

A critical element of the assessment process was to access good quality detailed data and information on WWTPs across the country. It became evident in the early stages of the assessment process that a single data set of the required information does not currently exist, and a number of data sources were used including:

- The Water NZ WWTP Database
- Water NZ 2016/17 Benchmarking results
- LAWA data set (NPS Freshwater)
- Ministry for the Environment maps (flow rates, land cover)
- Distance to the sea (analysis)
- Council Asset Management Plans

The first screening that was undertaken was to identify whether a plant discharged to freshwater or to the sea. Figure 2 shows the geographic spread across New Zealand of WWTPs.

This study has focussed only on WWTPs that are publicly owned and operated i.e. by councils, Watercare and Wellington Water. There are a number of WWTPs operating in New Zealand that are owned and operated by either government agencies (e.g. Defence, Department of Corrections) or private companies. These were not included in the study and the number of these has not been calculated.

This initial screening indicated there are 321 publicly owned WWTPs operating in New Zealand with the discharge split (sea versus freshwater) as shown in Table 2.

Table 2 Numbers of publicly owned WWTPs operating in New Zealand

WWTPs discharging to ocean or land environments	WWTPs discharging to freshwater
169	152

Further information on the breakdown of discharge types is provided in section 3.2.2.

Data collection has focussed on those WWTPs discharging to freshwater.

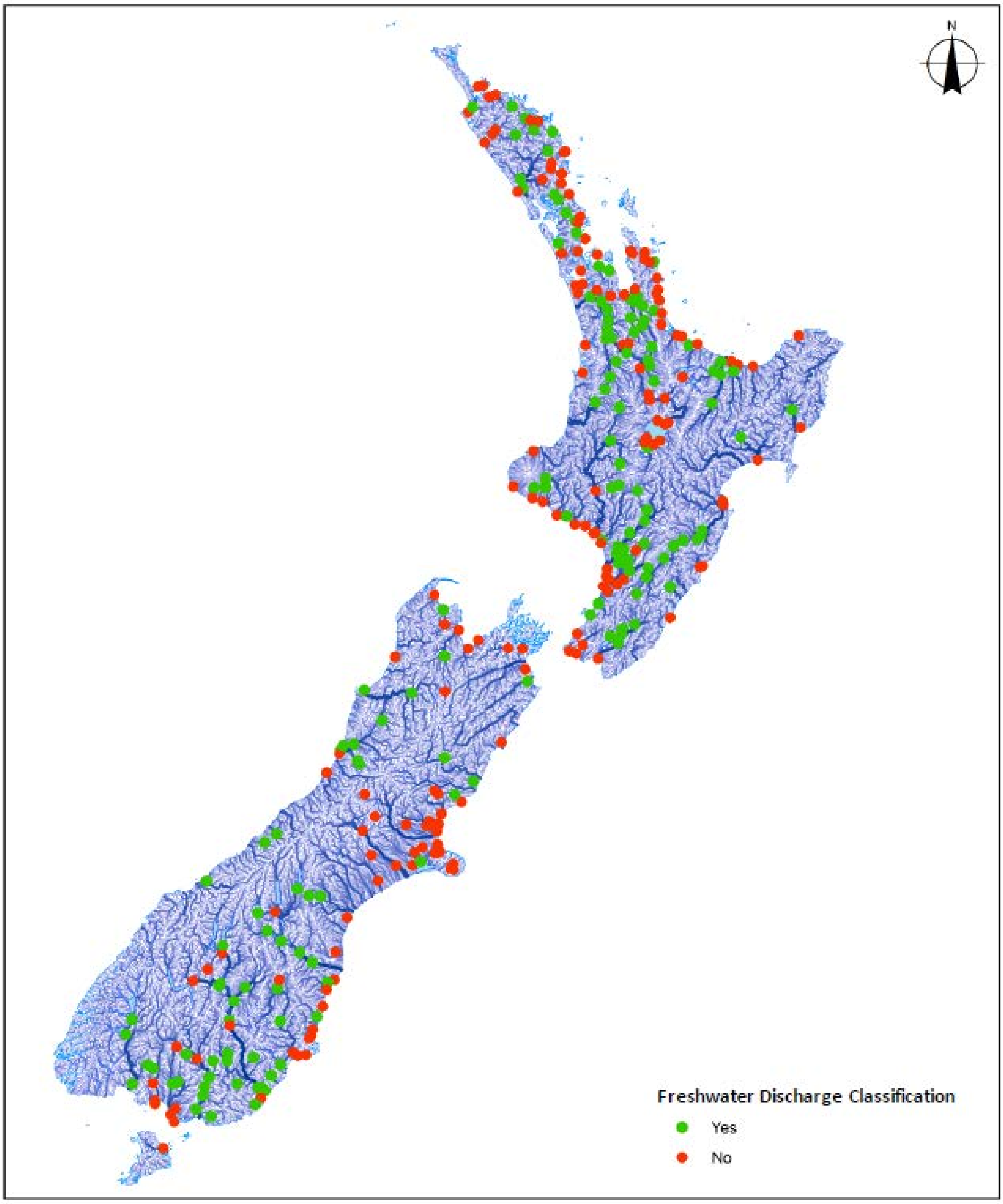


Figure 2 Spatial location of WWTPs

3.1.1 Gap analysis and gap filling

With significant gaps in the data sets available, the project team was required to look for independent data sets and sources of data. This involved analysis of published council documents, including Council Wastewater Activity Management Plans, Draft Long Term Plans and Annual Plans. All data was collated into one single repository.

Figure 3 summarises all of the data sources used to characterise WWTPs (Data Sources - Assets) and receiving environments (Data Sources – Environment).

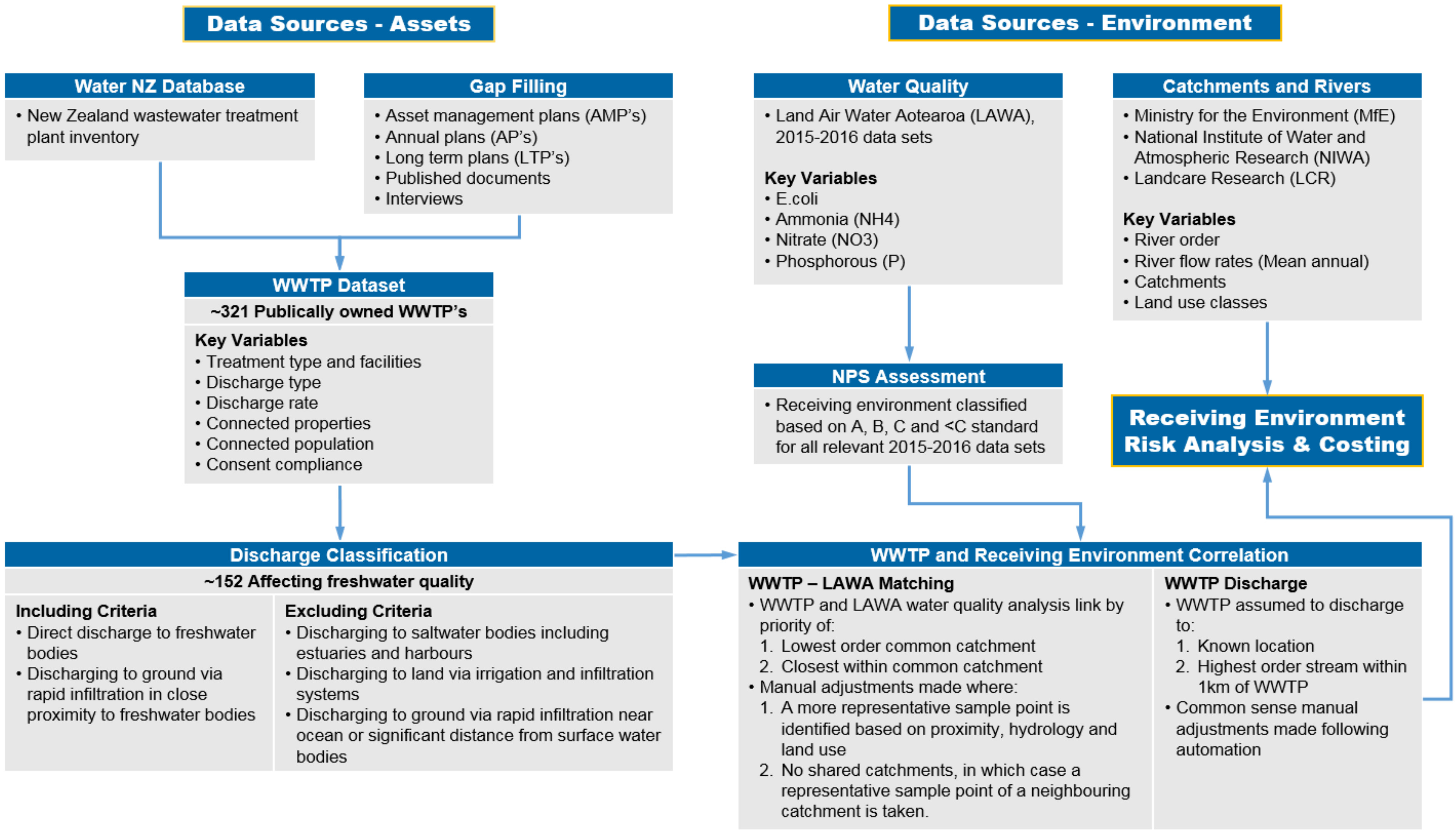


Figure 3 Data source map

3.2 Data on wastewater treatment plants

3.2.1 WWTP discharge rates

WWTP discharge rates were primarily sourced from the Water NZ WWTP inventory that includes data for the year of 2014/15 or 2015/16. These discharge rates have been updated where more recent data is available in published council documents. Where actual discharge rates were not readily available, an estimation of discharge rates was calculated by applying the following relationship:

$$Q_{Avg} = 0.19\, P^{1.07} \qquad \text{(Eq. 1)}$$

where P is the population and Q_{Avg} is the mean discharge rate in m^3/d.

This relationship was developed by correlating connected population and WWTP discharge rates across the available dataset.

For design and assessment of WWTP capacity a “population equivalent” or PE is commonly calculated. Population equivalent accounts for domestic population and also includes a capacity allowance for non domestic (i.e. commercial and industrial) users of a wastewater network. The calculation of this value varies depending on what type of industrial and commercial use applies. For simplicity this study has used population estimates derived with equation 1 above to generate WWTP discharge rates where it is not provided in data.

3.2.2 Discharge classifications

The focus of this study is to consider WWTPs discharging to and affecting freshwater bodies. In line with this objective, each WWTP has been allocated to one of the following three categories based on the dominant receiving environment and criteria described:

1. **Ocean**
   i) Discharges via ocean outfalls,
   ii) Discharges to estuaries and harbours,
   iii) Discharges to a periodic saltwater environment that use an outgoing tide as a means to flush the treated effluent.
2. **Land**
   i) Discharges via irrigation,
   ii) Discharges via engineered infiltration systems,
   iii) Discharges to engineered wetlands for the purpose of passive treatment and infiltration.
3. **Freshwater**
   i) Discharges directly to rivers or lakes,
   ii) Discharges to ground via rapid infiltration systems with close proximity to surface freshwater bodies.

Classification of each WWTP has been conducted by first reviewing asset descriptions within published council documents and secondly reviewing data in the Water NZ WWTP inventory. Classification was completed by assessing aerial imagery and GIS data sources if required. In some cases, WWTPs discharge to more than one of the receiving environments described, for example a few treatment plants discharge to land in the summer and have overflow allowances to a river during the winter or high flow periods. Where WWTPs discharge to multiple environments classification was made considering the dominant discharge type and objectives of this report.

Figure 4 shows graphically the distribution of discharge types that apply for New Zealand WWTPs. Based on this classification, nearly half of the nation's WWTPs discharge to freshwater, with approximately one quarter each discharging to the land and ocean. As most of New Zealand's larger population centres are located on the coast the discharge classification skews towards the ocean on a per population basis. Freshwater and land based discharges from publically owned treatment plants serve 13% and 5% respectively of New Zealand's total current estimated population (4,897,000).

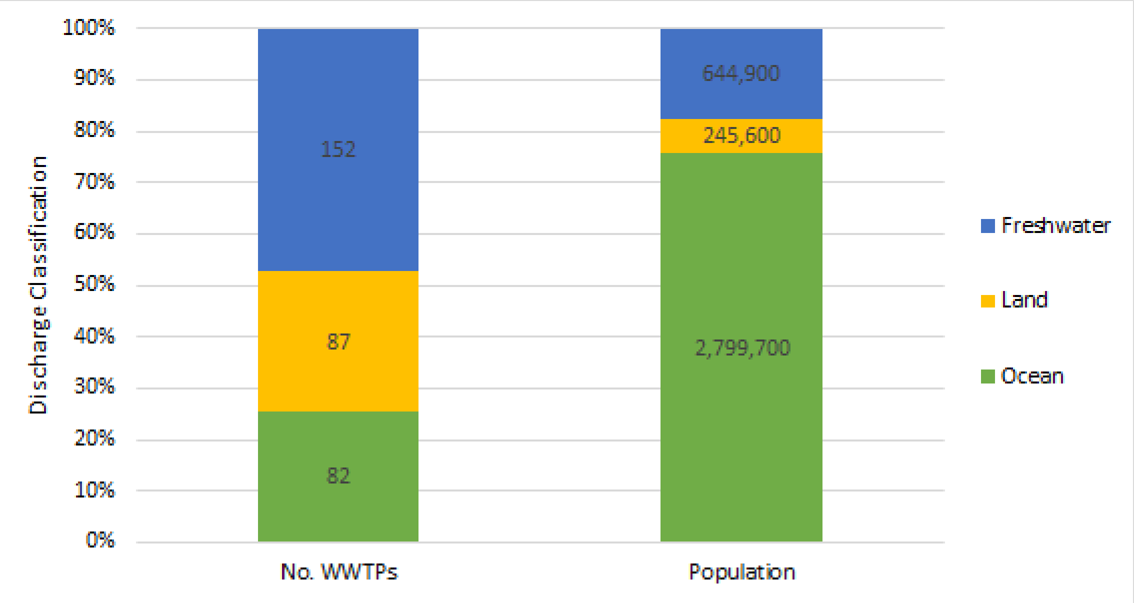


Figure 4 Discharge classifications for all council owned WWTPs in New Zealand

3.2.3 Summary of WWTPs discharging to freshwater

Table 3 summarises the distribution of WWTPs that discharge to freshwater by region and size. The total number of WWTPs i.e. including those discharging to the coast or land are also listed for comparison. The study distinguishes between WWTPs based on the following population categories:

- Large – greater than 10,000 people
- Medium – 5,001-10,000 people
- Minor – 501 – 5,000 people
- Small – Less than 501 people

Table 3 Summary of WWTPs discharging to freshwater in New Zealand

Region	No. of WWTPs in each population category (Total / Freshwater discharge / Upgrade required to meet NPS Freshwater at discharge)				
	Large (>10,000)	Medium (5,001 – 10,000)	Minor (501 – 5,000)	Small (<501)	Total
Auckland	3 / 0 / 0	1 / 1 / 0	8 / 4 / 3	5 / 1 / 1	17 / 6 / 4
Bay of Plenty	4 / 0 / 0	3 / 2 / 2	7 / 3 / 3	2 / 1 / 1	16 / 6 / 6
Canterbury	7 / 0 / 0	0 / 0 / 0	18 / 5 / 5	20 / 7 / 7	45 / 12 / 12
Gisborne	1 / 0 / 0	0 / 0 / 0	1 / 1 / 1	0 / 0 / 0	2 / 1 / 1
Hawke's Bay	1 / 0 / 0	0 / 0 / 0	6 / 4 / 4	3 / 1 / 1	10 / 5 / 5
Manawatu-Wanganui	4 / 2 / 2	3 / 3 / 3	15 / 11 / 11	15 / 8 / 8	37 / 24 / 24
Marlborough	1 / 0 / 0	0 / 0 / 0	3 / 1 / 1	0 / 0 / 0	4 / 1 / 1
Nelson	1 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1 / 0 / 0
Northland	1 / 0 / 0	1 / 1 / 1	18 / 8 / 8	10 / 2 / 2	30 / 11 / 11
Otago	5 / 0 / 0	1 / 1 / 1	13 / 9 / 9	16 / 10 / 10	35 / 20 / 20
Southland	1 / 0 / 0	1 / 1 / 1	11 / 6 / 6	10 / 7 / 7	23 / 14 / 14
Taranaki	1 / 0 / 0	2 / 1 / 1	5 / 2 / 2	3 / 2 / 2	11 / 5 / 5
Tasman	1 / 0 / 0	1 / 0 / 0	3 / 2 / 2	3 / 1 / 1	8 / 3 / 3
Waikato	6 / 5 / 3	9 / 5 / 5	20 / 10 / 9	21 / 7 / 6	56 / 27 / 23
Wellington	6 / 2 / 1	2 / 2 / 2	3 / 3 / 3	2 / 0 / 0	13 / 7 / 6
West Coast	0 / 0 / 0	1 / 1 / 1	6 / 4 / 4	6 / 5 / 5	13 / 10 / 10
Total	**43 / 9 / 6**	**25 / 18 / 17**	**137 / 73 / 71**	**116 / 52 / 51**	**321 / 152 / 145**

The data analysis shows a predominance of WWTPs discharging to freshwater (82%) that service small or minor populations. Only nine WWTPs service populations greater than 10,000. Based on plant numbers Waikato, Otago and Manawatu-Wanganui have the highest number of WWTPs discharging to freshwater.

Only 7 out of 152 WWTPs do not need an upgrade if meeting the NPS Freshwater Attribute B at the discharge point is required.

Table 4 summarises the total populations serviced by WWTPs that discharge to freshwater.

Table 4 Summary of populations serviced by WWTPs discharging to freshwater

Region	Total No. of WWTPs	Estimate of total population served
Auckland	6	16,280
Bay of Plenty	6	20,320
Canterbury	12	5,270
Gisborne	1	640
Hawke's Bay	5	7,960
Manawatu-Wanganui	24	132,900
Marlborough	1	690
Nelson	0	0
Northland	11	26,560
Otago	20	23,590
Southland	14	20,150
Taranaki	5	9,620
Tasman	3	2,580
Waikato	27	281,120
Wellington	7	79,130
West Coast	10	18,060
Total	152	644,900

3.2.4 Data on WWTP consent compliance

Data from the Water NZ 2016/17 Benchmarking database indicates a low level of consent non-compliance and the following statement was provided within the document, based on the data received:

"Participants recorded very few consent non-compliances. In 2016-17 only one abatement notice was received by Wairoa, and four participants received a total of seven infringement notices".

To test this outcome GHD undertook a review of the compliance of WWTPs within the Waikato region that discharged into freshwater bodies. This review was facilitated through Waikato Regional Council (WRC) staff and looked specifically at compliance with the 3 parameters linked to the NPS Freshwater. The outcome of the review indicated that the Water NZ summary is not an accurate reflection of compliance in at least the Waikato region.

A summary of the compliance data WRC provided for WWTPs discharging to freshwater indicated the following level of non-compliance across the 27 plants:

- 30% *E. coli* non-compliance
- 30% ammonia non-compliance
- 18% total nitrogen non-compliance
- 48% combined non-compliance

WRC has provided the following commentary in relation to this data:

"*This data should not be read out of context of the overall performance of the consent holder. It notes that many consent holders in recent times have upgraded their WWTPs with technology that significantly improves discharge quality. When being replaced upon expiry, the consents that authorise these discharges have consequently included conditions that set significantly lower discharge limits that reflect these improvements. So whilst there are at times minor exceedances of these tighter limits, these in themselves do not necessarily result in adverse effects of any significance, i.e. a minimal non-compliance (which may be just one solitary outlier sample) will likely result in a minimal environmental effect.*

Consents that authorise discharges from WWTPs contain many dozens of conditions. When monitoring these consents, WRC assigns compliance status to a consent based on a range of factors, in particular the likelihood of adverse effects associated with any non- compliance. A non-compliance that has the potential to result in an effect significantly greater than that authorised is consider a "high priority non-compliance" and the site is consequently considered to be in significant non-compliance. From the data presented, only one WWTP was considered to be significantly non-compliant in the 2017/18 year.

That said, WRC notes that there are still some older consents where compliance is achieved, but with less stringent consent limits. As these consents expire and are replaced, WRC comments that tighter condition limits can be expected in order to give effect to the Vision and Strategy for the Waikato and Waipa River catchments and the NPS Freshwater."

It was not possible within the timeframe of this study to obtain a similar level of detail for all regions of New Zealand. WRC support was critical in enabling this analysis to be undertaken and it would be of value to test other regions to understand if the level of non-compliance sits at the same level as the Waikato region.

3.3 Data on wastewater networks

3.3.1 Data sources

For this study it was not practicable to locate, map and interrogate the impact of all wastewater network overflows occurring across New Zealand. The approach taken was to gather the data available from the major centres and representative mid and smaller centres on the extent of overflows occurring, and to provide a summary of management and consenting approaches being applied.

As outlined in section 5.1 the impact of wastewater overflows on receiving water quality is in most cases very short term due to the infrequent nature of overflows; and in wet weather conditions wastewater overflows may be only a small contributor to the contaminant load when compared to other diffuse sources. Removal or reduction in wastewater network overflows will often not contribute significantly to achieving NPS Freshwater quality targets in a water body and investment may be better targeted at reducing contaminants in stormwater runoff.

It is acknowledged however that there are other important drivers for removing and reducing wastewater network overflows, these being from the perspective of both cultural values and community concern.

A number of regional policies provide specific direction that wastewater overflows to freshwater are not acceptable. As an example, the Regional Freshwater Plan for Greater Wellington Regional Council (2014) identifies (clause 5.2.12) that discharge containing sewage should pass through land or an artificial wetland with the explanation being:

"*This policy is designed to take into account the view of tangata whenua in the Wellington region that human waste should not be discharged into fresh water, even if it is treated to a high degree.*"

The Auckland Council Regional Plan (Air, land and Water) states that:

"In areas of new urban development, wastewater networks should be designed, constructed, operated and maintained so that wastewater overflows only occur in extreme circumstances. In existing Urban Areas, wastewater overflows may be occurring more frequently. An appropriate frequency of discharge or other appropriate performance measures will need to be defined through the consent processes for wastewater networks, noting that the Regional Plan: Coastal requires a BPO analysis to justify having more than two wet weather wastewater overflows per annum leading to public health advisory notices being issued for a water recreation area".

The public reaction to wastewater network overflow events is understandably negative. There has been much publicity over the last year about the impact of wastewater network overflows on beach closures in Auckland, and wastewater network overflows through residences due to extreme heavy rainfall.

The public perception that wastewater network overflows are unacceptable in any situation can be a strong influence on council strategy to reduce/remove overflows even if the environmental impact of the overflow is minimal.

As examples, Appendix C provides a summary of the approaches being taken to manage and reduce wastewater network overflows, and the drivers behind these approaches in the following centres:

- Auckland (Watercare)
- Christchurch
- Dunedin
- Queenstown Lakes
- Wellington

3.4 Data on receiving waters

3.4.1 Approach to receiving environment definition

For the purpose of this project, the freshwater receiving environment is considered to be the waterway or land area where the wastewater from a treatment plant discharges to after being treated through primary, secondary and/or tertiary means.

Freshwater receiving environments for this project consist of streams, rivers and lakes varying in size and quality. Discretion has also been applied to including some estuarine receiving environments as well as land based discharges where there is likely to be limited (or no) treatment before entering a freshwater body (i.e. rapid infiltration).

3.4.2 Relevant water quality parameters

River and stream water quality varies across New Zealand within different regions and catchments. The existing water quality conditions of receiving river and stream environments has been determined from water quality data from the LAWA website.

The website provides a database which includes water quality monitoring conducted by regional councils across New Zealand.

Nitrate[4], ammonia and *E.coli* are the parameters selected for analysis within this project. These are contaminants of concern for wastewater discharges and are also identified within the NPS Freshwater with corresponding numeric water quality and narrative standards (NPS Freshwater excerpts included in Appendix B). The attributes for nitrate and ammonia are part of the 'ecosystem health' (toxicity) value and *E.coli* is for 'human health for contact recreation' value under the NPS Freshwater.

3.4.3 NPS Freshwater attribute analysis

Data from LAWA were used to provide a background assessment of receiving water quality for rivers that have WWTP discharges. Up to three LAWA water quality monitoring points were associated to each WWTP by matching through the lowest order common catchments.

Where data was unavailable, data from a neighbouring similar catchment was applied to best describe the expected state of the receiving environment. It is important to note that this analysis is not directly relating the effect of WWTP discharges on compliance of the receiving environment, as other sources of contaminants exist. The purpose of the analysis is to consider how WWTPs are distributed with respect to receiving environment quality on regional and national levels.

Figure 5 shows an example of LAWA and WWTP discharge location matching.

This background assessment was then used to inform the relevant attribute state to consider for application of the NPS Freshwater standard. The water quality data of the receiving environment has been used with regards to the analysis and results on *E.coli*, nitrate and ammonia compliance with NPS Freshwater standards.

[4] Note that the LAWA website only provides data for total oxidised nitrogen (which includes the sum of nitrogen nitrite and nitrogen nitrate concentrations). The NPS Freshwater refers to nitrogen nitrate (nitrate) for ecosystem health of rivers. Total oxidised nitrogen roughly equates to nitrogen nitrate as the nitrogen nitrite component of total oxidised nitrogen is often small. For consistency this report refers only to nitrate.

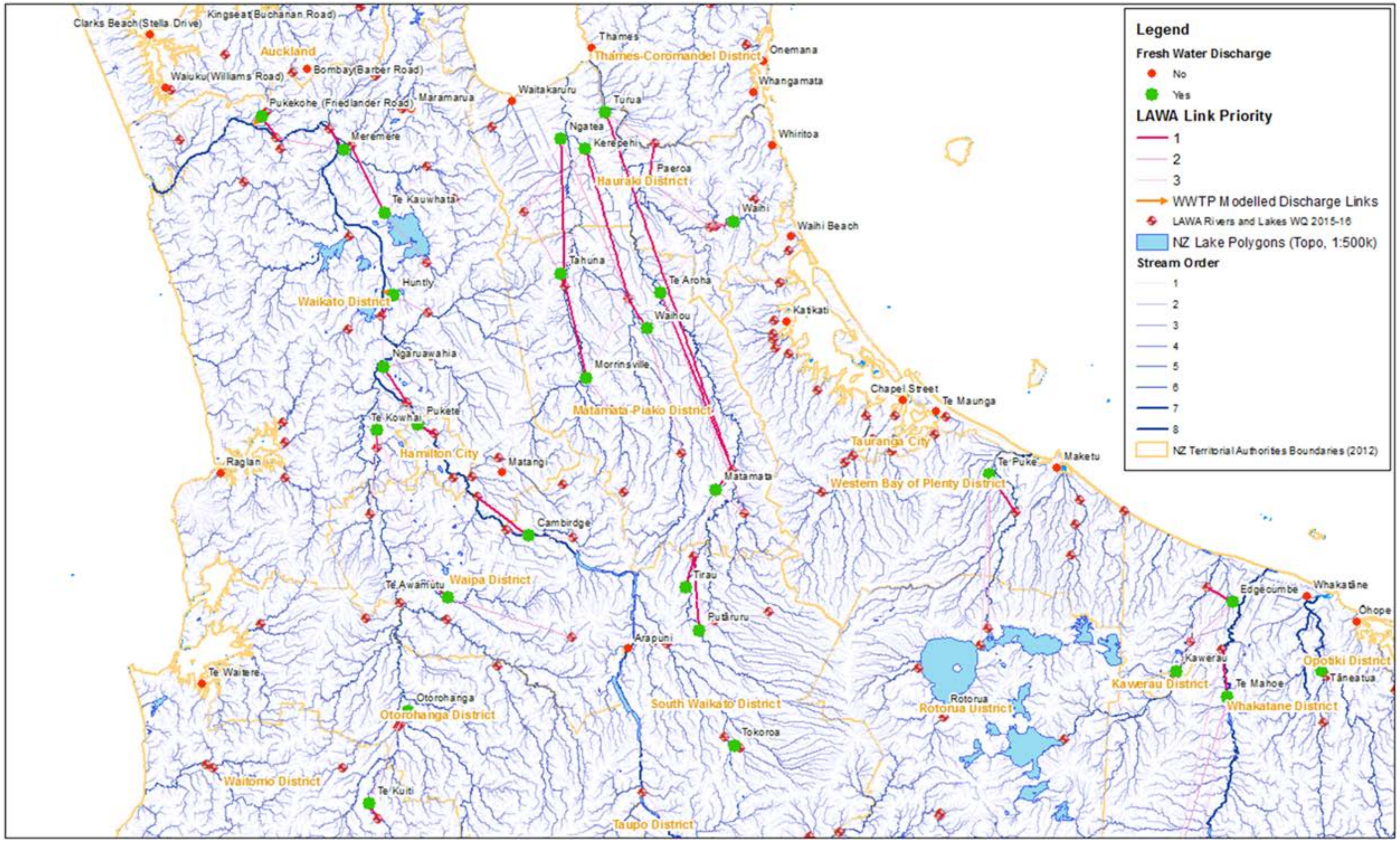
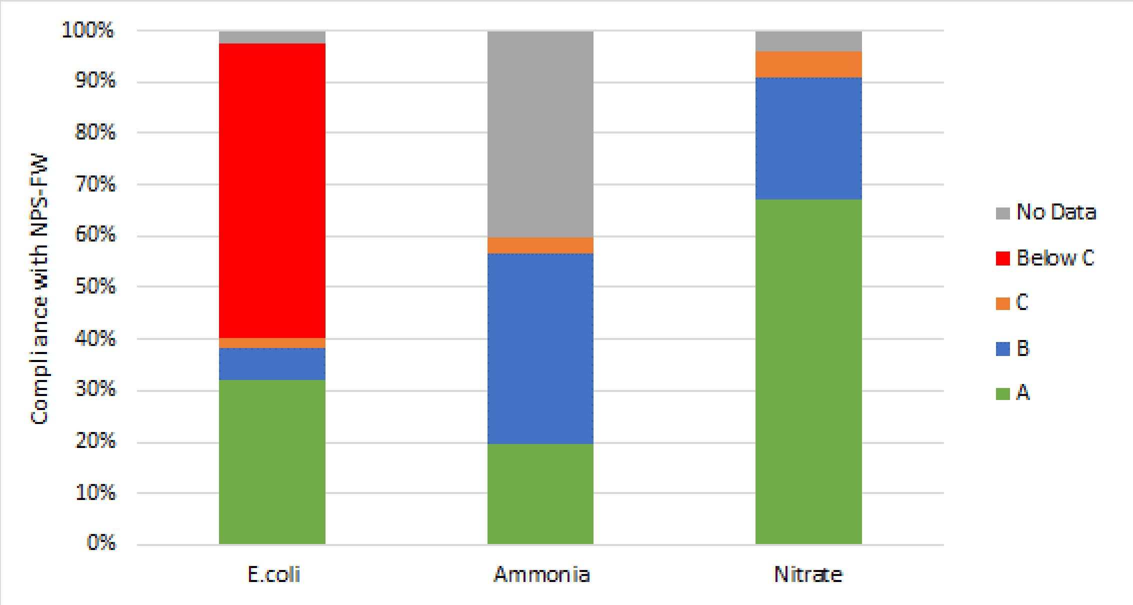


Figure 5 WWTP and LAWA site matching

The numeric and the narrative state for each of the three selected attributes (nitrate, ammonia and *E.coli*) were considered.

Figure 6 shows the distribution of receiving water quality as assessed to the NPS Freshwater standards for all sites matched to a WWTP.



Note - Pie charts developed on a per WWTP basis and some receiving waters may be double counted where multiple WWTP's discharge to it.

Figure 6 Receiving water quality as NPS freshwater attribute states

Figure 6 shows that more than 50% of receiving environments have levels of *E.coli* that do not meet Attribute C targets. The majority of receiving environments exceed Attribute A and B standards for nitrates. There are significant gaps in the data available for ammonia. Where data is available, most receiving environments met either 'A' or 'B' attributes.

Regional Councils across the country are in varying stages of implementing the NPS Freshwater. To provide a consistent approach and an aspirational target, the study assumes that NPS Freshwater B Attribute states for *E.coli,* total nitrates and ammonia are the target to be met in receiving waters.

This is consistent with the NPS Freshwater requirement that regional councils are expected to improve water quality over time in relation to human health. It is also more broadly consistent with community expectations for high treatment and water quality requirements to be applied to discharges of sewage effluent.

4. Sensitivity analysis of the impact of wastewater discharges on receiving water quality

4.1 Impact of WWTP discharges on the receiving environment

The size and character of the respective catchments and their river flows, the nature of the catchment land use and associated non-point source runoff, and other point-source industrial and municipal discharges all contribute to the quality of the receiving environments.

For the purpose of this analysis, the receiving environment is all of the freshwater bodies affected by a contaminant source or discharge and the focus is on the quality of the surface waterways.

In some circumstances, improvements to WWTP discharges may have negligible or little influence on improving the receiving environments to a NPS Freshwater standard, and may be outweighed by other contributors in the catchment. Thus, despite best endeavours, WWTP improvements without reducing contaminant load from land use within a catchment may not achieve the desired outcome in the receiving environment.

4.1.1 Approach

A high level sensitivity analysis was completed in order to provide an indication of WWTP contribution to achieving desired NPS Freshwater outcomes in receiving environments.

The impacts of a WWTP discharge on the receiving environment is variable, and dependent on the existing state of the receiving environment and the quality of the wastewater being discharged. The environmental analysis aimed to identify the relative benefit of upgrades to WWTPs on the respective freshwater receiving environments.

Two key metrics were selected for this purpose:

- Land cover; and
- Water quantity / relative flow contribution.

These metrics are described following, along with a benefit risk assessment.

It is stressed that this analysis is at a very coarse and high level in order to provide some level of environmental sensitivity to cost estimates for WWTP upgrades. It must also be noted that this analysis only considers land cover and water quantity and not other factors relevant to treated wastewater discharges including cultural and/or social sensitivities.

4.1.2 Land cover

The Land Cover database (sourced from Landcare Research New Zealand Ltd) was used to provide an analysis of the predominant land cover within the catchments of the receiving freshwater environments. The land cover categories were divided into ‘nutrient contributing land uses’ and ‘non-nutrient contributing land uses’ and used to provide a coarse level measure of the likely nutrient-based water quality within the receiving environments. Figure 7 provides an example of the land cover analysis undertaken.

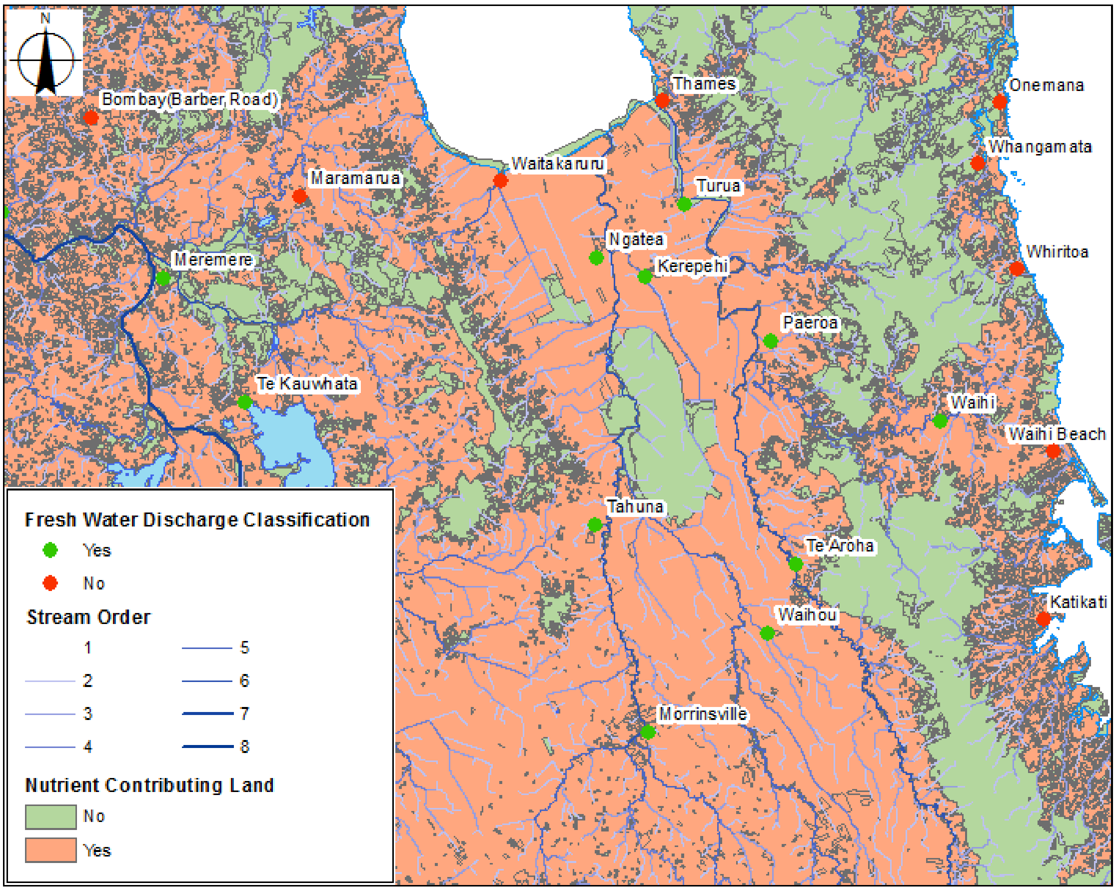


Figure 7 Land use nutrient source assessment example

The land cover categories are defined by assessing land use within the lowest order catchment related to the WWTP discharge location; with the catchment spatial definitions determined from the Ministry for the Environment database for river environment classification (2010). An example of a catchment overlay is shown in Figure 8.

The contaminant contribution of catchments to WWTP receiving environments was classified into one of three categories based on land cover:

- "small" if the overall nutrient contributing land within the catchment is greater than 70% (i.e. the WWTP is likely to have a "low" contribution to water quality parameters relative to the wider catchment),
- "moderate" if the overall nutrient contributing land within the catchment is between 30-70% (i.e. the WWTP is likely to have a "moderate" contribution to water quality parameters relative to the wider catchment),
- "large" if the overall nutrient contributing land within the catchment is less than 70% (i.e. the WWTP is likely to have a "large" contribution to water quality parameters relative to the wider catchment).

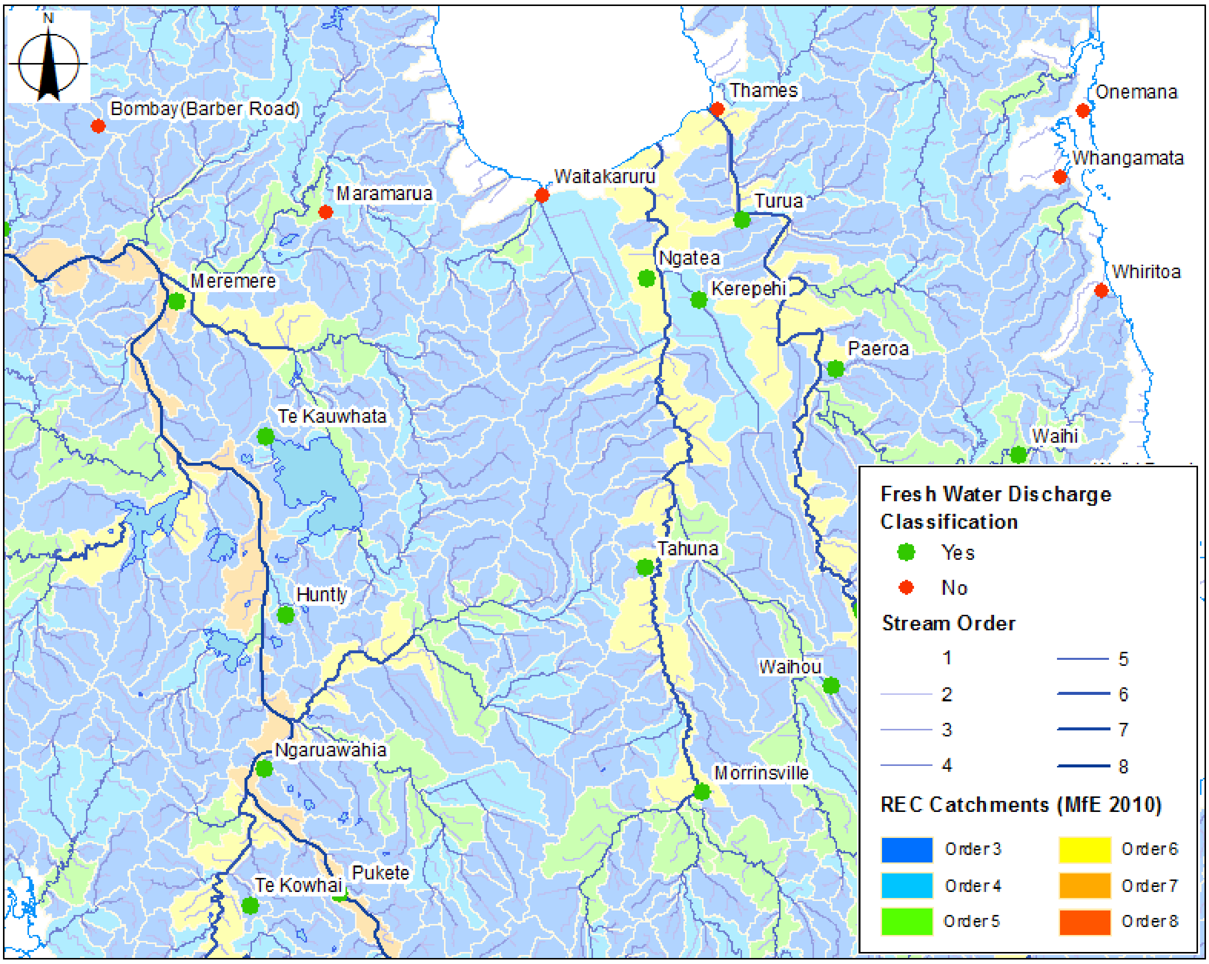


Figure 8 Catchment definitions example (catchments of order < 3 not shown)

4.1.3 Water quantity / relative flow contribution

The relative flow contribution of each WWTP to the receiving environment was determined by considering mean discharge rates and mean river flow rates.

WWTPs were then classified into one of three categories:

- “small” if the overall water quantity being discharged is less than 0.1% of the receiving environment flow rate;
- “moderate” if the overall water quantity being discharged is between 0.1% - 1% of the receiving environment flow rate; and
- “large” if the overall water quantity being discharged is greater than 1% of the receiving environment flow rate.

4.1.4 Contribution

The “land use” and “water quantity / relative flow contribution” parameters were then combined to divide WWTPs into three overarching categories - small, moderate and large contribution categories,as outlined in Table 5 below. The two metrics are then combined into a benefit matrix (Table 6).The benefit matrix aims to identify the relative impact that each WWTP is likely having on the receiving environment.

Table 5 Contribution parameters and thresholds

Parameter	Percent divide		
Nutrient contributing land cover	>70%	30 – 70%	<30%
WWTP discharge contribution	<0.1%	0.1 – 1%	>1%
Contribution to receiving environment water quality	**Small**	**Moderate**	**Large**

Table 6 Benefit matrix

Impact matrix		WWTP discharge contribution		
		Small	Moderate	Large
Nutrient contributing land cover	Small	Small	Small	Moderate
	Moderate	Small	Moderate	Large
	Large	Moderate	Large	Large

For example, a WWTP discharge is categorised as having a "small" contribution to water quality within the receiving environment if the catchment contains more than 70% nutrient contributing land cover, and the overall discharge quantity is less than 0.1% of the receiving environment flow rate. Similarly, a WWTP is categorised as having a "large" contribution to water quality if the catchment contains less than 30% nutrient contributing land cover and the overall discharge quantity is greater than 1% of the receiving environment flow rate.

5. Impact of wastewater network overflows and case studies

5.1 Wastewater network overflows

As outlined in section 3.3 discharges from wastewater networks tend to be infrequent and in the case of wet weather overflows occur in periods when receiving environments are in high flow conditions. Where overflows are occurring within an urban environment contaminants from many other sources are also being washed into streams and rivers at the same time. Some common sources of pollutants similar to those carried in wastewater (e.g. *E. coli*) include dog and bird faeces and fertilizers. While wet weather overflows do contribute in part to contamination during these high flow events, the effect on fresh water quality is often short term with contaminants being washed through the system rapidly. For the remainder of time, contamination of urban waterways is associated with stormwater and direct inputs in dry conditions e.g. from ducks.

A study completed in 2015 by Christchurch City Council has been included as a brief summary in section 5.1.1 to provide context on the relative inputs from wastewater overflows as compared to other faecal sources. The study supports the premise that inputs from wet weather overflows can be relatively minor contributors to receiving water quality.

5.1.1 CCC study on faecal mapping

The Institute of Environmental Science and Research Limited (ESR) completed a study for Christchurch City Council in 2015 that investigated the sources of faecal indicator bacteria found in samples taken from Christchurch Rivers. In this study, six water samples were collected from nine sites between 16th April 2015 and 11th September 2015. The samples were taken during base flow conditions and after rainfall. This allowed for analysis of the relative contribution of direct contamination (e.g. from ducks), stormwater related inputs such as dog faeces being washed in, and human sources from wastewater network overflows.

The 2015 study followed earlier studies completed prior to and post the Canterbury earthquake. The 2015 study found that *E. coli* levels in the water samples exceeded recreational water guideline values on a number of occasions during base flow, and after rainfall almost all samples exceeded recreational water guideline values.

The microbial indicators and pathogens studied were *E. coli*, enterococci, Campylobacter spp. and as faecal source tracking was undertaken to determine the source of the faecal pollution.

The study outcomes are useful because they show the contribution of human faecal matter in Christchurch Rivers to be relatively low when compared to other sources. The study showed a predominance of wildfowl sources during base flow conditions. Following rainfall wildfowl and canine sources generally dominated and these were supplemented with human, ruminant and poultry sources. The study indicated that removal of wastewater overflows will not remove faecal contamination in Christchurch rivers.

As for many other centres (refer Appendix C) it is acknowledged that cultural and social impacts of wastewater overflows are a significant consideration when developing management approaches.

5.2 Case studies

Three cases studies were compiled to provide “real-world” examples on the challenges of consenting WWTP discharges, actual costs for upgrades and the assessed influence of WWTP discharges on receiving environment water quality.

5.3 Case study 1 - Cambridge WWTP

5.3.1 Key facts

- Consent issued: 1996
- Consent Expired: 2016
- Plant type: Secondary Treatment and disposal via Rapid Infiltration Beds to the Waikato River
- Population Projections: Growth Area, 2006 – 12,936 projection of 23,200 by 2041.

5.3.2 Background

The current plant at Cambridge consists of a series of process trains connected together to provide secondary treatment. The site has a long history of wastewater treatment, with it initially being the site of the now closed Weddel Crown Freezing Works Wastewater Treatment Plant. Waipa District Council purchased the site in 1995 and upgraded the system to that outlined in Figure 9. The upgrade was in accordance with the resource consents issued in 1996 and was undertaken in the period 1997-99.

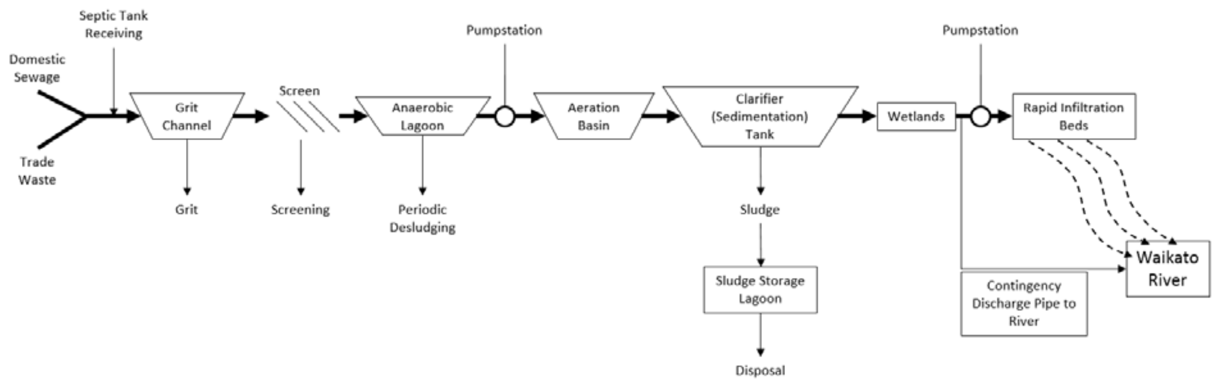


Figure 9 Cambridge WWTP schematic

Since the completion of the upgrade the discharges from the WWTP have not been able to comply consistently with the requirements of the existing discharge consent (960698) for some contaminants, particularly dissolved inorganic nitrogen.

5.3.3 Consent application process

In 2010, largely due to the consent compliance challenges, Waipa District Council commenced the process of securing a new consent for the plant. This was many years ahead of what was required and was largely driven by the ongoing compliance issues.

The consenting process commenced with securing consultancy services and the formation of a Project Advisory Group (PAG) supported by a Project Control Group (PCG). The PAG group consisted of membership from local Iwi and community board/councillors and the PCG council staff, consultants and independent advisors (Iwi and Waikato Regional Council). A separate tangata whenua working group was also set up, consisting of Iwi members of the PAG. The PAG met 12 times over the course of the project and provided council staff and consultants with information on the views of various stakeholders to input into the development of the proposed suite of consents required.

There were a number of drivers for the project, notwithstanding the non-compliance matters mentioned previously. Drivers for the project ranged from those outlined within the Resource Management Act and other regional and national planning tools, through to Waipa District Council's own planning and strategic imperatives. These are all explained in detail in the Assessment of Environmental Effects that accompanied the applications.

Waipa District Council also went to some length to ensure that the application was framed in a way that it would meet the best practicable option approach for discharge of the contaminants pursuant to the Resource Management Act. For the one wastewater site, seven separate consents were required, ranging from discharge of odour to air, through to a consent to place a structure on the bed of a river.

5.3.4 Proposed scheme

Following significant discussions and dialog, the PCG developed a plan for progressive improvement reflected in potential consent conditions and these are summarised in Table 7.

These conditions were deemed most appropriate to meet the projects vision and objectives and also to allow for the long term growth of Cambridge. As with most consent applications, the process must be "effects based" and focus on what is best for the receiving environment and not how the applicant will arrive at that point. Utilising the best practicable option approach also means that cost and community affordability must be taken into account.

Table 7 Case study 1 – Consent compliance values Cambridge WWTP

Consent parameter	Proposed limit from December 2019	Proposed limit from December 2022
Flow	35,200 m^3/day	35,200 m^3/day
cBOD	Not exceed 10 mg/l 90^{th} Percentile 20 mg/m^3	Not exceed 10 mg/l 90^{th} Percentile 20 mg/m^3
Suspended Solids	Not exceed 10 mg/l 90^{th} Percentile 20 mg/m^3	Not exceed 10 mg/l 90^{th} Percentile 20 mg/m^3
Total Nitrogen	No more than 130 kg/day	No more than 52 kg/day
Total Phosphorus	Summer limit (Dec – May) 25 kg/day	Summer limit (Dec – May) 13 kg/day
E-Coli	126 cfu per 100 mls	126 cfu per 100 mls

To achieve the consent conditions, Waipa District Council proposed a staged approach for the treatment plant, breaking the works down to three stages over a number of years, these stages being:

- Stage 1 – Retain existing WWTP (with physical works of first upgrade to commence 2016)
- Stage 2 – Upgrade the plant to achieve treatment scenario 1 (as outlined in the AEE) between 2019 and 2022
- Stage 3 Further upgrades between 2022 – 2046

The basis of the proposed consent conditions is to utilise BNR type technology, whilst acknowledging that over time technology will improve and other tools will become available to be deployed to meet consent compliance requirements.

5.3.5 Costs

The estimated costs for the scheme are presented in Table 8 following and are contained within the Waipa District Council 2012-2022 Long Term Plan.

Table 8 Case study 1 – Predicted capital investment

Capital Expenditure Year	Cost Estimate ($ Million excl. GST)
2016/17	$7 Million
2017/18	$7 Million
2020/21	$6 Million
Total	$20 Million

Operational costs for a new plant have been estimated at $1.4 Million/annum with an additional provision for sludge management costs of $1.1 Million/annum.

Works associated with any upgrade outside of that outlined in Table 8, include significant ground preparation works at the site, abandonment of the current ground disposal process, a new outfall diffuser and pond desludging. This work has been estimated at a further $6 Million, bringing the total cost of the works to an estimated $26 Million.

Waipa District Council operates a wastewater rating system that collects rates from all properties connected to a scheme. Alongside the works required for Cambridge, work is also needed for the Te Awamutu WWTP which also requires a consent renewal.

The table below outlines the rates increases estimated over 10 years that will be required to cover the upgrade costs to Waipa District ratepayers connected to a network. These rate increases cover both the Cambridge and Te Awamutu WWTP upgrade projections.

Table 9 Waipa District Council predicted rates increases

Year	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
Wastewater Rate	$494	$450	$462	$475	$496	$516	$559	$727	$974	$1,049	$1,116
% increase		-8.9	2.7	2.8	4.4	4	8.3	30.1	34	7.7	6.4

5.3.6 Receiving environment

Cambridge WWTP currently discharges treated wastewater into the Waikato River near Pukerimu Lane, Cambridge. A Waikato Regional Council water quality monitoring site is located approximately 12 km downstream at Narrows boat ramp (immediately downstream of Airport Road bridge).

Monitoring results from 2015 to 2016 show that the Waikato River is within the NPS Freshwater Attribute A value for total oxidised nitrogen (which as explained in 3.4.2 equates to nitrate) and below the Attribute C value for *E.coli*. Absolute data was not able to be obtained for ammonia, however concentrations over the two years of data appeared to vary between below the detection limit to 0.055 g/m^3, and only exceeding 0.03 g/m^3 (Attribute A) once during this period. The Waikato River is likely to be within the Attribute A value for ammonia concentrations.

Approximately 55% of land cover within the catchment of the Cambridge WWTP has been categorised as nutrient contributing land. This indicates that there is a moderate proportion of land within the catchment that could be contributing towards the existing nutrient concentrations within the Waikato River. Further, the WWTP typically contributes approximately 0.03% to the total flow of the Waikato River. This is a small water quantity contribution compared to the overall volume of the receiving water body.

The water quantity contribution suggests nutrients and other outputs from the WWTP are likely to be diluted after reasonable mixing and provide a small contribution to existing nutrient and *E.coli* concentrations of the receiving environment.

Utilising the sensitivity analysis framework employed in this report, an upgrade of the existing Cambridge WWTP to a grade which meets the NPS Freshwater Attribute B for total oxidised nitrogen, ammonia and *E. Coli*. at the end of pipe would likely provide a "low" benefit to the existing water quality of the receiving environment. This is because the Cambridge WWTP sits in a catchment with a moderate proportion of nutrient contributing land cover, and the overall discharge quantity is less than 0.1% of the receiving environment flow rate.

5.3.7 Current state

Council has resolved to identify the $20 Million required for upgrades in its Long Term Plan; but has also committed to undertaking further works to determine if a more cost effective solution to the plant upgrade can be found. Over the past two years it has been working with NIWA and undertaking trials at the site utilising wetland treatment technology to determine if there are more environmentally sustainable options available to it for treatment.

Council is also looking to policy and planning mechanisms to enable a long term more environmentally sound approach for the site. This includes the emerging "Off Set Mitigation Policy" in Waikato Regional Councils Plan Change 1 (Healthy Rivers) process.

The consent application process for the new consents is currently on hold.

5.3.8 Case study relevance

Under the three main categories of interest this case study provides the following key facts:

- Resource consents – The case study provides an example of a treatment plant re-consenting process that is not only long and complex, but has also arrived at an outcome that will require a community to invest significantly in the upgrade of a plant if fully implemented.
- Cost estimates – A total investment of $26 Million is estimated by council to add a BNR type technology to the WWTP plant (with associated civil works) to service a projected population of 23,200.
- Receiving environment - The review of the WWTP contribution to receiving water quality in section 5.3.6 highlights that the WWTP discharge is small in relation to other diffuse sources of pollution in the wider catchment.

5.4 Case study 2 - Ngatea WWTP

5.4.1 Key facts

- Consent issued: June 2006
- Consent Expired: October 2015
- Plant type: Oxidation Pond
- Population Projections: *not available*

5.4.2 Background

The Ngatea WWTP has a consent to discharge up to 6050 m^3/day of treated wastewater to the Puhunga Canal and to discharge effluent to ground. The current consent expired in October 2015 and the Hauraki District Council is currently progressing though a consenting process. The treatment plant is currently operating under RMA s124 protection status. The application for the replacement consent was publically notified and only two submissions were received. Only one of these submissions wished to be heard with the issues raised by the submitter covering the following:

- Policy issues – NPS Freshwater
- Nutrient loadings
- Avian botulism management
- Microbial risk assessment.
- Review condition

It is understood that the consenting process is still progressing as Hauraki District Council, Waikato Regional Council and the submitter continue to work together to try and address the issues raised.

5.4.3 Current plant performance

The Ngatea WWTP is performing well for a plant of its type based on the data supplied by Hauraki District Council and reproduced in Table 10 below.

A recent upgrade of the Ngatea WWTP significantly improved the performance of the plant from a typical oxidation pond system to a much higher level of treatment. This higher level of treatment included the installation of a baffle within the oxidation pond to reduce short circuiting, and a tertiary rock filter to polish the effluent prior to discharge.

Table 10 Case Study 2 Ngatea WWTP performance data

Parameter	Ngatea WWTP 2009 - 2015 median	"Typical" primary oxidation pond median	"Typical" tertiary oxidation pond median
BOD, g/m^3	3	40	30
Suspended solids, g/m^3	15	50	40
TN, g/m^3	15	40	35
TP, g/m^3	5	8	8
E. coli, MPN/100ml	1,650	10,000	5,000

Given this high level of performance against other like plants, Hauraki District Council have not allocated any funding to upgrade the plant and propose to continue to operate the site to the current standard.

5.4.4 Receiving Environment

Ngatea WWTP currently discharges treated wastewater into a farm drain that flows in an easterly direction adjacent to Phillips Road. The farm drain flows for approximately 1 km before flowing into the Piako River, near the Piako River and Punanga Canal confluence. A Waikato Regional Council water quality monitoring site is located on the Piako River approximately 35 km upstream of the Piako River and Punanga Canal confluence at the Paeroa-Tahuna Road bridge.

Monitoring results from 2015 to 2016 show that the Piako River is within Attribute B for total oxidised nitrogen and below Attribute C for *E.coli*. Absolute data was not able to be obtained for ammonia, however concentrations over the two years of data appeared to vary between below the detection limit to 0.120 g/m^3, and exceeding 0.03 g/m^3 (Attribute A) on 12 instances during this period. The Piako River is likely to be within Attribute B for ammonia concentrations.

Approximately 100% of land cover within the catchment of the Ngatea WWTP has been categorised as nutrient contributing land. This indicates that there is a large proportion of land within the catchment that could be contributing towards the existing nutrient concentrations within the farm drain (i.e. the WWTP likely has a relatively low contribution to nutrient and *E. coli* concentrations within the receiving environment).

The WWTP typically contributes approximately 9.1% to the total flow of the farm drain. This is a large (large benefit) water quantity contribution compared to the overall volume of this receiving water body, thus nutrients and other outputs from the WWTP are likely to influence existing nutrient concentrations after reasonable mixing.

The level of benefit of the receiving environment (farm drain), from a WWTP upgrade, is not of the same magnitude for downstream the Piako River since the water quantity contribution of the WWTP compared to the overall volume of the Piako River is small.

Nutrients and other outputs from the WWTP are likely to be diluted after reasonable mixing and provide a small contribution to existing nutrient concentrations of the Piako River.

5.4.5 Case study 2 relevance

Under the three main categories of interest this case study provides the following insights:

- Resource consents – Unlike the other case studies presented in this report, the Ngatea WWTP case presents a situation where a waste stabilisation type plant is considered to be operating well and achieving a reasonable level of treatment and consent compliance. The consent renewal approach taken by Hauraki District Council relies on the fact that the plant is performing well. Hauraki District Council proposes that the operating permit remains the same as current and the plant configuration remains unchanged. The consent process undertaken by council drew very few submissions (2) with only one wishing to be heard. At the time of drafting this report, the consent process was still ongoing.
- Cost estimates – None have been specifically developed since Hauraki District Council plan to not upgrade the plant. The underlying issue that sits with a community such as Ngatea is the affordability of any upgrade to the system and the impacts on local rates. Analysis undertaken for the wider study suggests that an upgrade to this plant (if the consenting strategy is not accepted and an upgrade is required) would cost in the order of $3.7 Million with associated operational costs. Hauraki District Council have advised they expect the costs will in reality be higher, although detailed design of the upgrade would be needed to confirm this.
- Receiving environment - This case study has direct relevance to the wider study in that a plant upgrade may indeed improve the quality of the receiving environment, even with the high contribution of nutrients from the land in the surrounding catchment. However while the WWTP discharge influences the water quality of the direct receiving environment (farm drain) it is unlikely to have much influence on the downstream Piako River.

5.5 Case study 3 - Wellsford WWTP

5.5.1 Key facts

- Original consent issued: 1989
- Original consent Expired: December 1999
- Plant type: Secondary Treatment and discharge into Tributary of the Hoteo River
- New consent issued: November 2017
- New consent expires: November 2052
- Proposed Plant: Tertiary treatment and discharge
- Population Projections: Growth Area, 1800 PE and growing to 5000 PE

5.5.2 Background

The Wellsford WWTP was commissioned in 1972 and consisted of a waste stabilisation pond system and discharge to the receiving environment. The plant was designed to service the area of Wellsford, with Te Hanna being added on in 2006. Discharge from the plant represents a large portion of the volume of the flow in “Tributary A” (the receiving environment) and at times during summer can be all of the flow.

Prior to the amalgamation of the water industry in Auckland and the original consent term expiring, Rodney District Council (RDC) made an application for renewal. Given the challenges of operating and upgrading the plant, the renewal process took some time and was not completed prior to the 2010 Auckland City amalgamation process.

The plant has over the years failed to comply with a number of standards of its resource consent particularly with regards to total suspended solids, total inorganic nitrogen and faecal coliforms. In 2014 to address some of these issues, Watercare undertook an upgrade of the site by installing a new (temporary) Membrane Filtration Plant. This has rectified the non-compliance matters in relation to total suspended solids and faecal coliforms but not total inorganic nitrogen.

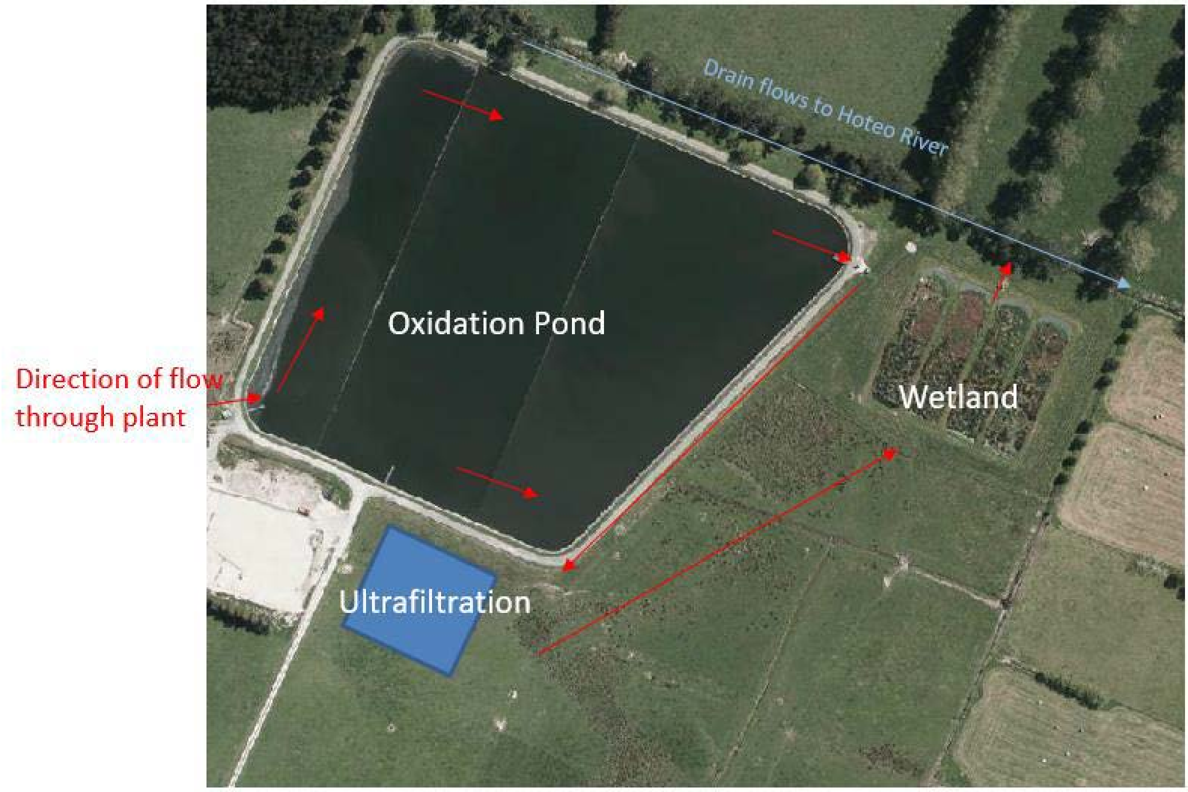


Figure 10 Case study 3 – Wellsford WWTP

5.5.3 Consent process

The discharge to the tributary was previously authorised under resource consent 886559. This consent expired on 31 December 1999. An application to replace the consent was lodged with, and accepted by, the then Auckland Regional Council six months prior to the expiry date to enable the consent to continue to be exercised while the new resource consent was being sought. Nine years following the initial application an updated application was lodged (in September 2009) by RDC. This application requested, amongst other things, a much shorter consent duration than previously.

Upon becoming responsible for the Wellsford WWTP, Watercare spent several years attempting to progress the consent application. In 2014, Watercare undertook a strategic wastewater servicing framework and implementation programme to consider long term (i.e. 30 – 50 year) wastewater servicing requirements for the Auckland Region. This included a review of the servicing requirements for Wellsford and Te Hana. This service review, along with changes to the policy framework in Auckland, lead Watercare to undertake a new assessment for a replacement application to update the one previously lodged. This included a new alternatives assessment supported by further technical investigations. This was informed through consultation with iwi, neighbours, and the wider community all utilising the RMA prescribed Best Practicable Option approach. A consent for a 35 year period was issued in November 2017.

The new consent proposed a two stage approach to manage growth and minimise environmental effects. Stage one of the contained consent conditions for an initial five year period whilst “Advanced Wetland Treatment” technology is assessed at the site. This technology is new to New Zealand and as such, Watercare suggest that it is appropriate to undertake a pilot programme to ensure that it meets expectations at the site. The five year period will enable the technology to be assessed under different conditions, as well as providing an opportunity to test different treatment media.The former and final consent conditions for the plant are outlined below in Table 11.

Table 11 Case study 3 – Wellsford WWTP current and proposed consent conditions

Parameter	Unit	Former	New	
			Median	*95th percentile*
BOD	g/m^3	<20	5	-
TSS	g/m^3	<30	15	20
Nitrate – N	g/m^3	-		7
Ammonia – N	g/m^3	-	-	4
TIN	g/m^3	<10	5	-
Total P	g/m^3	-	1.5	
Dissolved Oxygen	g/m^3	-	Minimum of 5	
E.coli	cfu/100 ml	<1000	260	-

5.5.4 Proposed scheme

As noted above, the Wellsford WWTP Upgrade is proposed to be an Advanced Wetland treatment process. The Advanced Wetland Treatment system is new technology in New Zealand, but has achieved excellent treatment quality results internationally.

The successful adoption of this technology has the potential to greatly benefit other communities throughout New Zealand. Upgrading to more advanced treatment processes can be very expensive and affording such upgrades is problematic for many local authorities, particularly those serving smaller communities.

The Advanced Wetland Treatment system produces treated wastewater at an equivalent standard to an advanced activated sludge process, but is much more cost effective. It also incorporates a more culturally sensitive process in that it involves land contact and enables the use of vegetation in the treatment process.

The plant at Wellsford will be designed to serve a population of approximately 5,000 PE by 2052 with an average design flow of approximately 1,730 m^3/day. Under the Wellsford WWTP upgrade proposal, the oxidation pond and existing inlet screen will be retained but all other treatment processes will be replaced. The new treatment process will comprise:

- Inlet screen and oxidation pond (existing);
- Alum dosing;
- New membrane filtration plant to replace existing temporary unit;
- Advanced Wetland Treatment; and
- UV disinfection.

The current discharge point to the Tributary will be maintained.

5.5.5 Costs

As part of the optioneering process, through the consent Watercare analysed capital and operational costs. Table 12 below outlines the costs of all shortlisted options (developed through the AEE process) along with that of the preferred option 4a (1).

Table 12 Case study 3 Wellsford WWTP upgrade cost estimates

Option Number	Wastewater treatment option	Total capital cost $ Million	Annual operational cost $ Million	Major receiving environment	Overall summary
4a (1)	Upgrade existing treatment plant with advanced wetland treatment, maintaining discharge at current location	9	0.4	Tributary / Hoteo River	Lowest capital cost. Includes land contact in treatment process options and maintains stream flow in Tributary A. With inclusion of restoration of Tributary A could have significant environmental benefits.
4a (2)	Upgrade existing treatment plant with advanced treatment process (SBR). Maintain discharge at current location	16	0.3	Tributary / Hoteo River	One of the lower cost options and maintains stream flow in Tributary A. Proven treatment technology. With inclusion of restoration of Tributary A could have significant environmental benefits.
7(a)	Land Disposal (Dual Discharge)	22	0.64	Land / Hoteo River	Includes land disposal for at least some of the year. Only removes discharge from Tributary A during low/no flows. Potential issues around lack of control over irrigation of Wellsford Golf Course. Could limit irrigation capability.

5.5.6 Receiving environment

Wellsford WWTP currently discharges treated wastewater into a tributary of the Hoteo River southeast of Wellsford. There are no routine Regional Council water quality monitoring sites located within the catchment (LAWA sites).

A Northland Regional Council water quality monitoring site is located in an adjacent catchment with similar properties as the Wellsford WWTP catchment. Monitoring results from 2015 to 2016 show that the adjacent catchment is within the Attribute A values for total oxidised nitrogen, within the Attribute B for ammonia and below the Attribute C for *E.coli*. Water quality results provided in a report prepared for the resource consent for the Wellsford WWTP indicate the water quality within the tributary is in the Attribute 'C or D category' for ammonia, Attribute A for total oxidised nitrogen and Attribute D or E for *E.coli*.

Approximately 94% of land cover within the catchment of the Wellsford WWTP has been categorised as nutrient contributing land. This indicates that there is a large proportion of land within the catchment that could be contributing towards the existing nutrient concentrations within the receiving environment. Further, the WWTP typically contributes approximately 6.1% to the total flow of the receiving environment. This is a large (large benefit) water quantity contribution compared to the overall volume of the receiving water body, thus nutrients and other outputs from the WWTP are likely to influence existing nutrient concentrations after reasonable mixing.

An upgrade of the existing Wellsford WWTP to a grade which meets the NPS Freshwater Attribute B for total oxidised nitrogen, ammonia and *E. Coli*. at the end of pipe would likely provide a moderate benefit to the existing water quality of the receiving environment.

The moderate benefit is based on a large proportion of nutrient contributing land within the catchment and large water quantity contribution to the receiving environment.

5.5.7 Current state

At the time of drafting this report, the consent, as described, has been granted and the pilot plant is being constructed on site. Once complete, operation of the pilot plant will inform final plant design and enable a fully operational Advanced Wetland Treatment system to be built.

5.5.8 Case study 3 relevance

- Resource consents – The case study highlights the complexity and timeframes that can apply to consent processes for WWTPs within smaller communities. The re-consenting process, in this particular instance, took almost 18 years from first application to the consent being granted. A large part of this delay may have been related to the previous Councils ability to fully fund upgrade costs. Whilst it was not possible to assign a direct cost to this process, due to the longevity, it can only be assumed that it was reasonably significant.
- Cost estimates – Watercare has identified upgrade options that range from a capital investment of $9 Million to $ 22 Million to serve a future population equivalent of 5000. These cost estimates are a useful reference for this study. The case study also highlights a potential lower cost option for councils when undertaking treatment plant upgrades required to achieve enhanced environmental outcomes, whilst managing capital and ongoing operation and maintenance costs. As outlined above the option Watercare has chosen to advance, Advanced Wetland Treatment systems are a new technology in New Zealand. Capital investment is estimated at $ 9M for this option. The work that Watercare is undertaking in not only proving its capability, but also constructing a full scale plant, will provide valuable information to other wastewater providers that are considering adopting a similar approach.
- Receiving environment – An upgrade of the existing Wellsford WWTP to a grade which meets the NPS Freshwater Attribute B for nitrate, total oxidised nitrogen, ammonia and *E. Coli*. at the end of pipe will likely provide a moderate benefit to the existing water quality of the receiving environment.

6. Upgrade cost development

6.1 Methodology and assumptions

To assess the cost of upgrades across a significantly large portfolio of plants that are varied in both size and nature, a generic approach was developed. The project team utilised the extensive knowledge available through a database of WWTP upgrade projects maintained by GHD. Each quarter, the Plant Cost Index (PCI) in this database is updated, and the index factor is applied to original costs to provide “Current Costs”. The method of calculating the PCI is from Brennan DJ & Greenfield PF (1994) and has been further developed, and updated using data from the ABS (Australian Bureau of Statistics).

Overall, (capital city) construction costs in Australia are comparable to New Zealand construction costs. Arcadis (2017) compared construction costs for 44 cities around the world and ranked Auckland #13 and Melbourne #14. Unit costs in a regional/remote areas are usually higher and this often coincides with smaller plant capacities. Use of data from Australia provided a broader range of projects than can be sourced out of New Zealand where there are limited examples of BNR/MBR type plants constructed.

Cost curves have been further validated using case study data and cost estimates from New Zealand WWTP upgrades.

6.2 Overview

To achieve the requirements of the NPS Freshwater in the key attributes, a number of possible treatment processes were assessed. This assessment looked at the ability of each type of process upgrade to understand if it could achieve the outcomes required to meet the Attribute B state at the point of discharge.

Table 13 following is the output of this assessment and shows that only an upgrade to a Biological Nutrient Removal (BNR) – Activated Sludge Plant, with an Ultra Violet disinfection would reliably give the outcomes required in all parameters. It should be noted that this table was developed to guide process selection for this study and is indicative only.

The assessment outcome was carried forward into a cost assessment for each WWTP and used to develop numbers for a national cost envelope.

Table 13 Assessment of treatment process capability to meet Attribute B

Process	E. coli (<1,000cfu)	Ammonia (<0.4 mg/L)	Nitrate (<3.5 mg/L)	All 3
Septic tank	No	No	Yes	No
Oxidation pond / waste stabilisation pond	No	No	Yes	No
Modified waste stabilisation pond	No	No	Yes	No
Trickling filter / Rotating biological contactors	No	No	Yes	No
Submerged aerated filter, recirculating filters	No	No	No	No
Activated Sludge	No	Yes	No	No
BNR – Activated Sludge Plant	No	Yes	Yes	No
+ Ultra Violet Disinfection	Yes	-	-	-
Waste stabilisation pond + Ultra Violet	Yes	No	Yes	No
BNR – Activated Sludge Plant + Ultra Violet	Yes	Yes	Yes	Yes

Notes:

- *This table has been developed by TWWS to guide process selection for this study and is indicative only. Process capability and reliability is not guaranteed in all cases and site specific constraints may apply*
- *WSP followed by only Ultra Violet could be problematic and is typically not recommended, as there may be issues with algae impacting on the performance and operation of the Ultra Violet.*

Figure 11 and Figure 12 show data from the cost database for Membrane Bioreactor (commonly called MBR plants), BNR – Activated Sludge plants and Ultra Violet plants.

Corresponding best-fit curves used as the basis for developing cost curves in section 6.3 are included.

For smaller plants (discharges < 5,000 m^3/d) the cost curves are based on MBR plant price indices. The development of these cost curves allows a simple process to be employed to understand the total potential upgrade cost for plants across the country.

The curves are based on utilising flow data to determine upgrade costs. The following flow types are used to determine capacity requirements for WWTPs:

- The Average Dry Weather Flow (ADWF) is the average daily rate of wastewater that needs to be collected and treated in a WWTP, usually with an allowance also for groundwater infiltration.
- The Peak Wet Weather Flow (PWWF) is the peak inflow rate that expected by a plant allowing for stormwater infiltration during high flow periods. For this study Peak Wet Weather Flow is taken as 5× Average Dry Weather Flow.

The Average Dry Weather Flow is used to estimate capacity for the BNR – Activated Sludge and MBR plants, and Peak Wet Weather Flow is used for the Ultra Violet plants. Flow rates are calculated based on population estimates.

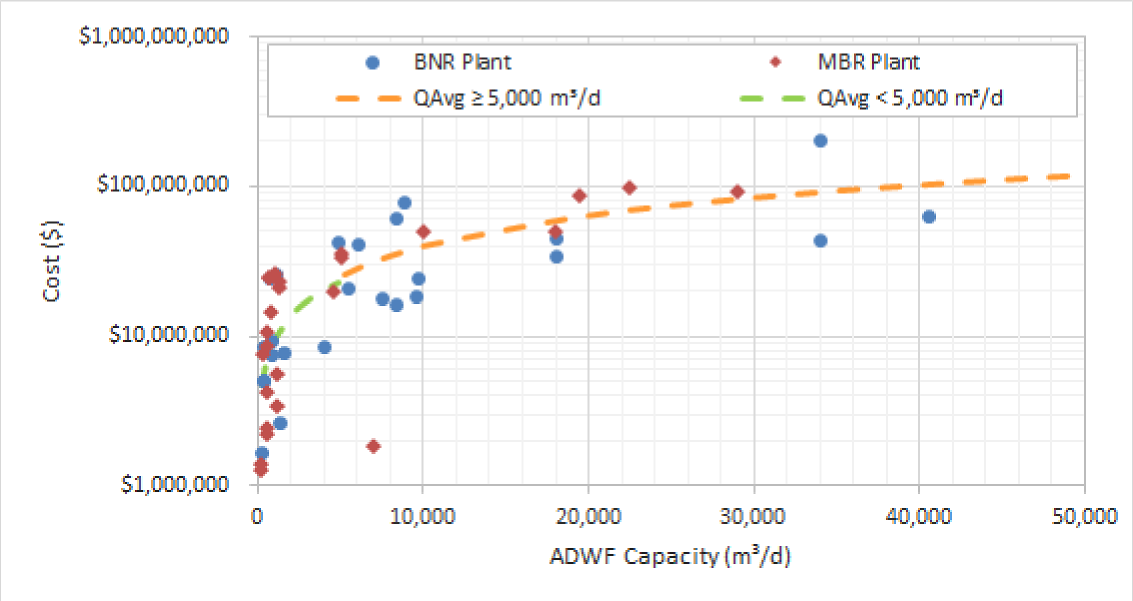


Figure 11 BNR – Activated Sludge cost nomograph

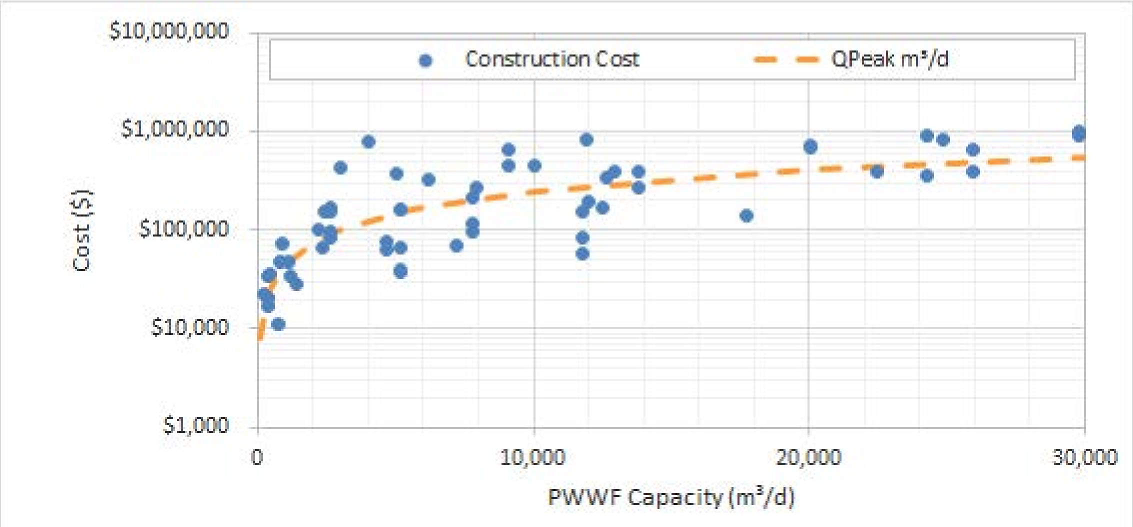


Figure 12 Ultra Violet cost nomograph

Small scale BNR process limitations

Based on guidance[5] for small package treatment plants (less than around 375 kL/d) nutrient release limits should be based upon the performance capabilities of the package plant, best practice environmental management and limits required for sustainable disposal.

Package treatment plants are often serviced on a routine basis (quarterly is common) and do not have skilled staff permanently managing them. It is thus important to note that many package plants available are not capable of achieving a high standard of nutrient reduction consistently; however, this may be adequate in the context of the receiving environment and method of disposal of wastewater.

Many municipal WWTPs are of a small size and may service small populations without any foreseeable growth. When these plants are managed by large councils it is reasonable to expect that standards of maintenance and operation will be high. However as discussed in section 8.8 a key concern from the industry is that installation of better treatment technology can be beyond the capacity of many small communities, both in terms of initial capital investment and ongoing operational expertise.

For the purposes of this study, it is assumed small plants (less than 375 kL/d) will not be upgraded to a BNR standard.

6.3 Cost curves

The following cost curves were developed from the nomographs presented in section 6.2:

Standalone Ultra Violet upgrade:

$$UV_{Cost} = 1{,}000\ E\ I\ Q_{Avg}{}^{0.74} \qquad \text{(Eq. 2)}$$

Where Q_{Avg} is the mean discharge rate in m^3/d, E is a cost index taken as 1.10 to represent a conversion from AUD to NZD and I is a markup index of 1.5 (description below).

Activated Sludge:

$$AS_{Cost} = 0.8\ BNR_{Cost} \qquad \text{(Eq. 3)}$$

It was assumed that the cost of an activated sludge upgrade is 20% less than the cost of a BNR upgrade. For larger plant upgrades (greater than 5 ML/d), the relative cost difference is expected to be less than 20%. For smaller plant upgrades (less than around 0.5 ML/d to 1 ML/d) BNR upgrade costs may be up to 100% higher than standard Activated Sludge upgrades.

Biological Nutrient Reactor with Activate Sludge (BNR-AS) upgrade:

$$BNR_{Cost} = \begin{cases} 195 \times 10^3\ E\ I\ R_{UV}\ Q_{Avg}{}^{0.56}, & Q_{Avg} < 5{,}000\ m^3/d \\ 76 \times 10^3\ E\ I\ R_{UV}\ Q_{Avg}{}^{0.68}, & Q_{Avg} \geq 5{,}000\ m^3/d \end{cases} \qquad \text{(Eq. 4)}$$

Where R_{UV} is a cost reduction factor of 0.97 where UV is not required and 1.0 where UV is included in the costing.

The cost curve for plants discharging < 5,000 m^3/d is based on MBR technology. It is assumed that small plants (discharge < 375 m^3/d) will be upgraded to activated sludge processes and not full BNR specification. Where existing activated sludge processes are to be upgraded to BNR or MBR technology it is assumed that the upgrade costs will be 25% of the complete cost.

[5] EM725v2- Queensland Department of Environment and Heritage Protection " Assessing applications for sewage treatment works – assessment guideline

6.3.1 Standard markups

The cost curves represented by Equations 2-4 are developed from a cost database that typically represents tendered construction prices. Considering the project scopes listed within the database a markup index (*I*) is applied to all upgrades. This includes:

- Markups of 10% for design services.
- An allowance of 20% for civil, mechanical and electrical works not represented in the nomographs.
- A contingency of 20% to represent potential site-specific additional expenses.

6.3.2 Resource consents

It can be a costly and time consuming process to obtain consents for either a WWTP resource consent renewal or new consents to permit a change in a treatment process. Often councils will combine consent amendments with providing for changes needed to better service the community e.g. increasing plant capacity and thus the rate of discharge to be permitted. A change to the process may require new consents e.g. for disposal of bio-solids.

Cost associated with gaining required resource consents to facilitate a plant upgrade have not been included in the cost curves; these are added separately as an assumed fixed expense based on plant size as shown in Table 14. Consenting costs are not included for upgrades that only consider adding Ultra Violet treatment to an existing plant.

Table 14 Assumed consenting costs

WWTP cize (population)	Assumed consenting costs
Large (>10,000)	$ 1,000,000
Medium (5,001 – 10,000)	$ 500,000
Minor (501 – 5,000)	$ 250,000
Small (<501)	$ 100,000

The values listed in Table 14 combine a number of costs associated with the resource consenting process and exclude design.

Typically, to gain a resource consent for a WWTP discharge the following costs apply:

- Legal fees
- Commission of technical consultant to undertake studies in support of an Assessment of Environmental Effects (e.g. planning, air quality, traffic management, ecology etc.)
- Hearing costs (consultant evidence preparation and presentation)
- Regional Council processing fees which may include payment for independent technical reviewers appointed by the regional and or district council
- Consultation costs (community meetings, consultation documents)
- Internal staff costs to manage and support the consenting process.

The values in Table 15 have been adopted in this study to recognise that there is a cost to gaining resource consents. In practise there will be considerable variation between projects depending on the complexity of an application and also whether there are any particular points of disagreement between the applicant, community and regulator.

6.4 Operation and maintenance

Operation and maintenance (O&M) costs typically include the following:

- Power
- Chemicals/Cleaning agents
- Membrane replacement (if required)
- Biosolids disposal
- Maintenance (civil structures, mechanical and electrical)
- Operator input and labour
- Testing and analysis

Upgraded from a waste stabilisation pond to a MBR/BNR introduces a number of additional costs. Based on examples provided to GHD the cost increase can be in the order of a multiplier of 2.5.

Rates used in the study are derived from plants operating in New Zealand. Study assumptions include:

- The increased cost of operating the upgraded plants is assumed to be \$0.82 per m^3.
- This is based on increased plant operational costs of \$0.71 per m^3 and solids disposal rates of \$93 per tonne.
- It is assumed that sludge is produced at a rate of 1 m^3 per 1,233 m^3 of wastewater and has a density of 1.4 tonnes/m^3.

These increased operational costs are applied as a mean rate across all plant upgrades, with 25% of this value being applied to the upgrades of existing activated sludge processes where applicable. In recognising that the operational costs of existing plants vary significantly due to factors including size, location and specific treatment types, a mean value approach is taken here to avoid implying undue accuracy.

6.5 Limitations

The cost estimates presented in this section have been developed solely for the purpose of evaluating potential order of magnitude capital costs for widespread treatment augmentation. They are sufficiently accurate to serve this purpose. They cannot be used for budget setting purposes as site specific considerations have not been investigated and the works have not been fully scoped. A functional design is recommended if a budget estimate is required.

7. Results

7.1 Compliance with NPS Freshwater standards

The primary objective of this study is to determine the costs of upgrading WWTPs to improve water quality in freshwater environments. The NPS Freshwater Attribute B has been set as a target and the basis of the assessment through considering the objectives of the NPS and the technology available for upgrading WWTPs.

Results in this section are presented via a primary assessment considering the costs associated with achieving the NPS Freshwater B attributes in the discharge of each WWTP.

Two supplementary assessments are included to provide further insight. The first is the sensitivity analysis described in section 4, which breaks down upgrade costs by the contribution that each WWTP has on the immediate receiving environment. The second considers upgrade costs only for those WWTPs which discharge to catchments where the water quality is below the B standard.

7.1.1 Primary assessment - WWTP discharge to meet Attribute B

Table 15 provides a summary of the estimated upgrade costs for New Zealand WWTP discharges to meet the Attribute B target of the NPS Freshwater at the plant by considering ‘best practice’ upgrades.

The costs are categorised by WWTP sized (based on contributing population) and estimates of probable capital and operating costs are given. These are cost increases over and above current asset capital value and current operational expenses. It is important to note that these are the costs to improve the quality of discharge from WWTPs and do not consider other factors such as the contribution the WWTP makes to overall receiving water quality.

To meet the B attribute target it is estimated that 145 WWTPs will require upgrades. The total capital investment to achieve this target is estimated to be between $1.4 and $2.1 Billion, with an annualised cost of $150 to $220 Million.

Of the WWTPs discharging to fresh water that require upgrading, 84% are servicing minor (<5001 people) or small populations (<501 people). The annual cost impact of the WWTP upgrades is greatest for the small communities (<501 people) at approximately $3,576 for each affected household. The average annual cost impact is $1,138 per affected household. The higher cost for the small communities represents the impact that sharing the cost of upgrades has on a smaller number of affected households. The annual cost impact is based on an interest rate of 6% per annum and repayment term of 25 years, plus the increase in annual operation expense associated with the upgrades[6]. The annual cost impact per household affected assumes that the costs associated with a WWTP upgrade will be meet by the households contributing to that plant.

Table 16 presents the cost breakdown on a regional basis. High household costs are estimated for the Taranaki and West Coast regions. These cases are highlighted by the small average size of the WWTPs and the high per capita discharge rates, indicating further analysis or investment in the networks could prove beneficial in conjunction with WWTP upgrades.

[6] Amortisation rates and terms are taken for consistency with BECA 2018, *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards*.

Table 15 Summary of WWTP upgrade costs to meet B Attribute target of NPS Freshwater at the WWTP by WWTP Size

WWTP Size (Population)	No. WWTPs affected	Population affected	Estimate of probable capital cost ($Million)	Estimate of probable operating cost ($Million/year)	Estimate of annual cost impact ($Million/year)	Annual cost impact per household affected ($/year)
Large (>10,000)	6	177,690	$290 - $430	$15 - $23	$38 - $57	$716
Medium (5,001 – 10,000)	17	111,490	$330 - $500	$11 - $16	$37 - $55	$1,106
Minor (501 – 5,000)	71	133,520	$610 - $910	$12 - $17	$59 - $89	$1,496
Small (<501)	51	12,660	$150 - $230	$1.6 - $2.4	$13 - $20	$3,576
Total	**145**	**435,370**	**$1,400 - $2,100**	**$39 - $59**	**$150 - $220**	**$1,138**

Table 16 Summary of WWTP upgrade costs to meet B Attribute target of NPS Freshwater at the WWTP –

Region	No. WWTPs affected	Population affected	Estimate of probable capital cost ($Million)	Estimate of probable operating cost ($Million/year)	Capital cost per population ($/person)		Operating cost per population ($/person/year)		Annual cost impact per household ($/year)	
					Affected	Total	Affected	Total	Affected	Total
Auckland	4	10,030	$32 - $48	$0.59 - $0.89	$3,996	$31	$74	$1	$1,044	$8
Bay of Plenty	6	20,320	$55 - $83	$1.2 - $1.8	$3,400	$314	$76	$7	$922	$85
Canterbury	12	5,270	$31 - $46	$0.28 - $0.41	$7,295	$79	$66	$1	$1,718	$19
Gisborne	1	640	$3.5 - $5.2	$0.034 - $0.05	$6,826	$135	$66	$1	$1,620	$32
Hawke's Bay	5	7,960	$34 - $52	$0.63 - $0.94	$5,412	$542	$98	$10	$1,408	$141
Manawatu-Wanganui	24	132,940	$330 - $500	$13 - $20	$3,116	$2,073	$125	$83	$994	$662
Marlborough	1	690	$2.7 - $4.1	$0.021 - $0.032	$4,973	$96	$38	$1	$1,154	$22
Nelson	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Northland	11	26,560	$100 - $150	$2.1 - $3.2	$4,815	$1,392	$99	$29	$1,285	$372
Otago	20	23,590	$120 - $180	$2.1 - $3.1	$6,268	$856	$109	$15	$1,617	$221
Southland	14	20,150	$84 - $130	$1.6 - $2.4	$5,185	$1,309	$101	$25	$1,367	$345
Taranaki	5	9,620	$74 - $110	$2.6 - $3.8	$9,630	$1,215	$332	$42	$2,929	$370
Tasman	3	2,580	$16 - $24	$0.22 - $0.32	$7,781	$349	$105	$5	$1,926	$86
Waikato	23	117,340	$240 - $360	$6.5 - $9.7	$2,576	$857	$69	$23	$731	$243
Wellington	6	39,630	$130 - $200	$4.8 - $7.2	$4,208	$358	$151	$13	$1,297	$110
West Coast	10	18,060	$120 - $180	$3.1 - $4.7	$8,188	$6,190	$217	$164	$2,315	$1,750
Total	**145**	**435,370**	**$1,400 - $2,100**	**$39 - $59 Million per annum**	**$3,957**	**$467**	**$112**	**$13**	**$1,138**	**$134**

7.1.2 Supplementary assessment one - Sensitivity analysis – land use contribution and relative flow rate

Table 17 breaks down the regional capital expenditure from Table 16 based on the relative contribution to the receiving environment each WWTP makes.

Considering the distribution of upgrade costs on a regional basis, the assessment shows that a relative high percentage of upgrade costs within the Bay of Plenty region are attributed to large contributing WWTPs. Similarly, significant proportions of upgrade costs for Taranaki, Tasman, Wellington and the West Coast are identified for medium and large contributing plants.

Following tables, Table 18 to Table 20 provide a more detailed breakdown of the analysis for the regions based on small, moderate, large contributing plants.

Table 17 Contribution based estimate of capital cost to upgrade WWTPs discharging to freshwater to meet NPS Freshwater Attribute B State

Region	Estimate of probable capital cost by relative contribution classification ($ Million)			
	Small	Moderate	Large	Total
Auckland	$14 - $20	$18 - $28	-	$32 - $48
Bay of Plenty	$4.1 - $6.1	$29 - $44	$22 - $33	$55 - $83
Canterbury	$22 - $33	$8.7 - $13	-	$31 - $46
Gisborne	$3.5 - $5.2	-	-	$3.5 - $5.2
Hawke's Bay	$30 - $44	$4.9 - $7.4	-	$34 - $52
Manawatu-Wanganui	$240 - $360	$73 - $110	$18 - $27	$330 - $500
Marlborough	$2.7 - $4.1	-	-	$2.7 - $4.1
Nelson	-	-	-	-
Northland	$41 - $62	$45 - $67	$17 - $25	$100 - $150
Otago	$59 - $89	$52 - $78	$7.4 - $11	$120 - $180
Southland	$52 - $77	$18 - $28	$13 - $20	$84 - $130
Taranaki	$2.2 - $3.2	$72 - $110	-	$74 - $110
Tasman	-	$16 - $24	-	$16 - $24
Waikato	$110 - $160	$92 - $140	$41 - $62	$240 - $360
Wellington	$4.7 - $7.1	$110 - $160	$20 - $30	$130 - $200
West Coast	-	$94 - $140	$24 - $36	$120 - $180
Total	**$580 - $880**	**$630 - $950**	**$160 - $240**	**$1,400 - $2,100**

Table 18 Summary of WWTP upgrade costs to meet B Attribute target of NPS Freshwater by region for large contributing plants

Region	Cost to meet NPS for ($ Million):			Best practice ($ Million)	Annual Opex ($ Million/year)	Annual cost impact per affected household ($/year)
	E.coli	Ammonia	Nitrate			
Auckland	-	-	-	-	-	-
Bay of Plenty	$0.46 - $0.69	$17 - $26	-	$22 - $33	$0.65 - $0.98	$1,096
Canterbury	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-
Hawke's Bay	-	-	-	-	-	-
Manawatu-Wanganui	$0.28 - $0.42	$14 - $21	-	$18 - $27	$0.26 - $0.39	$2,453
Marlborough	-	-	-	-	-	-
Nelson	-	-	-	-	-	-
Northland	$0.32 - $0.48	$13 - $19	-	$17 - $25	$0.4 - $0.6	$1,270
Otago	$0.11 - $0.16	$5.8 - $8.7	-	$7.4 - $11	$0.092 - $0.14	$2,000
Southland	$0.24 - $0.36	$10 - $16	-	$13 - $20	$0.27 - $0.41	$1,523
Taranaki	-	-	-	-	-	-
Tasman	-	-	-	-	-	-
Waikato	-	$33 - $50	$20 - $30	$41 - $62	$1.2 - $1.8	$714
Wellington	-	$16 - $24	-	$20 - $30	$0.59 - $0.89	$2,672
West Coast	$0.42 - $0.64	$19 - $28	-	$24 - $36	$0.48 - $0.72	$5,070
Total	**$1.8 - $2.7**	**$130 - $190**	**$20 - $30**	**$160 - $240**	**$4 - $5.9 Million per annum**	**$1,296**

Table 19 Summary of WWTP upgrade costs to meet B Attribute target of NPS Freshwater by region for moderate contributing plants

Region	Cost to meet NPS for ($ Million):			Best practice ($ Million)	Annual Opex ($ Million/year)	Annual cost impact per affected household ($/year)
	E.coli	Ammonia	Nitrate			
Auckland	$0.26 - $0.39	$13 - $19	$3.1 - $4.6	$18 - $28	$0.3 - $0.45	$1,001
Bay of Plenty	$0.43 - $0.64	$20 - $30	$5.8 - $8.7	$29 - $44	$0.53 - $0.8	$788
Canterbury	$0.13 - $0.19	$8.4 - $13	-	$8.7 - $13	$0.084 - $0.13	$1,193
Gisborne	-	-	-	-	-	-
Hawke's Bay	$0.058 - $0.087	$4.8 - $7.2	-	$4.9 - $7.4	$0.044 - $0.066	$1,424
Manawatu-Wanganui	$0.43 - $0.65	$60 - $90	$14 - $22	$73 - $110	$1.6 - $2.5	$1,548
Marlborough	-	-	-	-	-	-
Nelson	-	-	-	-	-	-
Northland	$0.47 - $0.7	$37 - $55	$8.6 - $13	$45 - $67	$0.85 - $1.3	$1,062
Otago	$0.79 - $1.2	$45 - $67	$23 - $35	$52 - $78	$0.93 - $1.4	$1,899
Southland	$0.2 - $0.3	$18 - $27	$6.2 - $9.3	$18 - $28	$0.21 - $0.31	$1,874
Taranaki	$1.5 - $2.3	$58 - $86	-	$72 - $110	$2.5 - $3.8	$2,882
Tasman	$0.25 - $0.38	$14 - $21	-	$16 - $24	$0.22 - $0.32	$1,926
Waikato	$0.85 - $1.3	$70 - $110	$33 - $50	$92 - $140	$1.9 - $2.9	$1,175
Wellington	$2 - $2.9	$85 - $130	-	$110 - $160	$4.1 - $6.2	$1,209
West Coast	$0.77 - $1.2	$72 - $110	$5 - $7.6	$94 - $140	$2.7 - $4	$2,054
Total	**$8.1 - $12**	**$500 - $760**	**$100 - $150**	**$630 - $950**	**$16 - $24 Million per annum**	**$1,447**

Table 20 Summary of WWTP upgrade costs to meet B Attribute target of NPS Freshwater by region for small contributing plants

Region	Cost to meet NPS for ($ Million):			Best practice ($ Million)	Annual Opex ($ Million/year)	Annual cost impact per affected household ($/year)
	E.coli	Ammonia	Nitrate			
Auckland	-	$11 - $16	-	$14 - $20	$0.29 - $0.44	$1,106
Bay of Plenty	$0.064 - $0.096	$4 - $6	-	$4.1 - $6.1	$0.046 - $0.068	$1,277
Canterbury	$0.31 - $0.46	$21 - $32	-	$22 - $33	$0.19 - $0.29	$2,082
Gisborne	$0.051 - $0.077	$3.4 - $5.1	-	$3.5 - $5.2	$0.034 - $0.05	$1,620
Hawke's Bay	$0.067 - $0.1	$24 - $37	-	$30 - $44	$0.58 - $0.87	$1,406
Manawatu-Wanganui	$1.9 - $2.8	$190 - $290	$2.1 - $3.2	$240 - $360	$11 - $17	$888
Marlborough	$0.036 - $0.054	$2.7 - $4	-	$2.7 - $4.1	$0.021 - $0.032	$1,154
Nelson	-	-	-	-	-	-
Northland	$0.5 - $0.74	$35 - $52	$13 - $19	$41 - $62	$0.86 - $1.3	$1,661
Otago	$0.82 - $1.2	$49 - $74	$14 - $21	$59 - $89	$1 - $1.5	$1,402
Southland	$0.47 - $0.71	$42 - $63	$0.25 - $0.37	$52 - $77	$1.1 - $1.7	$1,229
Taranaki	$0.028 - $0.042	$2.1 - $3.1	-	$2.2 - $3.2	$0.015 - $0.022	$10,800
Tasman	-	-	-	-	-	-
Waikato	$0.81 - $1.2	$72 - $110	$23 - $34	$110 - $160	$3.3 - $5	$570
Wellington	-	$4.7 - $7.1	-	$4.7 - $7.1	$0.063 - $0.094	$888
West Coast	-	-	-	-	-	-
Total	**$5 - $7.5**	**$460 - $700**	**$52 - $78**	**$580 - $880**	**$19 - $28 Million per annum**	**$912**

7.1.3 Supplementary assessment two - receiving environment targeted upgrades

The upgrade cost summaries presented in section 7.1.1 are developed with the aim of upgrading all WWTPs discharging to freshwater to the B standard. To supplement the primary assessment, this section evaluates the cost by targeting WWTP discharges to receiving environments that do not meet the B standard for each attribute.

Analysis of the receiving environments in section 3.4.3 shows poor compliance with *E.coli* standards with more than 50% of WWTPs discharging to an environment below the NPS Freshwater Attribute C standard. Ammonia and nitrate compliance was better, with less than 5% of WWTPs discharging to an environment of Attribute C standard or lower, though there is potential for notable error in this number due to the lack of site-specific data, particularly for the Ammonia attribute.

***E.coli* compliance**

Considering the low levels of *E.coli* compliance in the receiving environments and relative costs associated with reducing *E.coli* in WWTP discharges, there is merit in upgrading WWTPs discharging to environments with poor *E.coli* compliance.

These upgrades can represent the best value for money spent where the goal is to elevate water quality to at least the NPS Freshwater Attribute B standard across the three attributes.

Table 21 shows the estimated Ultra Violet upgrade costs for WWTPs discharging to environments that do not meet the Attribute B standard for *E.coli* by region (where UV treatment is not already installed). These upgrade costs are split into three benefit categories that represent the relative contribution of the WWTP to the receiving environment flows (see Table 5 for category divisions). Table 21 considers upgrades to 57 WWTPs with 11 of these falling within the large contributor category. A total cost of $7.09 – $10.64 Million is estimated to carry out these upgrades.

Ammonia and nitrate compliance

Section 3.4.3 indicates that there is relatively high compliance with the NPS Freshwater B standard for ammonia and nitrates in the receiving environments containing WWTP discharges. However this assessment is impeded by lack of data, particularly for ammonia.

Considering the category of plants with discharges that likely negatively affect receiving environments already below the B standard (i.e. those that likely have ammonia or nitrate discharge concentrations below the B standard where the receiving environment is assessed to be below the B standard), five plants are found. These five plants are highlighted by the ammonia attribute and the nitrate attribute does not suggest any upgrades for this analysis.

The upgrade costs for this category are estimated to be $67 - $91 Million; however, the lack of ammonia compliance data and the small sample indicates a greater (un-quantifiable) uncertainty exists than suggested by this range.

Targeted analysis of these plants would be required to improve certainty.

Table 21 Estimated UV upgrade expenses for WWTPs discharging to environments failing the NPS-FW B standard for *E.coli*.

Region	UV Upgrade benefit based on relative discharge ($ Million)			Total ($ Million)
	Small	Moderate	Large	
Auckland	-	$0.09 - $0.14	$0.17 - $0.25	$0.26 - $0.39
Bay of Plenty	$0.06 - $0.10	-	-	$0.06 - $0.10
Canterbury	$0.08 - $0.13	$0.01 - $0.01	-	$0.09 - $0.14
Gisborne	$0.05 - $0.08	-	-	$0.05 - $0.08
Hawke's Bay	-	$0.07 - $0.10	-	$0.07 - $0.10
Manawatu-Wanganui	$0.40 - $0.60	$1.74 - $2.62	$0.16 - $0.24	$2.30 - $3.45
Marlborough	$0.04 - $0.05	-	-	$0.04 - $0.05
Nelson	-	-	-	-
Northland	$0.06 - $0.10	$0.40 - $0.61	$0.32 - $0.48	$0.79 - $1.18
Otago	$0.42 - $0.63	$0.45 - $0.68	$0.09 - $0.13	$0.96 - $1.43
Southland	$0.28 - $0.42	$0.57 - $0.85	$0.07 - $0.11	$0.92 - $1.38
Taranaki	$0.03 - $0.04	-	$0.29 - $0.43	$0.31 - $0.47
Tasman	$0.16 - $0.24	-	-	$0.16 - $0.24
Waikato	$0.04 - $0.07	$0.34 - $0.51	$0.51 - $0.77	$0.90 - $1.34
Wellington	-	-	-	-
West Coast	$0.19 - $0.28	-	-	$0.19 - $0.28
Total	**$1.82 - $2.73**	**$3.67 - $5.51**	**$1.60 - $2.40**	**$7.09 - $10.64**

7.2 Waikato Region example - compliance with existing resource consents

As discussed in section 3.2.4, the level of consent compliance in the Waikato Region for the considered parameters is lower than expected. Levels of non-compliance in the key parameters are listed below:

- 30% *E.coli* non-compliance
- 30% ammonia non-compliance
- 18% total nitrogen (TN) non-compliance

This level of non-compliance at particular sites drives a need for plant upgrades to ensure that the plants comply. This is important to ensure that the impact on the environment is managed, but also that the consent holder complies with the consent order and is not at risk of enforcement action by the regulator. By understanding the parameters that each plant failed to comply against, the cost curves were able to be utilised to develop a total cost of upgrade needed for a plant to meet its consent.

This has been done and the results of this analysis is in the first column of Table 22.

Table 22 Estimated Cost to meet consent compliance Waikato Region

Parameter	To comply with consents* ($ Million)	To comply with consents^ ($ Million)
Waikato Region Total	$89 - $134	$52 - $78

* Based on upgrade cost assumptions; ^ Based on local knowledge

The question of whether this truly reflects the cost of required upgrades was then posed.

Given the project teams in depth knowledge of the regional infrastructure they were able to apply a filter where plants with minor non-compliance matters, or those related to operations and maintenance practices causing compliance issues, could be removed, leaving only those in need of major capital input left. This value is shown in the second column in Table 22.

This translates to a capital input of $52 - $78 Million into regional treatment plants that discharge into freshwater to ensure that consent parameters are met. This does not include the operation funding needed to operate either the new plants, or funding for those other sites that need more minor input to address non-compliance matters.

Costs for upgrading plants across all of New Zealand are not calculated, since as noted earlier in the report the data readily available indicates non-compliance is not major issue. However based on this Waikato example, with more detailed investigation there will be more cases around New Zealand identified and associated cost upgrades will apply.

8. Discussion

8.1 Future environmental requirements

This study has focussed on achieving the B Attribute values of the NPS Freshwater. At the time of writing this document, regional councils across the country are in varying stages of implementing the NPS Freshwater. To provide a consistent approach and an aspirational target, the study assumes that NPS Freshwater B Attribute states for *E. coli*, total nitrates and ammonia are the target to be met in receiving waters. This is consistent with the NPS Freshwater requirement that regional councils are expected to improve water quality over time in relation to human health. It is also consistent with community expectations for high receiving water requirements to be applied to discharges of sewage effluent.

8.2 Phosphorus

While the NPS Freshwater does not include an attribute value for phosphorus it does contain a requirement on councils to manage phosphorus as part of periphyton management. For many WWTPs resource consent conditions include phosphorous values. Phosphorus (Total or dissolved reactive phosphorus) is important with regards to water quality as it is an essential nutrient for plant life with too much phosphorus potentially causing rapid weed growth or algal blooms which can have adverse effects on stream/river/lake ecosystem health. Erosion, fertiliser use, and WWTPs are all sources of high phosphorus. More direct management of phosphorous discharges in the NPS Freshwater in future (by, for example, imposing limits and bottom lines) has the potential to impact on WWTPs.

8.3 Capital cost estimates

8.3.1 Combined upgrade considerations

Upgrade costs for WWTPs have been calculated assuming that individual WWTPs are upgraded and that the point of discharge remains the same. In some cases upgrading the discharge to a land based discharge or amalgamating existing WWTPs and wastewater networks may provide the optimal solution for capital and operational expense. These options would require individual case-by-case feasibility studies which have not been carried out in this report.

8.3.2 Consenting

Consenting plants under the RMA is a significant process and one that should not be underestimated. WWTP consenting processes can take both significant time (between 2 and 4 years) and cost (an average consent process would be in the order of $500,000 to secure). The cost of consenting is not a one off expense, with a return period similar to that which the capital cost are amortised over. An allowance has been made in section 6.3.2 for consenting costs and applied through capital expenses line item. Notwithstanding this assessment of costs, all three case studies in this report outline a consenting process that has been both long in duration and difficult to secure.

8.4 Operational costs estimates

The scope and timeframe of this work has not allowed for a complete and in depth analysis of the impact of the upgrades on local authorities, both from a balance sheet view and from a purely operational perspective. The following items have been considered only at a high level through this review and included in the summary table through the annual operational expenses line item.

8.4.1 Operational costs

Typically, the upgrades considered through this report see plants moving from low technology, low input, low resource need to operate (i.e. an oxidation pond system) to high input across the board. Based on the data available directly related to the operation of a BNR-Activated Sludge plant the increment in operating cost could be a factor of 2.5 applied to current.

8.4.2 Solids treatment and handling

A key aspect of any transition from waste stabilisation pond technology to BNR-Activated sludge type processes is solids treatment and handling.

Waste stabilisation ponds typically store solids within the ponds and these are periodically cleaned out, on an as required basis. Participants in the WaterNZ survey provide little data concerning solid management and anecdotally, through industry discussion, many waste stabilisation ponds have not been desludged for many years and there is a large volume of stabilised solids remaining in the systems.

BNR-Activated sludge plants produce sludge as part of the treatment process. This sludge needs to be managed on a day to day basis and disposed of in an environmentally sustainable fashion. This handling and disposal of sludge is factored into the operational costs but at a high level only.

Solids handling and disposal matters are complex and sit outside the scope of this report. It is however, important for the matter to be raised and the reader be aware of the complexity and costs that management can add to any treatment plant upgrade process.

8.5 Ability for small WWTPs to meet BNR discharge standards

Small treatment plants are often serviced on a routine basis (quarterly is common) and do not have skilled staff permanently managing them. It is important to note that many plants available are not capable of achieving a high standard of nutrient reduction consistently; however, this may be adequate in the context of the receiving environment and method of disposal of wastewater.

8.6 Operational capacity

Operation of a BNR-Activated sludge WWTP is a complex activity. If there is a drive to upgrade the significant number of waste stabilisation pond systems to more complex mechanical plant, effort is needed to ensure that the workforce capability is adequate for such a change.

One of the most significant challenges that the water industry is facing at this time is an aging workforce. Working in the industry is considered neither a career of choice nor desirable, and replacement staff are difficult to find. Based on feedback from the project focus group, there is some industry focus on this issue, but to date it has failed to make measurable progress over time. Coupled with this, the difficulty in attracting technical staff to the provinces has resulted in many councils being short of resources, applying under trained and unsupervised staff to the operations of key infrastructure services such as WWTPs.

Unless this significant skill shortage is addressed as part of any requirement to upgrade treatment systems, operational outputs will be less than optimal when new plants are installed.

8.7 Project data

A critical requirement for this project was the ability to access and utilise quality data on WWTPs. Early on in the project it became evident that the data set available for the project was not a robust and complete as it needed to be. The project team had access to data from multiple sources to undertake the analysis, including:

- Ministry for the Environment Freshwater database
- Water NZ Benchmarking
- Water NZ Cosine Database
- LAWA Data
- Water NZ WWTP Inventory

The majority of these data sets contained incomplete and/or old or out of date information.

A key finding for the project team in the early stages of the project is that there is simply no single and complete database within the country that contains all information related to WWTPs and associated infrastructure. The data sets for wastewater network information is even less accurate and available than the WWTP data, making analysis of this part of the network challenging.

The WaterNZ Benchmarking document contained the most comprehensive information on plants, piped assets and performance information, however participation in this process is voluntary and the data sets are also incomplete and can lack robustness at a detailed level.

This lack of a consolidated quality database required early effort from the project to develop a set of data to base the analysis outlined within the report on. The database was developed from a combination of the above data sets, an in depth analysis of Councils Wastewater Activity Management Plan on line, and importing of data supplied via direct contact with the industry.

This database now contains information on all WWTPs owned and operated by local authorities along with associated baseline performance data. The long term strategy to manage this database has not been determined as yet, but there would be some value in the wider industry taking ownership to maintain the information moving forward.

8.8 Industry focus group workshop

One of the key aspects of this project was the inclusion of the wider water industry in the process. A significant amount of industry discussion was held as the project was developed and there was a significant reliance on data supplied through those discussions and key industry contacts.

A key element of this industry involvement was holding a focus group towards the end of the project. The purpose of this focus group was to present the draft findings of the review to a small group of key industry players and gain input and insight into the proposed outputs through facilitated discussion.

The participants of the focus group were:

- Watercare Services Limited
- Water New Zealand
- Hamilton City Council
- Wellington Water
- Hauraki District Council
- Waipa District Council
- Western Bay of Plenty District Council
- Queenstown Lakes District Council

The outputs of the workshop provided significant input into the project and included suggestions ranging from technology challenges facing the wider industry to the resourcing challenges outlined in section 8.6 above. Input from the group has allowed a more accurate assessment to be made on operation costs of new plants, if installed, along with commentary on the challenges related to resource consenting processes.

8.9 State of current waste stabilisation pond upgrades

Over the last decade, many councils with waste stabilisation ponds have proceeded with upgrades to their plants. These upgrades have been completed, in many instances, in an attempt to comply with new standards or consents imposed by regulatory authorities, to address mounting environmental concerns or increase treatment capacity and cater for growth.

Whilst some of these upgrades have been successful, a mounting list have not.

There are a number of reasons behind this, ranging from new and untried technology being sold to councils without appropriate due diligence being undertaken, councils not understanding their system and its inputs resulting in inappropriate technology being installed. Also the high cost of a greenfield solution, such as an BNR-Activated Sludge type system (alongside abandonment of existing infrastructure that still holds residual value in council's balance sheet).

9. Conclusions

Receiving water quality is influenced by both diffuse and point source contaminant contributions from other activities and land uses within the catchments where there are WWTP discharges.

This study reviewed the likely contribution of WWTP discharges to receiving water quality based on other potential sources of nutrients within receiving water catchments and the relative rate proportion (i.e. WWTP discharge versus stream/river flow).

This assessment was used to allocate a small, moderate, or large contribution classification to each WWTP as a means of assessing the relative worth of investing in a WWTP upgrade.

The assessment showed that if investment is focussed on meeting NPS Freshwater Attribute B values at the point of discharge the estimate national capital spend would be in the range of $1.4 to $2.1 Billion. The assessment shows that the smallest investment (total capital cost in the range of $160 Million to $240 Million) is necessary to upgrade WWTPs that are having a "large" contribution to the water quality of their receiving environment. However a much larger investment (total capital cost in the range of $630 Million to $950 Million) is necessary to upgrade WWTPs that are having a "moderate" contribution to their receiving environment.

Of the WWTPs discharging to fresh water that require upgrading, 82% are servicing minor (<5001 people) or small populations (<501 people). The annual cost impact of the WWTP upgrades is greatest for the small communities (<501 people) at approximately $3,576 for each affected household. The average annual cost impact is $1,138 per affected household.

The higher cost for the small communities represents the impact that sharing the cost of upgrades has on a smaller number of affected households. The annual cost impact is based on an interest rate of 6% per annum and repayment term of 25 years, plus the increase in annual operation expense associated with the upgrades[7]. The annual cost impact per household affected assumes that the costs associated with a WWTP upgrade will be meet by the households contributing to that plant.

A number of challenges associated with upgrading from low technology waste stabilisation technology to higher technology treatment systems were identified. In addition to increased operating costs, there are challenges associated with sourcing suitably skilled operators and disposal of waste sludge.

Based on case studies included in the study it was also found that acquiring resource consents for WWTP upgrades can be a lengthy and costly process for councils.

[7] Amortisation rates and terms are taken for consistency with BECA 2018, *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards*.

10. References

- Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards , Beca 2018
- Faecal Sources in the Avon River/Otakaro, Heathcote River/Opawaho and the Estuary of the Heathcote & Avon Rivers/Ihutai, 2015, prepared by ESR for Christchurch City Council.
- Reducing Wastewater Overflows – A Pragmatic Approach to Optimise Capital Investment in Christchurch, Wilson and O'Brien, OzWater 2018.
- Dunedin City Wastewater Overflows, An assessment of receiving water environments, prepared by Ryder Consulting, November 2015.
- LAWA – Land, Air, Water, Aotearoa. https://www.lawa.org.nz/
- LCR – Landcare Research, Landcover database, Version 41
- NIWA – National Institute of Water and Atmospheric Research
- WaterNZ – New Zealand Wastewater Treatment Plant Inventory (2017)
- MfE – Ministry for the Environment, River Environment Classifications (2010)
- MfE – Ministry for the Environment, River Flows (2016) https://data.mfe.govt.nz/x/odt3cv
- Upgrading waste stabilisation ponds: Reviewing the Options, Ratsey -The Wastewater Specialists, Paper for water New Zealand Conference 2016.

11. Limitations

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Appendices

Appendix A – Common Abbreviations and Glossary

Common Abbreviations

Abbreviation	Definition
ADWF	Average Dry Weather Flow
BCI	Building Cost Index
BNR	Biological Nutrient Removal
BPO	Best Practicable Option
CSO	Combined Sewer Overflow
DWF	Dry Weather Flow
DWO	Dry Weather Overflow
E.coli	Escherichia coli
GIS	Geographical information System
NPS	National Policy Statement
MBR	Membrane Bioreactors
PCI	Plant Cost Index
PE	Population Equivalent
RDII	Rainfall Derived Inflow and Infiltration
RMA	Resource Management Act
SBR	Sequencing Batch Reactors
WSP	Waste Stabilisation Pond
WWTP	Municipal Wastewater Treatment Plant
WWO	Wet Weather Overflow
WWF	Wet Weather Flow

Glossary

Term	Explanation
Actiflo	Actiflo is a proprietary accelerated settlement process. It uses both coagulant and polymer to coagulate and flocculate suspended and dissolved contaminants, along with a fine sand (microsand) which provides a ballast to aid settlement. pH adjustment may be required to optimise coagulation. Settlement occurs in a lamella clarifier, and the microsand is recovered through a hydrocyclone. Removed contaminants require further treatment.
Affected Population	The population served by a WWTP requiring upgrade.
Annualised Costs	The annual cost of owning, operating and maintaining an asset over its entire life. For the purposes of this report, this is defined as the annual payments on a loan taken out to cover the capital costs of upgrades at an interest rate of 6% pa and a term of 25 years plus the increase in annual operating cost associated with those upgrades. [8]
Aquamats	AquaMats are a high-surface area media which hang down through the depth of WSP's. Biomass, including bacteria, protozoa and a range of higher life forms, grows on the surface of the media. Diffused air aeration is provided to increase the amount of oxygen available for aerobic organisms to break down contaminants, and to aid with water movement through the pond depth. By increasing both oxygen availability and the amount of biomass present in the WSP, the treatment capacity is increased.
Baffles	WSP's are prone to short circuiting and baffles can assist with preventing this.
BioFiltro	In a BioFiltro Plant, WSP effluent is sprayed over the surface of a bed of wood shavings, which is naturally colonised with microorganisms, forming a biofilm. The top layer of the bed is populated with earthworms which both aerate the bed and break down contaminants. The biofilm oxidises dissolved organics and other nutrients, while the worms break down solid organic material. The removal of ammonia is due to nitrification.
Biological Nutrient Removal (BNR)	Biological Nutrient Removal (BNR) is an activated sludge-based process used for nitrogen and phosphorus removal from wastewater.
Building Cost Index (BCI)	The appraisal method of estimating building costs by multiplying the original cost of the property by a percentage factor to adjust for current construction costs. The Building Price Index illustrates price development for newly constructed dwellings, that is, the price an investor or final consumer pays for a construction project.

[8] Amortisation rates and terms are taken for consistency with BECA 2018, *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards*.

Term	Explanation
Combined Sewer Overflow (CSO)	A CSO is a constructed overflow in a network that combines wastewater and stormwater in the same pipe.
Compliance	Discharge of treated wastewater in most situations is subject to a Resource Consent that permits the discharge. Resource Consents typically include a number of conditions that must be complied with. Compliance in this reports relates to compliance with Resource Consent conditions.
Contingency	When there is uncertainty in a cost estimate a contingency value is often added to cover this uncertainty. Contingency is calculated as a percentage of the total cost estimate.
Dry Weather Flow (DWF)	DWF refers to the average rate of flow in a wastewater network during periods of dry weather with minimum infiltration.
Escherida coli (*E.coli*)	Escherichia coli (abbreviated as *E. coli)* are bacteria found in the environment, foods, and intestines of people and animals. *E. coli* are a large and diverse group of bacteria and are used as an indicator that faecal contamination in water has occurred.
Floating wetlands	Floating Treatment Media or Floating Treatment Wetlands use microbes and bacteria in present within the root zone to remove nutrients in the water.
Geographical information System (GIS)	GIS is a framework for gathering, managing, and analysing data. GIS integrates many types of data. It analyses spatial location and organizes layers of information into visualizations using maps and 3D scenes.
Household	For this report, the number of households has been determined from population data and it is assumed there are 2.7 people per household.
Membrane Bioreactors (MBR)	MBR is an activated sludge-based treatment processes that uses membrane filtration to separate the treated effluent from biomass, rather than settlement.
Nutrient Sources	In rural catchments nutrients are commonly sourced from animal faeces and excess fertilizer. In the urban environment nitrogen and phosphorus is picked up in stormwater from a range of sources including wildfowl and animal faeces, fertilizers and other garden products.
Nutrients	Nutrients refers primarily to phosphorous and nitrogen. Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems however, in excess concentrations they can cause adverse effects on water bodies including excess algal growth. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive.

Term	Explanation
Partioned Ponds	Partitioning ponds to create several smaller ponds in series can significantly reduce the effects of short-circuiting and thus improve performance.
Population Category	The study distinguishes between WWTPs based on the following population categories: • Large – greater than 10,000 people • Medium – 5,001-10,000 people • Minor – 501 – 5,000 people • Small – Less than 500 people
Preliminary and General (P&G)	"P&G" is calculated in cost estimates as a percentage of the total capital cost and typically covers a number of costs that have not been specifically itemised such as site establishment and dis-establishment, contractor admin and project management, health and safety systems, temporary buildings and traffic management.
Receiving Water	Receiving water is the stream, river or lake that the WWTP treated water discharges in to.
Sequencing Batch Reactor (SBR)	Sequencing batch reactors or sequential batch reactors are a type of activated sludge process for the treatment of wastewater.
Total Population	The total population of a region that are served by Territorial Authority owned and operated WWTPs. This includes WWTPs discharging to land and the ocean environments.
Ultra Violet (UV) Treatment	UV treatment applies electromagnetic energy to micro-organisms and retards their ability to reproduce.
Waste Stabilisation Pond (WSP)	WSPs are large ponds that utilise a variety of mechanisms to remove pollutants from wastewater. These treatment mechanisms include settlement, and aerobic, anoxic and anaerobic biological processes.
Wastewater Treatment Plant (WWTP)	Municipal wastewater treatment plant

Appendix B – NPS Freshwater Attribute Tables

NPS Freshwater Attribute Tables (NPS-FW 2017, Appendix 2, pg. 30-40)

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Nitrate (Toxicity)		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95^{th} Percentile**	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
National Bottom Line	6.9	9.8	
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e. risk of death) for sensitive species at higher concentrations (>20 mg/L).

Note: This attribute measures the toxic effects of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Value	Ecosystem health		
Freshwater Body Type	Lakes and rivers		
Attribute	**Ammonia (Toxicity)**		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median*	**Annual Maximum***	
A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>0.24 and ≤1.30	>0.40 and ≤2.20	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
National Bottom Line	**1.30**	**2.20**	
D	>1.30	>2.20	Starts approaching acute impact level (i.e. risk of death) for sensitive species

* Based on pH 8 and temperature of 20°C.

Compliance with the numeric attribute states should be undertaken after pH adjustment.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	*Escherichia coli (E. coli)*				
Attribute Unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)				
Attribute State[1 2]	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100 mL	% exceedences over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL	Description of risk of Campylobacter infection (based on *E. coli* indicator)
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*

E (Red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%*

* The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

[1] Attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

[2] Attribute state must be determined by satisfying all numeric attribute states.

Appendix C – Wastewater network overflow example management approaches

C.1 Overview

The following Councils and network owners were interviewed and provided information about their network overflows:

Table C-1 Summary of Network Overflow Information

Network Owner	Information Received
Christchurch City Council	GIS Location map of all overflows Faecal source tracking report (ESR, 2015) City-wide wastewater optimisation - Phase 2 - preliminary solutions (WCS Engineering, April 2017) CCC Overflow Consent Modelling report Draft V12 Reducing wastewater overflows: a pragmatic approach to optimise capital investment in Christchurch (OzWater paper 2018)
Dunedin City Council	GIS Location map of all overflows Overflow events track sheet (monitored events since 2012)
Queenstown Lakes District Council	GIS maps of recorded dry weather overflows
Watercare Services Ltd	Auckland Wastewater Network - Annual Performance Report 1 July 2016 to 30 June 2017. Wastewater Network Strategy Executive Summary (Final June 2017) Watercare's Comprehensive Wastewater Network Discharge Permit Summary Presentation
Wellington Water	City maps including: Wellington Region Wastewater Overflow Locations and Consent Status Wastewater overflow locations

C.2 Christchurch City Council

There are a number of WWO's in Christchurch that discharge to both the Avon and Heathcote Rivers; ultimately entering the Avon-Heathcote Estuary.

Christchurch City Council (CCC) was granted a discharge consent for these overflows by Environment Canterbury (ECan) in 2014. The essence of the associated consent conditions was that the frequency and volume of overflows was required to reduce progressively to 2025. Consent conditions also required that a network model be used to demonstrate compliance, with the relevant condition being reproduced following:

"*For the purposes of determining compliance with Condition (5) and Condition (6), the overflow frequency shall be calculated using a field-calibrated computer model which predicts the annual average number of overflow events and total overflow volumes into the Avon and Heathcote Rivers and the Avon-Heathcote Estuary. The model shall use a long-term time series methodology to assess current system performance against actual rainfall records. The period of actual rainfall to be analysed shall be of 25 years duration (later amended to 15 years) and the period end shall be less than three years from the date of the analysis being undertaken*."

The basis for reducing the frequency of overflows as outlined in the resource consents is inferred to be largely a response to community concern rather than being due to impacts on receiving water quality. CCC has demonstrated through faecal mapping studies (summarised in section 5.1.1) that overflows from the wastewater network are a relatively small and infrequent contributor of contaminants.

The long time series modelling required to demonstrate consent compliance took several months. Due to unrepaired earthquake damage to the wastewater network, CCC staff expected that compliance with the permitted overflow frequency in the consent would not be achieved. Due to time constraints, the decision was made to proceed with preparing to apply for a new overflow consent, in parallel with the long time series modelling.

CCC chose to apply optimisation techniques to modelling rather than a traditional trial-and-error approach to determine projects to reduce overflows. Hence rather than looking at the costs and options for case by case removal or reduction of specific overflows; CCC analysed multiple combinations of storage addition, infiltration reduction, increased network conveyance and treatment capacity across the network. This approach informed a cost benefit analysis on how options would benefit the overall system in terms of overflow reduction.

CCC took this approach because the city network is complex and CCC wanted to determine the most cost-effective suite of projects to eliminate wastewater overflows for a range of design storms (6-month, 1-year and 3-year ARI). The long term target was to reduce all overflows to no more than 2 events per year. The model optimisation software used by CCC (Optimizer WCS) coupled with their wastewater hydraulic model allowed thousands of combinations of solutions to be tested to determine the most cost effective suite of projects to reduce overflows. For reference the optimisation process is reported in a paper prepared by O'Brien and Wilson (OzWater 2018).

Optimisation scenarios were performed sequentially with an increasing number of allowable improvement alternatives including:

- 1. Conveyance improvements along existing alignments
- 2. Conveyance improvements along existing alignments, flow controls, flow diversions and storage
- 3. Conveyance improvements along existing alignments, flow controls, flow diversions, storage and I/I reduction alternatives

Table C-2 summarises the results of the analysis and Figure C-1 shows graphical representation of the return on investment for improvement scenarios.

Table C-2 Comparison of Phase 2 Optimisation Solutions (O'Brien and Wilson 2018)

ARI Design Storm Scenario	Initial Capital Cost (NZ$M)		
	1. Conv. Only	2. Conv. + Storage	3. Conv. + Storage + I/I Reduction
6-Month	11	11	n/a
1-Year	88	62	n/a
3-Year	191	147	123

As it turned out, the long time series modelling did demonstrate that CCC largely complied with its overflow consent, with only six locations overflowing more frequently than the permitted twice per year. The results of the optimisation project were used by CCC to identify the most cost-effective capital projects to achieve full compliance with their resource consent conditions,

Based on the optimisation study CCC has developed a targeted program of capital works; with the initial capital investment planned of ~ $10 Million investment for improving conveyance and storage pumping flow to a trunk main with spare capacity. This is much less than the $ 68 Million originally envisaged in the previous Long Term Plan, demonstrating the benefits of the optimisation process.

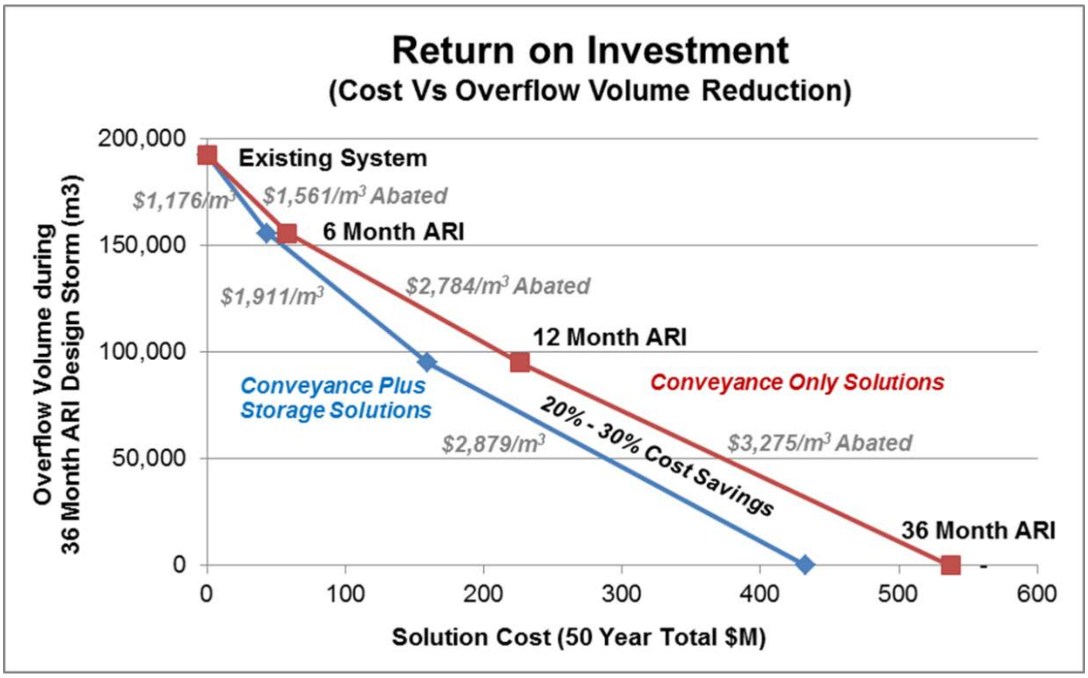


Figure C-1 CCC Analysis (2018) Return on Investment for Cost versus Overflow Volume Reduction.

Next steps for CCC include:

- Refine the design storms used for master planning based on 15-year LTS results;
- Additional flow monitoring and calibration; and
- Perform Phase 3 optimisation and capital works prioritisation based on the outcomes of the Phase 2 optimisation peer review and the revised design storm and updated hydraulic model.

C.3 Dunedin City Council

The [9]DCC Three Waters Strategic Direction Statement identifies 7 strategic priorities for the city including:

4. We will improve the quality of our discharges to minimise the impact on the environment.

5. We will ensure that, as a minimum, key service levels are maintained into the future.

These priorities were developed through a process of community consultation and have set the direction for investment in the three waters. The strategy specifically acknowledges the concerns of iwi associated with discharge of treated wastewater to the sea and land due to kaimoana becoming vulnerable to contamination.

In the strategy the DCC outlines an intent to reduce the number of wastewater overflows as a result of system capacity and an intent to engage the community "*in debate on the appropriate improvement targets and associated costs* "

Of relevance DCC has reported that the cost of preventing overflows (to both freshwater and the coast) is estimated at $35–$130 Million (2009–2011 figures). The forecast total spend over the next 10 years on improving the wastewater network is $48 Million.

The Dunedin city wastewater network currently incorporates a number of emergency and constructed overflows.

Constructed overflows to freshwater include:

- ◦Kaikorai Valley (Kaikorai Common and Kaikorai Valley Road, affecting the Kaikorai Stream)
- ◦North East Valley (affecting Lindsay Creek)

The Kaikorai Common and North East Valley overflows typically operate six to nine times per year. The Kaikorai Valley Road overflow is the most active, operating on average 19 times per year.

DCC hold resource consents that permit the constructed overflows and these direct the DCC to provide information to the public on the overflows, associated risks and ongoing progress for their prevention. A specific annual overflow frequency target is not applied.

In support of wastewater network discharge consent applications, DCC engaged Ryder Consulting Ltd (2015) to undertake a study on the impact of wastewater overflows on local ecology and receiving water quality. The study outcome support the findings from studies completed for other centres i.e. that overflows from the wastewater network in wet weather contribute, but are not the major source of receiving water contamination. The study noted that during any rainfall event, there is potential for a number of water quality guidelines and standards to be exceeded, as shown by annual stormwater compliance monitoring. However

[9] http://www.dunedin.govt.nz/your-council/council-documents/policies/3-waters-strategic-direction-statement

runoff from other landuses is a significant contributor and wet weather overflows by their nature are diluted and of short duration.

The study concluded that the ecological values in waterways examined were "*not particularly high and discharges from overflow conduits on their own appear to have little impact on biological communities*".

C.4 Watercare

Over the next 20 years, Watercare proposes to invest in the order of $3 billion in wastewater networks to improve performance and service growth. A significant part of that wastewater investment is the Central Interceptor, to enable growth in the central and southern areas of Auckland and also provide an interim solution for stormwater issues, providing time for Auckland Council to construct adequate stormwater infrastructure to service the area.

Watercare provides wastewater services to Auckland, New Zealand; from Te Hana in the North of the region to Waiuku in the South. The wastewater network consists of approximately 7,999 km of wastewater pipes, 167,264 manholes, 515 pump stations and 18 wastewater treatment plants.

The Watercare network incorporates both constructed wet weather overflows (termed Engineered Overflow Points by Watercare) and Combined Sewer Overflows (CSO's). The Auckland region is one of the few areas of New Zealand where CSOs are still operating within the network. Combined networks are designed to collect both stormwater and wastewater in a common pipe: with constructed overflow points (CSO's) that operate in rainfall events. Whilst the combined network only represents less than 4% of customers, it contains 68% of EOPs that overflow more than 12 times per year.

Wastewater can also discharge during wet weather conditions from manholes when there is lack of hydraulic capacity in the network and these overflows are referred to as "Type 3" overflows. A summary of the numbers of "EOPs" and Type 3 overflows currently identified in the Watercare network is provided below:

Table C-3 Summary of Watercare Engineered Overflow Points (EOPs) and Type 3 overflow locations

	Number of EOPs	Number of Type 3 Locations
2013	902	29
2015 (Wastewater Network Strategy)	787	29

A Comprehensive Wastewater Network Discharge Permit issued in June 2017 by Auckland Council permits overflows from the network. The allowable discharge frequency provided for by the permit is summarised as follows:

- An average of no more than two Wet Weather Overflow Events per Engineered Overflow Point per year; or
- –An alternative discharge frequency that can be shown to be the Best Practicable Option (BPO) if this cannot be achieved for one or more Engineered Overflow Points.

A suite of additional requirements are included as consent conditions with the underlying objective being that Watercare demonstrates and documents that it is a responsible network operator. This includes planning for growth in addition to progressively addressing existing legacy issues within the network.

Watercare is required to prepare, review and update a Wastewater Network Strategy every six years, and implement the Wastewater Network Improvement Works Programme set out in the Wastewater Network Strategy.

The first Wastewater Network Strategy Plan was delivered in June 2017 and the associated Wastewater Network Improvement Works Programme sets out how growth will be serviced, and how wastewater network performance will be improved over the next six-yearly planning period, as well as how works will be prioritised.

Watercare's approach to developing the strategy is summarised below:

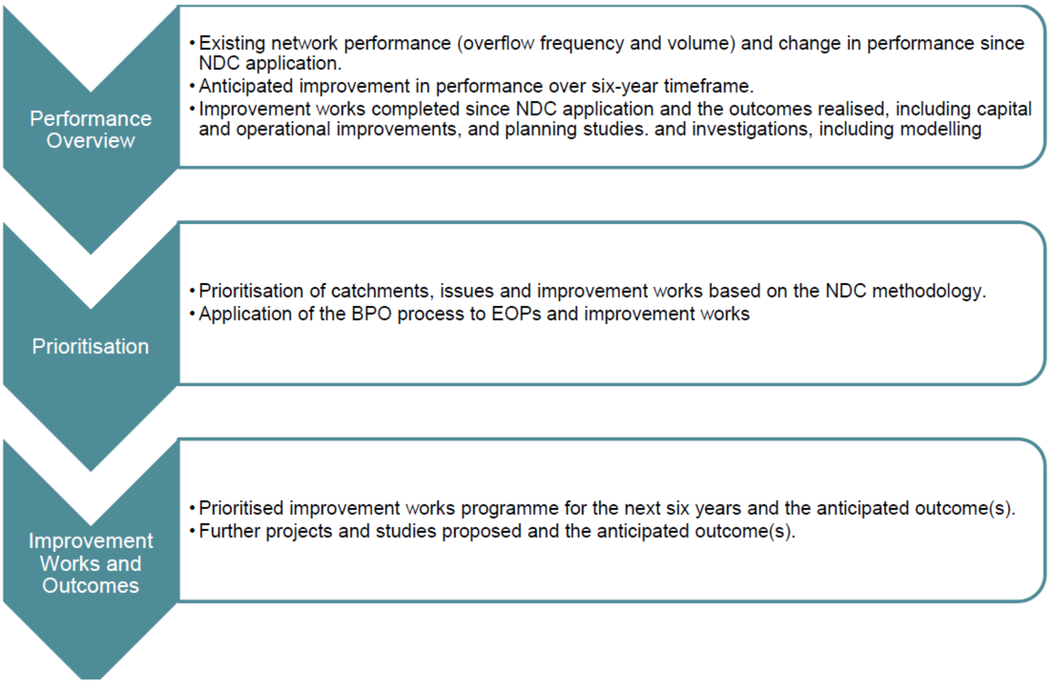


Figure C-2 Wastewater Network Strategy development process -Watercare

As well as developing new assets, Watercare is undertaking an Inflow and Infiltration (I&I) programme that will identify sources of stormwater entering wastewater networks, including those from private property.

Common to other parts of New Zealand Watercare is also investing in community education focussing on increased understanding of the impacts of incorrect disposal of fats and the various household items that block the system. For reference, the following pie chart (reproduced from Watercare Network Performance Summary 2016/17) shows the main causes of DWOs in the Watercare network in the 2016/17 period.

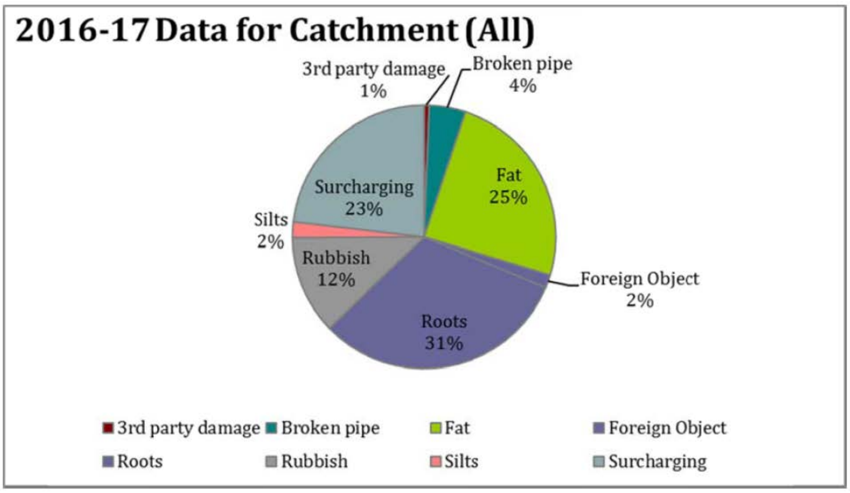


Figure C-3 Watercare networks 2016-17 data on network blockages

C.4 Wellington Water

Wellington Water is a shared-service, council-controlled organisation, jointly owned by the Hutt, Porirua, Upper Hutt and Wellington city councils and the Greater Wellington Regional Council. The wastewater network managed by Wellington Water incorporates 2391 km of pipeline and 191 pump stations directing wastewater to four WWTPs. All four WWTP's discharge treated water to the coastal marine area.

For this study Wellington Water provided maps of the known overflow points in their network.

The overflow points are categorised as follows:

- Emergency Overflow Connection, only known to overflow in rare circumstances (E)
- Not Consented & known to occasionally overflow in wet weather (N)
- Consented for wet weather wastewater overflow (Y)

Community concerns about wastewater overflows and consideration of iwi values is a key driver for Wellington Waters commitment to overflow reduction. GWRC policy as noted in section 3.3.1 signals that discharge of untreated wastewater is unacceptable and this is also a key consideration in developing strategy for network improvements.

Wellington Water has committed to a program of works to better characterise and then reduce overflows from their wastewater network.

This program of works includes development of master plans over the next five years for both stormwater and wastewater that will capture the issues and proposed solutions at a catchment wide level. Integral to these management plans will be stormwater and wastewater hydraulic models that will be used to inform how the networks perform under a number of scenarios and to assess what improvements will be needed to both manage future growth and reduce overflows. In taking this approach Wellington Water recognises that improvement in freshwater quality in their region can only be achieved if stormwater contamination is addressed in conjunction with improvements in the wastewater network. As an example the Hutt River water quality is significantly influenced by upstream rural activity as well as runoff from urban areas. The contribution of network overflows to long term receiving water quality is likely to be relatively minor in comparison.

For Wellington, the network is also aged in many areas and ongoing diffuse seepage into stormwater is likely of more concern in relation to influencing freshwater quality than occasional wet weather overflows, which tend to be short duration and flushed through the system quickly. Wellington Water have a network of 70 freshwater monitoring sites across their four city councils and have been tracking against the 2014 NPS-Freshwater “bottom line” for E coli since 2016. Refer Figure C-4 below. A preliminary analysis against the 2017 NPS-Freshwater indicates that 67 or the 70 monitoring sites would be grade E based on the compliance with 95%ile limit.

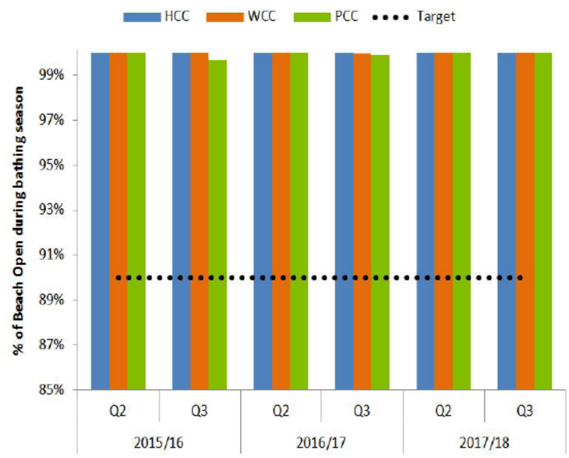
Wellington Water is at the start of the master planning program noted earlier and hence at this stage does not have costs developed for overflow reduction for all catchments. Work done in the Porirua catchment has estimated that an investment of $77 Million is required to reduce the current overflow frequency of approximately 10 per annum to 2 per annum. This estimate also accounts for projected population growth to 110,000 in a 35 year horizon. This catchment currently serves a population of approximately 82,000 as it includes both Porirua city and northern Wellington city suburbs.

It can be expected that the investment in network improvements to reduce overflows in the other catchments will also be significant.

Below are the results of our activities from 1 July 2017 – 31 March 2018.

Harbour quality

Target: Each monitored beach is suitable for recreational use 90% of the days during bathing season (1 Nov 2017 - 31 Mar)



Fresh water quality:
% of sites compliant

Target: 90% of all freshwater sites have a rolling 12 month median < or = 1000cfu/100ml3

- On Track
- Some concern
- Off track

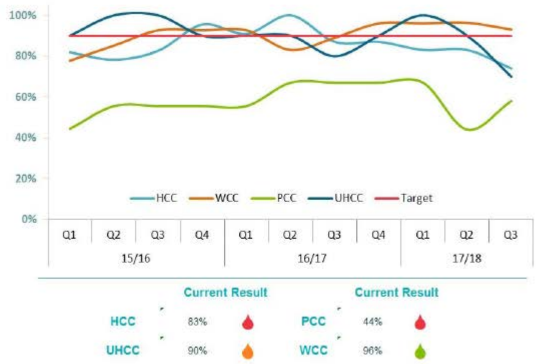


Figure C-4 Wellington Water quality monitoring summary 1 July 2017 to 31 March 2018

C.5 Queenstown Lakes District

The wastewater networks managed by Queenstown Lakes District Council (QLDC) do not have any constructed WWO's.

A key issue for QLDC is the occurrence of dry weather overflows caused by blockages from fat and building material.

Being a tourist centre there are many restaurants and hotels discharging wastewater to the network and poor practise by these operators has been the cause of many overflows. Gravel and debris from construction sites and infill housing is also a common source of foreign material in wastewater pipes.

In 2014 QLDC embarked on a programme of preventative maintenance that includes:

- Water blasting and then inspection of wastewater pipes with CCTV cameras.
- Identification and targeted remedial works such as construction of grease traps.
- Community education targeting construction companies, building trades and food outlets.
- Council has an inspector on site when new connections are made to the wastewater system, to ensure no construction material or fittings are dropped into the pipes.
- Information is provided to householders, through the Council's newsletter, displays and by direct mail, to help residents understand the consequences of flushing nappies and other inappropriate items down the toilet.

QLDC has also stepped up its enforcement with a Trade Wastes Bylaw introduced in 2015.

QLDC do not have any consents that relate to overflows, however they have commenced a project to prepare and lodge a consent application with the Otago Regional Council later this year. As part of this process QLDC are undertaking an assessment of current network performance and identifying areas of improvement in terms of reducing overflows.

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		Name	Signature	Name	Signature	Date
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