BEFORE THE HEARINGS PANEL SOUTHLAND REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	of an Application for Resource Consent to Discharge Water and Contaminants from the Invercargill City reticulated stormwater network to water **APP-201668843**
BY	**INVERCARGILL CITY COUNCIL**
	Applicant

BRIEF OF EVIDENCE OF Allan Thomas Leahy

Dated 27 July 2017

Filed by

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I, Allan Thomas Leahy state:

INTRODUCTION

1. My name is Allan Thomas Leahy.
2. I am Principal Technical Specialist in Stormwater Management at Stantec New Zealand Limited (Stantec), formerly MWH New Zealand Limited. I have been in this position since 2009.

QUALIFICATIONS AND EXPERIENCE

3. I have a Bachelor of Engineering majoring in civil engineering. I am a Fellow of the Institution of Professional Engineers New Zealand ('**IPENZ**') and a member of both the Institute of Public Works Engineering Australasia and WaterNZ. I was a founding committee member for the Stormwater Special Interest Group of WaterNZ. I was named Stormwater Professional of the Year at the May 2017 Stormwater Conference. I have been a judge for the Association of Consulting Engineers NZ (ACENZ) Innovate Awards of Excellence for 16 years and am an honorary life member of ACENZ. I am also an accredited RMA Commissioner.
4. I have over 30 years of engineering experience predominantly in stormwater management and design. I specialise in investigating, modelling, managing, consenting and designing systems to mitigate the effects of stormwater discharges from various types of land use change and activities.
5. For the past four years I have presented a course on Stormwater Management and Design for IPENZ and since last year have also presented a course on stormwater treatment. To the best of my knowledge these are the only stormwater courses currently offered in NZ outside of University. I have worked with the Auckland Council through the Auckland Unitary Plan hearings process, particularly on the flooding provisions and am continuing to work with them on the implementation of these provisions.
6. My evidence is in relation to Invercargill City Council's (ICC) Stormwater Discharge Consent Application lodged with Environment Southland.

CODE OF CONDUCT

7. I have read and am familiar with the Code of Conduct for Expert Witnesses in the current Environment Court Practice Note (2014), have complied with it, and will follow the Code when presenting this evidence. I also confirm that the matters addressed in this Statement of Evidence are within my area of expertise, except where relying on the opinion or evidence of other witnesses. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

INVOLVEMENT IN THE APPLICATION

8. I have been involved in considerations relating to the ICC Stormwater discharge consent application since around February 2016 when I was introduced to the system and discharge points in a site visit with ICC staff.

9. I have been involved in a number of discussions with ICC and Stantec staff on the application, reviewed phase one of the "*Invercargill Stormwater Consent Treatment Review _ Phase1 and Phase 2*" which was included within part 2 Appendix A to the "*Stormwater Discharges - Application Document*" and also reviewed the report "*Nutrient and Bacterial Loads in Urban Stormwater*" Stantec prepared for the three Southland District Councils in November 2016, which I will refer to later in my evidence.

SCOPE OF EVIDENCE

10. In my evidence I will:

    (a) Discuss the lifetime costs associated with stormwater treatment, referencing a paper presented at the 2017 stormwater conference on this matter and the implications in the Invercargill context.

    (b) Discuss stormwater treatment devices as summarised in the "*Invercargill Stormwater Consent Treatment Review _ Phase1 and Phase 2*" document and the issues around retrofitting stormwater treatment in existing urban areas, with particular emphasis on the Invercargill situation.

    (c) Summarise the outcomes of the "*Nutrient and Bacterial Loads in Urban Stormwater*" November 2016 report carried out by Stantec for the Southland District Council and its relevance to this application.

(d) Discuss the nature of the Invercargill City stormwater catchments with respect to the level of non-point source contamination likely to be generated from them and how these might be managed.

(e) Discuss alternatives for stormwater discharge that Invercargill City might have.

(f) Provide my conclusions on Best Practicable Options for the management of stormwater discharges for Invercargill City Council.

KEY MATTERS

Community Cost of Treatment

11. Over the last 25 years or more there has been an increasing emphasis in New Zealand on the management of contaminants transported and discharged in conjunction with stormwater discharges. In particular there has been an emphasis on the treatment of the non-point source pollutants by the use of specifically designed community based stormwater treatment systems.

12. This emphasis has led to the construction of a range of community based treatment devices in many of our urban centres. While the capital cost of these devices is split between being paid by developers (usually in greenfields situations) and the community (usually in retrofit situations), the operational cost is paid by the community.

13. This operational cost was discussed in a paper presented at the 2017 WaterNZ Stormwater conference held in Auckland by Dr Frank Tian, Auckland Council's Healthy Waters (Stormwater) Northern Operations Manager. I have attached this paper in Appendix 1 to my evidence.

14. In this paper Dr Tian advises that in Auckland "…*the total optimised replacement value of all public stormwater treatment assets currently accounts for less than 2% of the total asset value. However, at least 20% of Auckland Council's operations and maintenance expenditure is spent on these stormwater treatment assets to ensure their desired performance. In northern Auckland where there is a larger proportion of stormwater treatment assets, this percentage is over 30%."*

15. Dr Tian did not use this cost as an argument against stormwater treatment. In his verbal presentation he emphasised that point. His first conclusion in the paper, which I agree with, was that stormwater treatment related facilities play a critical role in improving runoff quality.

16. Dr Tian's paper focussed on optimising the operational practices for treatment devices. In my view though the paper also highlights that with the ongoing costs faced by the community of public treatment devices the outcomes achieved by the devices needs to be carefully considered to ensure that both capital and operational expenditure are focussed on the areas where greatest benefits will be achieved.

17. As a part of their work developing TR2013/043 "*Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment*" December 2013, Auckland Council has developed (an unpublished) spreadsheet to help estimate the costs of installing stormwater treatment. This spreadsheet provides estimated construction costs (excluding land costs) of $170,000 to $280,000 per hectare for a wetland servicing 5 Ha or less and $30,000 to $40,000 for a wetland servicing up to 40Ha.

18. Given the costs associated with stormwater treatment, I am very much of the view that to obtain the best outcomes both for our communities and the environment that we need to focus stormwater treatment efforts in areas where the greatest gains can be made in terms of limiting environmental effects, rather than trying to treat every single discharge.

Management at Source vs Treatment

19. While the targeting of treatment is starting to become more prevalent in stormwater management, it is different to the historical approach of applying treatment to all new discharges.

20. I note that the Auckland Unitary Plan, which (the stormwater provisions) became operative in November 2016, defines High Contaminant Generating areas, such as roads carrying over 5,000 vehicles per day, as areas requiring treatment. Other sites are considered on a case specific basis with the focus being on avoiding contaminant discharges to the stormwater system and hydrological changes, rather than simply relying on treatment.

21. I acknowledge that the Auckland and Southland regulatory environments are not the same. But I use this example from Auckland as more work has been done on the effects of urban stormwater discharges by the Auckland Council (and the legacy councils) than in any other region in New Zealand. This work is regularly used as the basis of evaluation up and down the country.

22. Treatment of stormwater discharges does not of course lead to "pure" water being discharged. At best it can only reduce the level of contamination in the discharge. Treatment efficiencies from designed stormwater treatment systems are variously quoted in typical stormwater references as varying between 10 and 90% removal of contaminants (once they are included within a stormwater flow). The percentage removal of contaminants typically depends on the nature of the contaminant and its concentration, the particular treatment mechanism, the antecedent conditions and the design of the system. I have included some references to treatment efficiencies in Appendix 2.

23. Given the above outcomes of treatment I consider that the first focus in stormwater quality management needs to be on avoiding contaminants getting in to the stormwater system. This can best be achieved by at source management on high risk sites.

24. I note that in the draft consent conditions included in Mr Dunning's evidence that there is considerable emphasis on identifying and managing the discharges from high risk sites. I agree with this emphasis as a sound stormwater management approach.

Existing and Future ICC Stormwater Discharges

25. I have considered the Invercargill context in terms of stormwater discharges. In particular, I note, the wastewater discharges present in the stormwater pipes in both dry and wet weather flows.

26. I have received advice from the Invercargill City Council Roading Asset Manager that around 11 percent of their Roads (or 31km out of 293km, from RAMM database) carry vehicle loads of over 5,000 vehicles per day. This increases to 13% when the State Highway infrastructure is included.

27. I note also in Ms Bennett's evidence that she considers the Invercargill stormwater discharges (excluding the wastewater component) as only having a minor effect on the receiving environment.

28. While I have seen no analysis of the makeup of roof types in Invercargill, my expectation is that it will be consistent with other New Zealand locations with a mixture of tiled, coated and uncoated corrugated iron. On this basis stormwater contamination generation from roofs would be consistent with other urban centres. Given that much of the development in Invercargill is older development, which is

less dense than more modern development I would expect overall contaminant generation would also be lower than in more recent developments.

29. Given the relatively low traffic densities, contamination from road sources would also be relatively low. Using the 5,000 vehicles per day threshold (as used in Auckland) this would only yield 11percent of the ICC controlled roads in the city as requiring treatment and that would only be triggered in the event of major redevelopment of that road corridor.

30. This leaves commercial and industrial sources and sewer inflow and infiltration (including cross-connections) as key areas to be addressed. I agree that the presence of wastewater in the stormwater system is undesirable and should not occur. However from a practical perspective I note that in every jurisdiction that I have worked in and made enquiries of, that to a greater or lesser extent there have been wastewater discharges included in the stormwater. These come from a mix of: illegal connections (both purposeful and from connection mistakes), blockages, overflows and infiltration through cracked or broken infrastructure.

31. I understand from Mr Loan's evidence that the ICC is investing in identifying and remedying sewer contamination sources and note the conditions in the draft consent conditions attached to Mr Dunnings evidence addressing this issue. I agree that from a stormwater discharge perspective that this should be a priority item for the ICC and I support continued efforts in this regard. I note though that no matter how much is invested in this area though, that I do not consider it likely that in practical terms the ICC will ever be able to guarantee that there is no wastewater in the stormwater. This is because the system is dynamic and a range of parties (not all within the ICC's control) influence the experience of cross-contamination.

32. I support the ICC's efforts to identify sources of wastewater discharges to the stormwater network, to isolate those discharges from the stormwater network and the inclusion of consent conditions to continue this work.

33. With respect to discharges from industrial catchments, I have read Mr Cocker's evidence on the work ICC has already carried out with respect to managing the risk of industrial site discharges to the stormwater system.

34. As I have already stated above, I support the proposed emphasis in the draft consent conditions attached to Mr Dunning's evidence with respect to identifying

and managing discharges from industrial and high risk sites. In this I consider that treatment is the last line of defence against contaminants from these sources. I consider that the stormwater management approach should first focus on the separation of potential contaminants from the stormwater system to limit the opportunities for cross contamination. From Mr Cocker's evidence this approach is already being employed in Invercargill.

35. The above measures are largely focussed on existing development. I note that risks from future developments are addressed within the Invercargill City Council Bylaw 2016/1 – *Code of Practice for Land Development and Subdivision Infrastructure*. This Code adopts the New Zealand Standard for Land Development and Subdivision Infrastructure, NZS 4404:2010 with amendments.

36. NZS 4404 addresses low impact design in the stormwater section and this is strengthened by an amendment within the ICC Code with the following statement "*The Developer shall implement low impact design principles for the treatment of stormwater. Where the developer does not believe that low impact design methods will be suitable the Developer shall provide reasons for this for approval by the Council."*

37. The Code therefore encourages the improved management of stormwater at or near source from future developments.

38. In my view, implementation of the proposed consent conditions will reduce the risks of contamination transported via the stormwater system impacting on the receiving environments from the existing system. Continued implementation of the subdivision code will reduce the risk of new contaminant sources adding to stormwater contamination.

Stormwater Treatment Options

39. An engineering assessment of the potential for treatment to be added to the existing stormwater network was carried out as part of the stormwater consent application in 2016. I reviewed Phase One of this assessment which was a desk top study of the system, contaminants generated and a literature review of treatment systems, their opportunities, constraints and efficacy. Phase Two comprised a field survey by an experienced engineer to confirm if the treatment devices identified during Phase One could be incorporated into the Invercargill Network taking in to account the specific constraints of each site. The assessment

document was included within the "*Stormwater Discharges – Application Document*" as Appendix A.

40. The assessment document appended to the application provides a summary on a treatment device and individual discharge basis. Rather than go in to the individual details here, in summary, constraints have been identified on both the ability to treat the contaminants of concern in catchments (in particular where they are wastewater) and on the ability to retrofit suitable treatment systems into the existing urban area.

41. The limitations of retrofitting stormwater treatment for Invercargill via large public devices are not surprising and would apply to most existing urban areas. These constraints really only leave opportunities to apply treatment on what I would describe as an opportunistic basis in conjunction with redevelopment. This is not unusual in an already developed urban area where infrastructure is already in place.

42. As I have described above, in my opinion these interventions should not simply be applied for every redevelopment but also need to focus on benefits to the receiving environment and the community as a whole. The key focus in my opinion needs to be on identifying the contaminants of concern and their sources and isolating or treating these at source rather than at the downstream end of the pipe system once they are diluted with stormwater.

43. Key source management techniques for point source discharges will be:

    43.1 Isolation of the discharge. That is, stop it getting in the stormwater by collecting it on-site or diverting it to the wastewater system, depending on the specific situation.

    43.2 On-site treatment prior to discharge into the stormwater system.

44. Key source management techniques for non-point source discharges would include:

    44.1 Stop generation of the contaminant, such as by the use of stabilised building materials.

    44.2 Treatment at source by either proprietary or bespoke design techniques. For example car parks or high use roads may be able to implement filters, swales or biofiltration type technologies to treat and manage discharges prior to reaching the piped system.

45. The keys with the above approach is that firstly it addresses stormwater quality prior to discharge into the Invercargill City Council system and prior to it being diluted with runoff from other sources, thus reducing treatment system size and both capital and operational cost. Secondly it focuses on the polluter addressing their discharge at source rather than the community having to address the issue. Thirdly it can be implemented into an existing urban area and allows for prioritisation of high risk areas.

46. I consider that the draft conditions of consent in Mr Dunning's evidence are consistent with this approach.

Nutrient Loads in Stormwater

47. As part of the Southland Economic Study undertaken by Environment Southland, Stantec were engaged by the three southland district councils' to investigate and provide initial advice on nutrient loads in stormwater discharges. The work involved review of information to identify documentation on nutrient loads within stormwater and then comparison of this against other sources of nutrient load, in particular from treated wastewater discharges from the Clifton wastewater treatment plant (WWTP). A copy of the report from this investigation is included as Appendix 3 to my evidence.

48. I understand that subsequent to publication of this report that NIWA have been engaged by Environment Southland to investigate nutrient loads further and in particular to provide more information on urban versus rural sources. NIWA requested and were supplied a copy of Stantec's report as an input into their study. I have not yet seen the outcomes from NIWA's work.

49. Key outcomes from Stantec's investigation were that:

49.1 There is limited information available that characterises New Zealand urban stormwater discharges in terms of nutrient loads.

49.2 It is difficult to compare urban and rural discharges and on the basis of the information available Stantec were not comfortable to draw conclusions on the comparison.

49.3 Total nitrogen and total phosphorous loads from Invercargill stormwater discharges were in the region of 3 to 5 percent of that generated by Invercargill's treated wastewater discharge from Clifton WWTP.

49.4 Faecal coliform loads from Invercargill stormwater discharges were in the region of 12 percent of that generated by Invercargill's wastewater discharges.

50. Based on this analysis I conclude that the nutrient and faecal coliform loads in the Invercargill stormwater discharges are considerably less (an order of magnitude less) that in its wastewater discharges. More substantive reductions in the nutrient and bacterial loads can be achieved by addressing wastewater discharges than stormwater discharges in Invercargill.

Alternatives to Existing Stormwater Discharges

51. I have been asked to consider and comment on what more Invercargill City could do from an engineering perspective in terms of providing alternative stormwater discharges. In particular whether there are alternative discharge techniques that could avoid some of the constraints imposed by the existing system and provide further treatment options.

52. The existing stormwater system is a predominantly piped gravity drainage system which is augmented by pumping during high flow or high tailwater (or receiving stream) conditions. Parts of the system have capacity to be gravity pressurised to enable discharge into streams passing through the city when these streams have elevated water levels, without the need for pumping. There are also some open channel systems including natural streams that form part of the drainage system.

53. The drainage system relies on infrastructure that has been installed over generations and uses the available topography to allow gravity flow to low points and outfalls.

54. Alternatives to this system might include: soakage, land disposal and infiltration or discharge to alternative outfalls.

55. I note that the NZWERF "*On-Site Stormwater Management Guideline*" recommends that soakage systems be at least 1.5 meters above groundwater levels and that the NZTA "*Stormwater Treatment Standard for State Highway*

Infrastructure" recommends a 3 meter separation. While I have not investigated the soils types and groundwater levels specifically I have been advised that the soil types and the groundwater levels in the majority of Invercargill preclude these methods of disposal.

56. To construct an interceptor system immediately prior to the existing outfalls that diverts stormwater discharges to an alternative discharge point while potentially being technically feasible would require considerable further piped infrastructure and pumping systems. Give the catchment areas, flows and volumes of discharge this alternative is simply not practically affordable to the community.

57. Based on the above I do not consider that there are any practically feasible alternative stormwater discharge methods for Invercargill that would achieve significant improvements in water quality.

Contaminant Load Model

58. I have been supplied with a copy of the meeting minutes for the pre-hearing meeting held on 23 June 2017. In particular I have been asked to comment on the proposal in Condition 11 to carry out annual contaminant load modelling using the Auckland Council's *Contaminant Load Model* (CLM) and the note in point 18 (j) of the minutes that "*Monitoring or modelling for contaminant loads from stormwater*" is a matter that remains in dispute.

59. I have been advised that the concern is that the CLM is not accurate for the Invercargill scenario because it has been developed in Auckland with volcanic soils rather than the Invercargill clay based soils.

60. My first response is that while the central Auckland Isthmus comprises volcanic soils, much of the region is actually comprised of weathered sedimentary rock comprising silts and clays.

61. To quote George Box though "all models are wrong, but some are useful". My view is that any contaminant load modelling is at best an approximation. As such the absolute numerical value of the answers is and always will be in question. The approximation provided by a model, can be improved with considerable effort expended on monitoring and calibration. My very strong view is that this effort is not justified in Invercargill in terms of the benefit that would be gained.

62. I personally would use a contaminant load model to help to identify possible high risk catchments and the potential benefits of mitigation measures. I would not rely

on the absolute value of the answers. A key point for me here is that even if we relied on the absolute value of the outputs, there is still the question of what effect these have on the receiving environment.

63. In terms of alternatives to the CLM, we are limited in terms of what is readily available. I am aware that:

    63.1 NIWA have developed a GIS based CLM. But the basic contaminant load engine supporting this model is the Auckland Council CLM.

    63.2 Dr Frances Chalmers developed a contaminant load model as part of her PhD thesis at the University of Canterbury, but this is based on Christchurch conditions and is not freely available for external use.

    63.3 The Christchurch City Council in its Waterways, Wetlands and Drainage Guide has also included a method for contaminant load estimation. This method though relates contaminant load to rainfall depth rather than land use, a concept I struggle with and is also stated as being calibrated for Christchurch, so is not necessarily suitable for Invercargill.

    63.4 Monash University in Australia developed the MUSIC model some years ago. MUSIC has however never been calibrated for New Zealand conditions and in my experience is not applied in New Zealand.

64. Based on the above and understanding the limitations of the CLM I am happy to use it in the Invercargill context.

CONCLUSIONS

65. Implementing stormwater treatment in particular in existing urban areas imposes considerable costs on the community. These costs are both capital and operational. While treatment is a very useful and necessary tool these costs mean that it needs to be applied after careful consideration of the both the costs and benefits and into priority areas. I do not consider treatment should be applied across the board.

66. I consider that in the Invercargill situation that the best gains for the community and the environment can be gained by identifying, isolating and removing specific contaminants from the stormwater discharges, rather than simply concentrating on treatment. This includes targeting wastewater discharges to the stormwater system, targeting potential industrial discharges before they happen and carefully considering and managing future development sites and their potential effects on the quality of stormwater discharges.

67. I do not consider that there are any practical alternative stormwater discharge options open to the Invercargill City Council.

68. I support the use of the Auckland Council Contaminant Load model as a tool to help identify focus areas and the possible effects of stormwater management mechanisms.

69. Overall, I consider the proposed conditions attached to My Dunning's evidence provide a good basis for the long-term management of stormwater in Invercargill.

Dated: 27 July 2017

Allan Thomas Leahy

Principal Technical Specialist (Stormwater Management)

Stantec New Zealand Limited

Appendix 1 – Paper Presented at 2017 WaterNZ Stormwater Conference

ARE WE FULLY PREPARED TO ENSURE THE LONG TERM PERFORMANCE OF STORMWATER TREATMENT FACILITIES?

Frank Tian, Jayesh Solanki, Andrew Skelton and Phillip Johansen – Auckland Council, New Zealand

ABSTRACT

Stormwater treatment facilities are required to minimise the adverse environmental effects associated with urban development. Development over recent decades has resulted in the construction of thousands of stormwater treatment facilities, and many of them have been vested in Council as public stormwater assets. Auckland Council is currently responsible for maintaining approximately 500 ponds or wetlands, 230 rain gardens, and 540 other types of treatment facilities such as proprietary filters, swales and coarse pollutant traps. With Auckland's housing market boom, an increasing number of stormwater treatment facilities will be built and vested in Auckland Council.

These facilities play a vital role in improving stormwater quality and mitigating hydrological deterioration from urbanisation. However, compared with conventional stormwater infrastructure such as pipes and manholes, special attention to these facilities are required to ensure their long term effectiveness and efficiency.

This paper outlines some of the special challenges of operating and maintaining stormwater treatment facilities in order to ensure their long term performance, and actions taken or to be taken by Auckland Council to overcome them, including:

- Providing for the long term operations and maintenance cost implications
- Special consideration for pond desilting activities
- Managing aquatic weeds and botulism problems
- Undertaking dam safety assessments
- Maintaining rain gardens within road reserves

This paper provides a high level review of the long term operation and maintenance aspects of stormwater treatment assets, so that we can ensure the long term performance of these facilities.

KEYWORDS

stormwater treatment facilities, financial forecast

PERSONAL PROFILE

Dr Frank Tian is presently Auckland Council's Healthy Waters Northern Operations Manager. He has 25 years of experience in many aspects of stormwater management and has previously held positions in the public sector, private sector, and in research. He received his PhD in 1997 in stormwater-related environmental issues from the University of Waikato and is a Chartered Professional Engineer.

1. INTRODUCTION

Twenty-five years have passed since the first publication of Technical Publication 10 (TP10): Stormwater Management Devices Design Guideline Manual by the legacy Auckland Regional Council. The management devices in TP10 are the means of capturing sediments and other contaminants, in order to meet the environmental objectives imposed by the previous Air, Land and Water Plan , and the new Auckland Unitary Plan (operative in part).

As a result, over the last twenty five years, thousands of stormwater management facilities have been constructed to protect or improve the receiving environment; and many of them have been vested with Auckland Council as public stormwater assets. Auckland Council currently maintains approximately 500 ponds or wetlands, 230 rain gardens, and 540 other types of treatment facilities (including proprietary filters, swales and coarse pollutant traps). With increasing development, more of these facilities will be built and vested in Auckland Council or Auckland Transport.

These facilities are very important in reducing environmental deterioration from urban development. However, the operation and maintenance of these assets, from the perspective of both technical skill requirements and financial implications, are quite different from those parts of the network associated purely with stormwater conveyance. Furthermore, compared with conveyance systems which have more than 100 years of maintenance experience, stormwater treatment devices have only a relatively short history. We are therefore still building up our knowledge and experience in relation to the long term operation and maintenance of these assets.

This paper outlines some special challenges of operating and maintaining water quality related stormwater facilities to ensure their long term performance, and actions taken, or to be taken by Auckland Council to manage these challenges, including:

- Providing for the long term operations and maintenance cost implications
- Special consideration for pond desilting activities
- Managing aquatic weeds and botulism problems
- Undertaking dam safety assessments
- Maintaining rain gardens within road reserves

2. PROVIDING FOR THE LONG TERM FINANCIAL IMPLICATIONS

Unlike stormwater conveyance systems which function only to collect and convey surface runoff, stormwater treatment facilities typically provide a number of functions and characteristics including:

A. Removal of pollutants; particularly sediments and metals, from runoff.
B. Managing stormwater flows and providing flood control
C. Increasing infiltration and recharging the groundwater (e.g. in peat recharge areas)
D. Providing amenity, ecological and social value. In other words, not only are they stormwater assets with functions of flood control and pollutant removal, but they are also important community assets. Many well-designed and constructed stormwater ponds or wetlands have become a signature features in their local communities. The Albany Lake as shown in Figure 1 is a good example. The public enjoy and utilise these community assets extensively and have a high expectation of the function and appearance of these assets.
E. Because these stormwater assets are constructed above, rather than below ground, they are more vulnerable to severe weather conditions such as strong winds, and long periods of drought or heavy storms. Littering and illegal dumping also cause damage to these above-ground facilities.
F. Legal requirements for regular inspection and maintenance. Nearly all stormwater treatment facilities were constructed as part of particular resource consent requirements. These resource consents not only regulate the design and construction of these facilities, but also the ongoing operation and maintenance.

Figure 1 Albany Lakes - stormwater assets with high amenity, social and ecological value

The above-mentioned functions and features mean that the long term operation and maintenance costs of these stormwater assets are significantly higher than those of conveyance assets. For example, the total optimised replacement value of Auckland Council's public stormwater assets are $5.6 billion. The total optimised replacement value of all public stormwater treatment assets currently accounts for less than 2% of the total asset value. However, at least 20% of Auckland Council's operations and maintenance expenditure is spent on these stormwater treatment assets to ensure their desired performance. In northern Auckland where there is a larger proportion of stormwater treatment assets, this percentage is over 30%. For the region as a whole, the proportion of treatment assets will increase, as the extent of new greenfield development grows.

These increased operational requirements need to be provided for when we prepare the long term financial forecast in the stormwater asset management plan, so that we have the required funding to maintain all stormwater treatment assets.

There are two major challenges facing us in doing so. The first is to forecast the number and types of stormwater treatment assets to be constructed and vested in council in future, in particular over the time frame of the LTP. At an operational level, knowing the number and types of stormwater treatment assets to be constructed and vested in council over the coming two years, is also a key undertaking. At Auckland Council, the Healthy Waters Operations team works with the regulatory teams to develop a database on the number of stormwater treatment facilities, particularly on ponds or wetlands, at different development stages.

Another challenge is to optimise our maintenance activities, from a financial perspective. For example, in Auckland, we remove more than 12,000 tonnes of sediments from a variety of treatment facilities including sediments removed from public catchpits. Nearly all of these sediments are contaminated and have to be dumped to the approved dumping sites at a considerable cost. If these sediments can be disposed of in a more economical way, we can reduce the maintenance and renewal cost of the stormwater treatment assets significantly. There are two approaches we can explore in future:

1. Working with Council's waste solutions department to explore the possibility of utilising their more favourable disposal rates negotiated with relevant suppliers, and
2. Looking at how we measure the sediment and dewatering the sediment on site which reduces transport costs and disposal costs. With over 500 ponds, we should be desilting around 25 ponds per year if they have to be desilted every 20 years. This promotes us to develop better ways of desilting and dewatering. We also need to look at desilting while the pond is fully operational. Setting up long term contracts may enable contractors to develop better methodologies and invest in the right equipment.

3. SPECIAL CONSIDERATIONS FOR POND DESILTING

After a certain period, the sediments settled in a stormwater pond or wetland must be removed. If a pond has a sediment forebay, that component will be desilted more regularly than the main body. After the amalgamation of all local authorities in the Auckland region in 2010, more than 50 stormwater ponds have been desilted. From desilting these ponds, we have gained experience and learnt some lessons. The following are the important considerations needing special attention.

A. Sediment quality: The sediments to be removed should be sampled and analysed before the pond desilting to decide where the sediments need to be disposed of.
B. Relocation of fish: A large number of fish, particularly eels, may exist in a pond even if the water quality does not appear high. Therefore, consideration must be given to the relocation of fish when developing a pond desilting methodology.
C. Bypass of runoff: Special consideration should be given to the bypass of runoff when a storm falls during the desilting process. This is particularly important for a large pond. Because of the large contributing catchment, even light rain can generate a significant flow going through the pond.

D. Determination of the quantity of removed sediments: This could cause potential contractual disputes if the specifications in the contract on how to measure the quantity of removed sediments are not clearly defined. The aspects to be considered include:
    a. using sediment volume or weight as the measurement unit;
    b. what evidence should the contractor provide for the claimed amount of removed sediments; and
    c. what the maximum acceptable water content level for the dumped sediments should be if sediment weight is used as the measurement unit.

    All these need to be carefully considered and well specified in the contract to avoid any potential claim disputes.
E. Informing the adjacent property owners about the potential impact on them from the pond desilting activity, particularly the potential odour issues.

4. MANAGING AQUATIC WEEDS AND BOTULISM

Two important but difficult issues for pond management are to manage the aquatic weeds and avian botulism problems during hot summers.

5.1 Aquatic weeds

Growth of aquatic weeds within a stormwater pond, particularly during hot summers, is inevitable. Normally a small volume of aquatic weeds in a pond will not affect the designed function of the pond, and these weeds may even help improve the treatment efficiency. However, when aquatic weeds cover a large portion of a pond, the following consequences may be encountered:

A. Increased flooding risk: the aquatic weeds can be washed downstream and block the outlet during a heavy storm, and
B. The pond does not look aesthetically attractive.

To manage the aquatic weed issue, the Healthy Waters Department has prepared a guideline which summarises the weed control methods and their pros and cons (Auckland Council, 2013). The most widely used methods for aquatic weed control in Auckland's stormwater ponds include chemical spray, grass carp, and mechanical/manual removal. This is still an area where more works are required to better manage the aquatic weeds.

5.2 Botulism

Avian botulism is a strain of botulism that affects wild and captive bird populations, most notably waterfowl. This is a paralytic disease brought on by the botulinum neurotoxin of the bacterium Clostridium *botulinum*, and it normally occurs during hot and dry summers. Avian botulism outbreaks attract a lot of attention from the public and the media.

To better manage this problem, the Healthy Waters Department has prepared an internal botulism management procedure. A pamphlet, which explains what avian botulism is and what Council and the public can do, has also been prepared.

The measures we currently take include:

A. Placing barley bales in ponds which have had avian botulism problems in the past. Barley bales reduce the presence of algae, and in so doing, keep the dissolved oxygen levels higher. This tends to reduce the incidence of avian botulism. Note that, based on our experience, the timing of the placement of barley bales in the ponds is important. Our experience is that the optimum time to install barley bales is in late October. Placement too early or too late may not achieve the desired results.
B. Erecting warning signs to remind people not to feed ducks while they are in the water, and reporting to Council if sick ducks are found.
C. If serious avian botulism occurs in a pond, early patrol of the pond by our contractors will be carried out in order to find the sick waterfowl earlier and therefore increase the chance of rescuing them successfully.

Avian botulism is a natural phenomenon that cannot be completely avoided. However, putting all possible measures in place will certainly mitigate the effects of avian botulism on waterfowl and improve the customer experience.

5. DAM SAFETY ASSESSMENT

Auckland Council's Healthy Waters Department manages 500 stormwater ponds which play an important role in improving stormwater quality and preventing flooding. However, some of these ponds have a large storage volume or a relatively high embankment which may pose risks to downstream people and their properties during a heavy storm.

NZ Building Act 2004 requires local authorities to carry out Potential Impact Assessment (PIC) and Dam Safety Assurance and Emergency Plans for all potentially risky dams in accordance with New Zealand Society of Large Dams Guidelines 2003 and The New Zealand Dam Safety Guidelines 2015.

Due to the large number of ponds owned by Auckland Council and their technical complexity, the Healthy Waters Department has formed a Dam Safety Assessment virtual team with members from planning, operations and capital project groups to lead the dam safety assessment.

The following tasks are undertaken by this team:

A. Collating relevant information for all potential large dams
B. Field surveying by registered surveyors for some old dams which we do not have reliable as-built information due to historical reasons
C. Undertaking dam condition assessment
D. Carrying out Potential Impact Assessment (PIC)
E. Undertaking independent review of the PIC assessment results

For those dams identified as being high risk from the PIC assessment, Dam Safety Assurance and Emergency Plans for each of them will be prepared, and these works are planned to be completed as soon as possible.

6. RAIN GARDENS WITHIN ROAD RESERVES

Rain gardens are being widely used to treat stormwater runoff. At Long Bay in Auckland's North Shore, more than 100 rain gardens have been constructed within public road reserves and more will be built in the near future. Not only do these rain gardens treat runoff from the public roads, they also beautify the local environment (refer to Figure 2).

Figure 2 Rain gardens in road reserves, Long Bay, Auckland

However, we have encountered a few challenges in maintaining these road rain gardens.

Similar to other areas in Auckland, oioi, a well-known New Zealand native plant, has been widely used as the major plant in the rain gardens in Long Bay, and they grow very well. However, for rain gardens within road reserves, the well-established oioi can have side effects on road users (refer to Figure 3).

Figure 3 A well-established road rain garden

The well-grown oioi lean towards the carriageway and footpath. When the footpath is not wide, it can affect its normal use, particularly for people with prams (please note that in Long Bay, Water Sensitive Design philosophy has been applied in the design of the development layout. Most carriageways and footpaths are relatively narrow). If rain gardens are constructed beside a driveway, the tall oioi tends to obscure the driver's view when they turn to the road. Council receives complaints about these plantings.

To mitigate this problem and to enable us to replace the clotted top layer of filtration media, we initially trimmed the tall oioi to approximately 300-400 mm for some rain gardens. Unfortunately, this caused the following problems:

A. The well-established thick oioi provided good shading, hence weeds scarcely grow. After the tall oioi was trimmed, sunlight easily penetrated through to the ground, resulting in faster growth of unwanted weeds.
B. The over-trimmed oioi do not look attractive aesthetically, and it takes a long period to grow back (refer to Figure 4).

Figure 4 Recovery of trimmed oioi in a road garden

To avoid these issues, we should consider:

A. Using other native plants that can grow in a similar environment but will not grow very tall, for rain gardens within road reserves.

B. For existing road rain gardens where oioi have been planted, do not trim them too short when they require trimming. Now we just trim the oioi that is leaning towards the carriageway and footpath and only trim the top part (seeds or flowers) for the tall Oi Oi. This can improve road safety and reduce inconvenience for footpath users, but avoid the above-mentioned problems.

7. CONCLUSIONS AND RECOMMENDATIONS

A. Stormwater treatment-related facilities play a critical role in improving runoff quality and reducing flooding risk. However, the on-going maintenance cost is substantially higher compared with conveyance assets. This should be fully considered in the long term financial forecast.
B. Careful consideration and detailed planning, such as runoff bypass, measurement and disposal of removed sediment, are required before desilting a stormwater pond to avoid possible adverse environmental consequence and contractual dispute.
C. Overgrowing aquatic weeds and avian botulism during hot summers are two challenges associated with stormwater pond management. Auckland Council's Healthy Waters Department prepared a technical guidelines to manage aquatic weeds, and has an internal protocol for avian botulism, to help the operations teams to better manage these challenges.
D. The Healthy Waters Department formed a virtual team to carry out Potential Impact Assessment (PIC) for the large stormwater ponds or those ponds with high embankments. For those dams identified as being high risks, Dam Safety Assurance and Emergency Plans will be prepared in accordance with relevant New Zealand

guidelines, to minimize the potential risk to the downstream people, properties and the environment.

E. Special consideration should be given to the selection and ongoing maintenance of plants used for rain gardens within road reserves, to avoid unnecessary inconvenience and safety concerns for road and footpath users.

8. REFERENCES

Auckland Council (2013). Review of Best Management Practices for Aquatic Vegetation Control in Stormwater Ponds, Wetlands, and Lakes. Auckland Council Technical Report 2013/026.

9. ACKNOWLEDGEMENTS

The work presented in this paper was funded by Auckland Council. Views expressed in this paper are those of the authors and do not necessarily represent the policies or position of the Council.

Appendix 2 – Treatment Efficiencies

Table 5-1
Expected contaminant reduction range of ponds (in %)(WMI, 1997)

Contaminant	Dry (flood)	Dry (ext. det.)	Wet
Total suspended solids	20-60	30-80	50-90
Total phosphorus	10-30	15-40	30-80
Total Nitrogen	10-20	10-40	30-60
COD	20-40	20-50	30-70
Total Lead	20-60	20-70	30-90
Total Zinc	10-50	10-60	30-90
Total Copper	10-40	10-50	20-80
Bacteria	20-40	20-60	20-80

From Auckland Regional Council: Technical Publication 10, Stormwater Management Devices: Design Guidelines Manual, May 2003.

Table 8-1
Long-term contaminant removal rates

Contaminant	Sized based on Runoff from 25 mm rainfall	Sized based on 2-year storm runoff volume
Total suspended solids	90	99
Total Phosphorus	60-70	65-75
Total Nitrogen	55-60	60-70
Metals	85-90	95-99
BOD	80	90
Bacteria	90	98

From Auckland Regional Council: Technical Publication 10, Stormwater Management Devices: Design Guidelines Manual, May 2003.

Table 6-6: Representative removal capability of treatment systems for a number of urban pollutants of concern. Adapted from Auckland (Hartwell & Silyn-Roberts 2002) and international (Schueler 1987) data.

Treatment System	Pollutant Removal Efficiency (%)						Comment
	Solids	Phosphorus	Nitrogen	BOD	Trace Metals	Bacteria	
Grassed Swale	20-60	20-40	20-40	20-40	20-60	20-40	High potential for re-suspension of sediment with any storm flow.
Soakage Basin	60-100	40-80	40-80	20-60	40-100	60-100	Dependent on extent of overflow permitted.
Dry Detention Basin	40-80	40-60	20-40	20-40	20-60	0-40	Efficiency in trace metal reduction is reduced for more soluble elements.
Extended Detention Wet Pond	60-80	40-80	40 -60	20-60	40-80	40-80	Sizing relative to runoff is volume dependent. Bacteria removal dependent on bird population for the system.
Wetlands	60-80	40-80	20-60	20-40	40-80	60-100	Removal includes soluble trace metals. Bacteria removal dependent on bird population attached to the system.

Note: The level of pollutant removal will be subject to the level of provision of treatment system volume or surface areas relative to catchment runoff. As a general rule, the higher the concentration of in-flowing pollutants, the greater the degree of removal.

From Christchurch City Council: Waterways, Wetlands and Drainage Guide, Part B Design

Appendix 3 – Nutrient and Bacterial Loads in Urban Stormwater, November 2016

REPORT

NUTRIENT AND BACTERIAL LOADS IN URBAN STORMWATER

Prepared for Southland District Council

8 November 2016

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Southland District Council

Nutrient and Bacterial Loads in Urban Stormwater

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1 Introduction

1.1 Scope of Work

The scope of this report is to set out the findings of the initial task from MWH's Notice to Client #4. That is:

- Review the availability of contaminant annual load data to predict loads from stormwater catchments and the removal rates for treatment devices for bacteria (*E.coli*) and nutrients (N and P).
- Based on available information, estimate the bacteria (*E.coli*) and nutrient (Nitrogen, N, and Phosphorus, P) load from urban stormwater in Invercargill as compared to that from treated wastewater for Invercargill, as a whole.

It is intended that these findings and estimations will provide an order of magnitude assessment on the relative contributions from the urban stormwater and wastewater sources.

2 Information Review

2.1 Sources

The sources reviewed were:

- Contaminant Load Model (CLM), Auckland Council, September 2010 and supporting documentation TR 2010/003 Contaminant Load Model User Manual and TR 2010/004 Development of the Contaminant Load Model .
- TP10 - Stormwater management devices design guideline, Auckland Council, 2003
- Waterways, Wetlands and Drainage Guide, Christchurch City Council, February 2003
- Stormwater Treatment Standard for State Highway Infrastructure, NZTA, May 2010
- On-site Stormwater Management Guideline, NZWERF, October 2004.

2.2 Contaminant Annual Load Data

The available information and limitations on contaminant annual load data regarding bacterial (*E.coli)* and nutrients (N and P) are summarised below based on the specific source documents.

2.2.1 Contaminant Load Model (CLM), Auckland Council

The Contaminant Load Model (CLM) is a spreadsheet-based model. The model is simple in principle - the area of a particular land use (source) within the area being studied (the catchment) is multiplied by the quantity of contaminants discharged from that land use (source yield) to provide an annual load from that source.

Given that the calculation of load does not use the local rainfall conditions, the model can be applied across New Zealand. It has not been calibrated for the specific Auckland weather patterns. This translation across NZ assumes that the generation of contaminant load from activities in the catchment are similar across the country, which is considered a reasonable assumption.

The main limitations from the CLM are:

- N, P and *E.coli* are not included in the model
- There is no explicit explanation for N, P and *E.coli* (or the lack of) in the Contaminant Load Model User Manual or in the Development of the Contaminant Load Model.
- A value from a load range is selected by the CLM spreadsheet for the quantity of contaminants discharged from that land use (source yield) to provide an annual load from that source. This potentially masks the inherent variability in contaminants loads from stormwater sources, unless this variability is applied independently

2.2.2 TP10 Stormwater management devices design guidelines, Auckland Council

The main limitations are:

- *E.coli* are not included in the contaminant loading ranges for various land uses as per the figure below. There are some contaminant loading ranges for FC (Faecal Coliforms), which can be used as an indication of *E.coli* load. TP10 contaminant loading ranges is provided in Figure 2-1.

Table 4-4
Contaminant loading ranges for various land uses
Figures are in kg/ha/yr except for FC (no./ha/yr)

Land use	TSS	TP	TN	Pb (median)	Zn	Cu	FC	COD
Road	281-723	.59-1.5	1.3-3.5	.49-1.1	.18-.45	.03-.09	1.8E+08	112-289
Commercial	242-1369	.69-.91	1.6-8.8	1.6-4.7	1.7-4.9	1.1-3.2	5.6E+09	306-1728
Residential (low)	60-340	.46-.64	3.3-4.7	.03-.09	.07-.20	.09-.27	9.3E+09	NA
Residential (high)	97-547	.54-.76	4.0-5.6	.05-.15	.11-.33	.15-.45	1.5E+10	NA
Terraced	133-755	.59-.81	4.7-6.6	.35-1.05	.17-.51	.17-.34	2.1E+10	100-566
Bush	26-146	.10-.13	1.1-2.8	.01-.03	.01-.03	.02-.03	4.0E+09	NA
Grass	80-588	.01-.25	1.2-7.1	.03-.10	.02-.17	.02-.04	1.6E+10	NA
Pasture	103-583	.01-.25	1.2-7.1	.004-.015	.02-.17	.02-.04	1.6E+10	NA

Figure 2-1. Table 4-4 TP10 Stormwater management devices design guideline

2.2.3 Waterways, Wetlands and Drainage Guide, Christchurch City Council (CCC)

This document references a Simple Method for Estimating Annual Urban contaminant loads from developing areas (Schueler, 1991).

This simple method uses a flow weighted mean concentration factor for the contaminants. Values for N and P are included and are reported as being appropriate for Christchurch.

The main limitations of this method are as follows.

- The flow weighted mean concentration factor is not included for *E.coli* or other bacterial indicator.
- The flow weighted mean concentration factors for the contaminants are based on data for other cities and is reported as appropriate for Christchurch conditions.
- The CCC guide uses a concentration based method calibrated for Christchurch rainfall, rather than a land use based method. This means that direct application of the method to Invercargill is not appropriate because doubling the annual rainfall depth will double the contaminant load, with no change in the type of land use.

  For example, based on available data mean monthly rainfall from NIWA 1981 -2010, the Invercargill Mean average rainfall depth (1150 mm) is approximately a double of the Christchurch Mean average rainfall depth (650 mm). Following the Simple Method formula presented in Figure 2-4**Error! Reference source not found.** and assuming that the other parameters are the same for Invercargill and Christchurch (catchment runoff coefficient, flow weighted mean concentration of pollutants, area and corrector factor), the estimation for TN and TP will be approximately double for Invercargill in comparison to Christchurch:
  - TN Invercargill 37,074 kg/year in comparison to TN Christchurch 20,955 kg/year
  - TP Invercargill 3,707 kg/year in comparison to TP Christchurch 2,095 kg/year

Without calibration for Invercargill, this method is not recommended for the contaminant load estimation.

$$L = \varphi P C K_p A/100{,}000 \quad (kg/yr) \qquad \text{Eqn (6-1)}$$

where P = Rainfall depth (mm/year). Adopt mean annual rainfall depth given in Figure 21-4 (typically 650 mm).

φ = A correction factor for P for storms that produce no runoff. Adopt 0.85 for Christchurch.

C = Catchment runoff coefficient for the site. Refer to *Chapter 21.3.4: Runoff Coefficient*.

K_p = Flow-weighted mean concentration of pollutant in urban runoff (mg/m³). Use values in Table 6-3.

A = Total area of site (ha).

Table 6-3: Recommended provisional mean concentrations of pollutants in urban runoff (K_p values) for Christchurch (Schueler, 1991). Data are from other cities, but seem appropriate for Christchurch conditions.

Urban Pollutant	Flow Weighted Mean Concentration (K_p) Factor g/m³	mg/m³
Suspended solids		
less than 10 ha	33	33,000
greater than 10 ha	33-200	33,000-200,000
construction	4000	4×10^6
Total Phosphorus		260
Total Nitrogen		2500
Chemical Oxygen Demand (COD)		35,600
Biochemical Oxygen Demand (BOD)		7000
Zinc		400
Copper		50
Lead		75
Hydrocarbons		500

Figure 2-2. Table 6-3 and Simple Method for Estimating Annual Urban contaminants Waterways, Wetlands and Drainage Guide, Christchurch City Council

2.2.4 Stormwater Treatment Standard for State Highway Infrastructure, NZTA

The main limitation is:

- No numerical concentrations are provided for the contaminants of interest

2.2.5 On-site Stormwater Management Guideline, NZWERF

The main limitation is:

- No numerical concentrations are provided for the contaminants of interest.

2.3 Removal Rates for Treatment Devices

The documents reviewed provide a range of qualitative and quantitative information on the removal of contaminants from stormwater discharges based on a range of treatment devices. The level of contaminant removal for each treatment devices is subject to a combination of factors including:

- The range of flow rates
- The contaminant load and concentrations
- The nature of the contaminants types and whether they are entrained or dissolved
- The specific design of the device
- The extent of vegetation establishment or its state of growth
- The time of the year.

The available data on removal rates for treatment devices regarding bacterial (*E.coli*) and nutrients (N and P) are summarised below based on the specific source document.

2.3.1 Contaminant Load Model, Auckland Council (CLM)

The main limitations are as follows.

- As discussed above the CLM does not include N, P or *E.coli* and therefore the load reduction factors used for each of the stormwater management options do not include these contaminants.
- CLM uses a single load reduction factor for each contaminant/stormwater management option whereas the efficiencies of the stormwater treatment devices are usually quoted as wide ranges. This inherent variability should be reinforced when reviewing the results of the load predictions.

2.3.2 TP10 Stormwater management devices design guidelines

Information provided in the TP10 Stormwater management devices design guideline regarding removal rates is summarised in Figure 2-3.

The main limitation is:

- No numerical removal rates are included.

Table 4-9
Potential contaminant removal effectiveness of stormwater management practices

Practice	Suspended Solids	Oxygen Demand	Total Lead	Total Zinc	Total Phosphorus	Total Nitrogen	Bacteria
API separators	-	o	o	o	o	o	o
Extended detention dry pond	+	>	+	>	>	-	o
Wet pond	+	>	+	>	>	-	o
Constructed wetland	+	+	+	+	+	+	o
Infiltration practices	+	+	+	+	+	>	+
Revegetation	+	+	+	+	>	>	-
Sand filter	+	-	+	+	>	-	>
Biofiltration (swale, filter strip, rain garden)	+	-	+	>	-	-	o

+ High potential for removal   > Moderate potential for removal
- Low potential for removal   o Insufficient knowledge

Figure 2-3. Table 4-9 TP10 Stormwater management devices design guideline

2.3.3 Waterways, Wetlands and Drainage Guide, Christchurch City Council

Information provided in the Waterways, Wetlands and Drainage Guide from Christchurch City Council regarding removal rates is summarised in Figure 2-4.

The main limitation is:

- The percentage range of removal rates are wide for each of the stormwater devices and contaminants. It is indicative only. The removal rates for solids and metals are consistent with the Auckland Contaminant load model.

Table 6-6: Representative removal capability of treatment systems for a number of urban pollutants of concern. Adapted from Auckland (Hartwell & Silyn-Roberts 2002) and international (Schueler 1987) data.

Treatment System	Pollutant Removal Efficiency (%)						Comment
	Solids	Phosphorus	Nitrogen	BOD	Trace Metals	Bacteria	
Grassed Swale	20-60	20-40	20-40	20-40	20-60	20-40	High potential for re-suspension of sediment with any storm flow.
Soakage Basin	60-100	40-80	40-80	20-60	40-100	60-100	Dependent on extent of overflow permitted.
Dry Detention Basin	40-80	40-60	20-40	20-40	20-60	0-40	Efficiency in trace metal reduction is reduced for more soluble elements.
Extended Detention Wet Pond	60-80	40-80	40 -60	20-60	40-80	40-80	Sizing relative to runoff is volume dependent. Bacteria removal dependent on bird population for the system.
Wetlands	60-80	40-80	20-60	20-40	40-80	60-100	Removal includes soluble trace metals. Bacteria removal dependent on bird population attached to the system.

Note: The level of pollutant removal will be subject to the level of provision of treatment system volume or surface areas relative to catchment runoff. As a general rule, the higher the concentration of in-flowing pollutants, the greater the degree of removal.

Figure 2-4. Table 6-6 Waterways, Wetlands and Drainage Guide, Christchurch City Council

2.3.4 Stormwater Treatment Standard for State Highway Infrastructure, NZTA

Information provided in the Stormwater Treatment Standard for State Highway Infrastructure from NZTA regarding removal rates is summarised in Figure 2-5.

The main limitations are as follows.

- Percentages range of removal rates are not consistent with the Waterways, Wetland and Drainage Guide, CCC nor the Auckland CLM for a number of parameters and methods of treatment. This demonstrates the inherent variability in reduction performance for stormwater treatment devices.
- *E.coli* or bacteria are not included.

Table 8-1 Removal Rates for Various Stormwater Practices for TSS and Nutrients					
Practice	Removal rates (%)				
	TSS	Nitrogen	Phosphorus	Zinc	Copper
Swales	70	20	30	75	60
Filter Strips	80	20	20	75	60
Sand Filters	80	35	45	90	90
Rain Gardens (normal)	90	40	60	90	90
Rain Gardens (w/anaerobic zone)	90	50	80		
Infiltration Practices	80	30	60	80	70
Wet Ponds	75	25	40	50	40
Wetlands	90	40	50	80	80
Oil Water Separators	15	0	5	5	5

Figure 2-5. Table 8-1 Stormwater Treatment Standard for State Highway Infrastructure

2.3.5 On-site Stormwater Management Guideline, NZWERF

Information provided in the on-site stormwater management guideline regarding removal rates is summarised in Figure 2-6.

The main limitation is:

- No numerical removal rate is included.

Table 3.9 Range of devices and their ability to remove contaminants from stormwater

Source: ARC TP10

Device	Contaminant							
	SS	HC	ME	OD	NU	PA	TO	LI
Filter	✓	✓	✓?	✓				✓
Trench	✓	✓		✓				
Rain garden	✓	✓	✓	✓				✓
Stormwater planter								
Rain tank								
Swale/filter strip	✓		✓	✓				
Wetland	✓	✓	✓	✓	✓	✓	✓	✓
Detention tank	✓							
Pond	✓	✓	✓	✓				?
Roof garden								
Roof gutters								
Depression storage	✓							
Permeable pavement	✓	✓	✓	?✓				
Catchpit insert	✓	✓	✓?	✓?				✓
Gross pollutant trap	✓			✓				✓
Litter trap								✓
Hydrodynamic separator	✓	?		✓				✓
Separators		✓						

Key to abbreviations of contaminants:

pH	power of hydrogen	SS	suspended solids
NU	nutrients (nitrogen and phosphorus)	PA	pathogens including bacteria
ME	metals (lead, zinc and copper)	LI	litter
HC	hydrocarbons, including TPH and PAHs		
OD	oxygen demanding substances (generally particulate organic matter)		
TO	toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites		
?	uncertain, depends on design of device or nature of contaminants		

Figure 2-6. Table 3-9 On-site Stormwater Management Guideline

2.4 Result of Summary

Taking into consideration the range of limitations of the different sources of information, the recommended approach to modelling bacteria and nutrient loads from stormwater if required is:

1. Use the contaminant loading ranges for various land uses provided by TP10 Stormwater management devices design guideline to estimate the total Nitrogen, Phosphorus and Faecal coliforms per year.
2. Use Faecal coliforms instead of *E.coli* as there is no load range for *E.coli* in any of the sources. Faecal coliforms provide an order of magnitude indication of *E.coli* loads
3. Use the percentages provided by Waterways, Wetlands and Drainage Guide, Christchurch City Council to estimate removal rates for different treatment devices selecting a mid-range value as a guide.

3 Comparison of Loads

3.1 Estimation of Nutrient and Bacteria Loads in the Stormwater

The Stormwater Discharges – Application Document prepared by MWH for the Invercargill City Council on September 2016, presented the Invercargill stormwater catchments discharging to the different water bodies, as per Figure 3-1. Waikiwi, Clifton, Waihopai, Kingswell and Otepuni catchments have been included in this load estimate as shown in Figure 3-1 and characterised in Table 3-1.

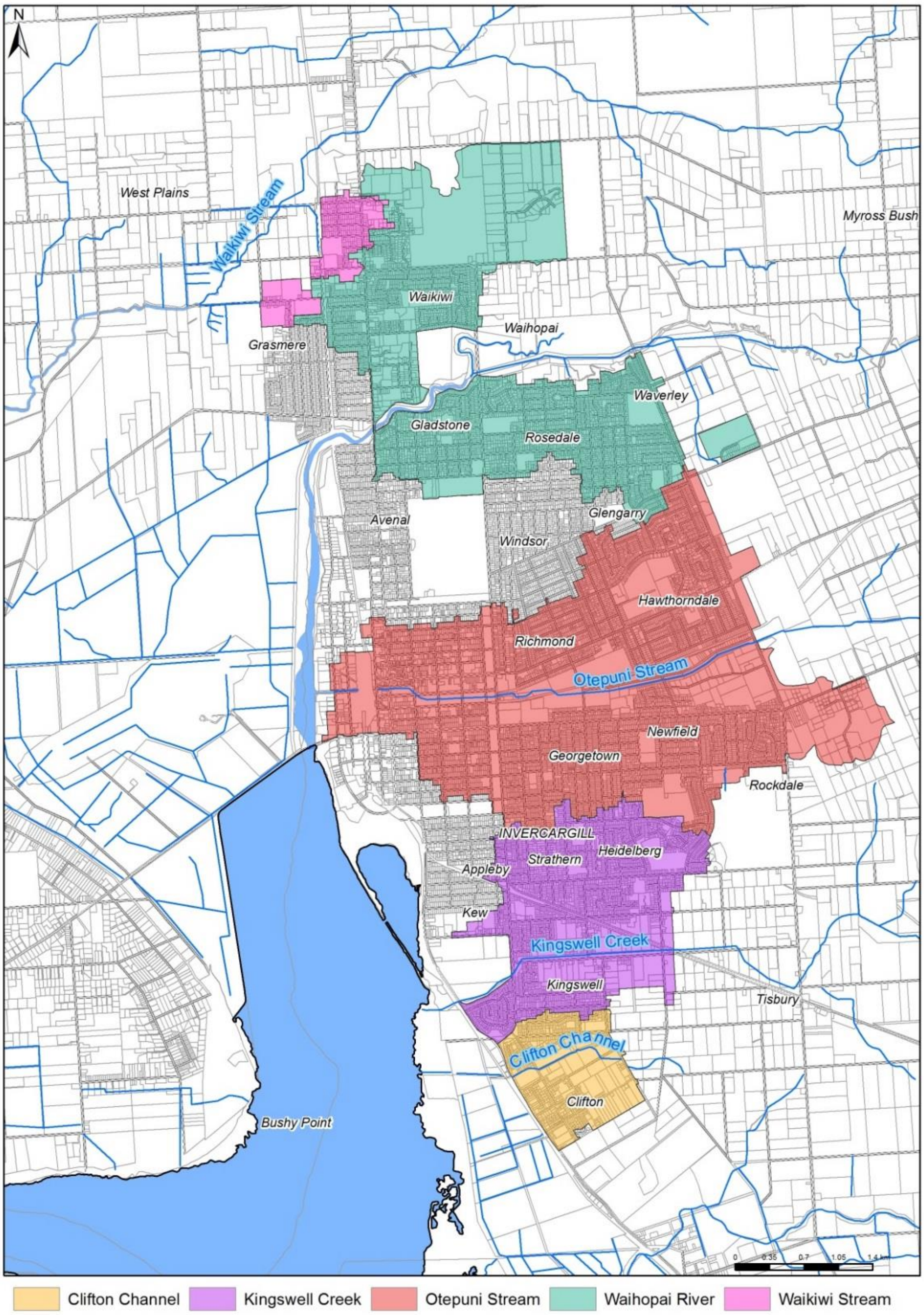

Figure 3-1: Extent of the stormwater catchments to each of the receiving streams

Table 3-1: Extent of the stormwater catchments

Catchment	Receiving Stream Catchment Area (sq-km)	Urban Invercargill Stormwater catchment area (sq-km)	Rural stormwater catchment Area (sq km)
Waikiwi	152.33	0.69	151.64
Clifton	2.82	1.31	1.51
Waihopai	188.01	7.03	180.98
Kingswell	12.54	3.82	8.72
Otepuni	38.25	10.49	27.76
Total	**393.95**	**23.34**	**370.61**

As discussed above, TP10 includes a wide range of contaminant loads for contaminants for each of the land uses. As a sensitivity check for each of the land uses considered, the lowest and the highest contaminant load has been calculated and included in **Error! Reference source not found.**.

In the absence of *E.coli* contaminant annual load data, the faecal coliforms (FC) values provided by TP10 have been adopted for this exercise.

It has been assumed that the Invercargill urban stormwater catchment is a mixture of road, residential (low) and commercial. An approximate assumption of the proportion of land area in each land use type has been made for this stage of the project as shown in **Error! Reference source not found.**. A more etailed assessment of land use areas will be performed in later stages of this project.

Error! Reference source not found. summarises the predicted annual loads of TN, TP and FC in the nvercargill urban stormwater discharges.

Table 3-2: Estimation of nutrient and bacteria loads based on TP10 contaminant loading ranges for urban Invercargill stormwater catchment area

Land use	% of catchment	TN (kg/year)		TP (kg/year)		FC (No/year)
		Low	High	Low	High	
Road	10%	303	817	138	350	4.20E+10
Commercial	20%	747	4,108	322	425	2.61E+12
Residential (low)	70%	5,392	7,679	752	1,046	1.52E+13
Total	**100%**	**6,442**	**12,604**	**1,211**	**1,821**	**1.79E+13**

3.2 Nutrient and Bacteria Loads Comparison for Stormwater and Wastewater

Based on the expected wastewater discharge quality for the Invercargill Wastewater Treatment Plant and the total annual inflow, the total nutrient (N and P) and bacteria (faecal coliforms) loads for the Invercargill urban stormwater and wastewater can be compared as presented in Table 3-3.

Table 3-3: Nutrient and bacteria load comparison for Invercargill urban stormwater and Invercargill wastewater loads

Contaminant	Invercargill Wastewater[1]	Invercargill Urban Stormwater	Percentage of the urban stormwater over the wastewater
TN	249,000 kg/year	6,440 – 12,600 kg/year	3 – 5 %
TP	39,800 kg/year	1,210 – 1,820 kg/year	3 - 5 %
FC	1.43E+14 No/year	1.79E+13 No/year	12 %

3.3 Recommendation

The nutrient load from urban stormwater is minimal in comparison with the wastewater source being less than 5%.

The estimate of the bacteria load is an order of magnitude lower than the wastewater. Stormwater treatment devices covered by the referenced design guides generally cannot treat for bacteria. Reduction in bacteria loads is generally achieved through source reduction, including the removal of sewage.

It is recommended that the scope of the continuing work will not include nutrients and bacteria in the assessment and will focus on the parameters including in the Auckland Contaminant Load Model, ie solids, copper, zinc, and total petroleum hydrocarbons.

[1] Derived from the Annual average sewage flow multiplied by the annual average concentration.

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