In the Environment Court of New Zealand
Christchurch Registry

I Te Koti Taiao o Aotearoa
Ōtautahi Rohe

ENV-2018-CHC-26 to 50

Under	the Resource Management Act 1991 (**RMA**)
In the matter of	appeals under clause 14 of Schedule 1 of the RMA relating to the proposed Southland Water and Land Plan (**pSWLP**)
Between	**Gore District Council, Southland District Council and Invercargill City Council (TLAs)**
	Appellants in ENV-2018-CHC-31, and section 274 party to appeals: ENV-2018-CHC-37 Southland Fish & Game Council; ENV-2018-CHC-39 Alliance Group Limited; ENV-2018-CHC-40 Federated Farmers of New Zealand; ENV-2018-CHC-50 Royal Forest and Bird Protection Society of New Zealand; ENV-2018-CHC-41 Heritage New Zealand Pouhere Taonga; ENV-2018-CHC-47 Te Rūnanga o Ngāi Tahu, Hokonui Rūnaka, Waihopai Rūnaka, Te Rūnanga o Awarua & Te Rūnanga o Oraka Aparima
And	**Southland Regional Council (Environment Southland)**
	Respondent

Evidence of Sue Bennett

22 March 2019

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Introduction

1 My full name is Susan Bennett. I hold a BA (Hons) in Natural Sciences from Cambridge University, UK, where I specialised in Chemistry and Molecular Biology.

2 I am employed as a Principal Environmental Scientist with Stantec New Zealand based in Dunedin. Prior to joining the Dunedin office at the start of 1997, I worked for the same company (then known as MWH) in Hong Kong for five years.

3 I have over 27 years' experience in environmental consulting, primarily involved with wastewater, stormwater, solid waste and biosolids management. My specialist area is the environmental effects of discharges.

4 Since joining Stantec in 1991, I have worked on a range of environmental management projects in Hong Kong, Australia and New Zealand. Relevant projects in the Southland region over the past ten years include:

(a) Wastewater projects: development of the proposed scheme and consenting of Te Anau, Tokanui, Riversdale and Nightcaps wastewater discharges, development of the wastewater strategy and biosolids strategy for Southland District, changes to the Mataura wastewater discharge consent;

(b) Stormwater projects: consenting of Gore, Southland and Invercargill stormwater discharges to freshwater and review of monitoring information to determine ongoing monitoring requirements for Gore stormwater; development of the Stormwater Quality Management Plan required by the Invercargill consent;

(c) Solid Waste projects: consenting of Bluff Closed Landfill;

(d) Southland Economic Project: I led the second part of the Territorial Authorities input to the project, which investigated the potential economic impact of responses to the limit setting process on wastewater and stormwater services, and I was one of the authors of the resultant "*Urban and Industry Report*", which was prepared by Environmental Southland with the close involvement of the Territorial Authorities;

(e) Ecology and Hydrology and Water Quality in the Waituna Catchment, project for Living Water: study summarised the condition of the Waituna catchment, and specifically focused on wetlands on private land, and methods to prioritise, protect, enhance and monitor them; and

(f) Waituna Lagoon Project for Environment Southland: I provided support with implementation projects, including the administration of the

Freshwater Improvement Fund, the review of the feasibility of options for lagoon opening and closing, the development of the Strategy and Action Plan and the Land Inundation Project.

5 I acted as either technical lead for these projects, or as technical specialist providing input and review of the environmental effects, particularly in relation to effects on water quality.

6 I have been an elected member of the Technical Committee for the Land Treatment Collective since 2017. As a member of the Environment Institute of Australia and New Zealand, I am bound by their Code of Ethics and Professional Conduct[1].

7 In preparing this evidence, I have reviewed the reports referenced in my evidence and statements of evidence of other experts, including:

(a) Environment Southland: Mr McCallum-Clark, Mr Rodway, Dr Snelder, Dr Lloyd, Mr Ward, Ms Robertson, and Mr Hodson;

(b) Ngā Rūnanga and Te Rūnanga o Ngāi Tahu: Ms Cain, Mr Skerrett, Dr Kitson and Ms Davidson;

(c) Southland Fish and Game Council (**Fish and Game**): Prof Death;

(d) Royal Forest and Bird Protection Society of NZ Inc (**Forest and Bird**): Ms McArthur;

(e) Department of Conservation: Mr Rance, Ms Sheppard and Ms Funnell; and

(f) Meridian Energy Limited: Dr James.

8 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of evidence

9 I have been asked by the three Southland Territorial Authorities (**TAs**) to prepare evidence in relation to effects from stormwater and wastewater schemes and options to upgrade infrastructure in light of the proposed Southland Water and Land Plan (**pSWLP**). This includes:

(a) Water quality implications of the objectives of the pSWLP;

[1] https://www.eianz.org/membership-information/code-of-ethics-and-professional-conduct

(b) Effects of stormwater and wastewater schemes; and

(c) Options to upgrade infrastructure.

10 Whilst I have read the evidence of Prof Death and Dr James on proposed water quality limits, I understand that this will be discussed as part of Topic B and hence I have not addressed this matter in this evidence.

Executive summary

11 Any discharge of wastewater or stormwater even after significant upgrade will result in a change in the quality of the water body after discharge, when viewed on an absolute, and unqualified basis. These discharges will contain contaminants, even after treatment, which will change the water quality.

12 In addition, any discharge of wastewater or stormwater, no matter how well treated, will contain contaminants which would add to cumulative adverse effects on human health. Human health can be impacted by a range of contaminants which will be present in these discharges, even after treatment, and will also be present in the water body from other sources. Whilst these can be limited such that the resultant effects are minor, in absolute terms the discharges will add to cumulative adverse effects on human health.

13 Dependent on the area of Southland considered, existing water quality ranges from degraded to pristine with respect to the ability of the various water bodies to comply with the required Plan standards and to support their identified values, particularly ecosystem and human health values. In order to achieve and protect the required values of the various water bodies, degraded water quality needs to be improved, and 'pristine' or 'good' water quality should be maintained, such that it continues to provide for the required values.

14 Water quality cannot be simultaneously maintained and improved in the same location. In scientific terms, maintenance of water quality would be keeping it the same. Improvement would be a decrease in the levels of contaminants of concern within the water. Therefore, it can only be one or the other, not both.

15 The effects of discharges from municipal wastewater schemes depend upon the nature of the catchment served, the degree of treatment achieved, and the nature of the receiving environment. These effects can vary, especially on a seasonal basis, both in terms of the treated wastewater quality and the ability of the receiving environment to assimilate the discharge. Municipal wastewater contains a variety of contaminants which can have a range of effects in the receiving environment. Many of these contaminants are considerably reduced through the existing wastewater treatment plants.

16 There are many options available to upgrade the quality of the discharge from a wastewater treatment plant and reduce the potential effects. The key requirements when designing an upgrade are the nature of the existing influent and treatment processes, and the sensitivity of the receiving environment and hence the treated wastewater quality to be achieved. This will vary considerably between locations.

17 Stormwater picks up a range of contaminants as it flows over urban surfaces before entering the stormwater network. Therefore, similar to wastewater schemes, the effects of discharges from municipal stormwater schemes depend upon the nature of the land use and contaminant sources within the catchment of the scheme, as well as the receiving environment. These can be highly variable spatially between catchments with different land uses, and temporally, dependent upon the duration between rain events, the intensity of the rainfall and the variability in activities undertaken in the period between discharges.

18 The primary effects from stormwater discharges are their contribution to the accumulation of metals and synthetic organic contaminants in sediment, and the potential public health impact if raw wastewater is present.

19 Whilst wastewater is typically connected to a single treatment location prior to discharge, stormwater schemes generally have a number of different discharge locations, even for small towns.

20 Improvements in the quality of stormwater discharges require a wide variety of measures intended to reduce the contamination of the stormwater entering the system, as well as, potentially, treatment of specific discharges. Generally, it requires a whole of catchment approach involving a package of measures designed to improve the discharges, rather than a specific technical upgrade.

21 Whilst some of these options result in significant reductions in contaminants, none result in complete removal of contaminants from the stormwater, and hence, even with implementation of these measures, some residual contamination will remain in the stormwater which will result in changes in water quality after discharge.

Water quality implications of the objectives of the pSWLP

Objective 6

22 The decision version of Objective 6 requires that "*There is no reduction in overall quality of freshwater, and water in estuaries and coastal lagoons, by: …*" maintaining or improving water quality. The objective is not qualified to a required standard or maintenance of a specific set of values, such as ecosystem health or

public health that are to be protected. The notified version omitted the word 'overall'.

23 It is not possible to have "*no reduction in quality*" for a new or reconsented existing wastewater or stormwater discharge or a discharge which is increasing in volume or reducing in quality due to population increases. Any such new or changing discharge will contribute a change in contaminant load to the receiving environment and will reduce water quality in an absolute sense. This is the case even if, after reasonable mixing, all the required values in the water body are protected and even if the new discharge represents an improvement upon the existing overall environmental situation.

24 An example of this concern is the implementation of a change from failing septic tanks to a Community Sewage Scheme, with a single discharge to water following appropriate treatment. This discharge could be direct to surface water or to groundwater after land discharge. In theory, such a scheme would potentially replace a number of direct discharges to land and water from septic tanks in areas close to residential buildings which can cause public health effects, with a single better treated discharge in a location with reduced public access.

25 A further example is the replacement of a direct discharge to surface water with a discharge to land resulting in a discharge to groundwater. As discussed by Mr Rodway, much of Southland's surface water is connected to groundwater. Hence, a discharge to groundwater will often result in a subsequent discharge to surface water following further treatment through the underlying soil profile and aquifer.

26 A specific example of this scenario is the proposed Te Anau wastewater scheme where treated wastewater will be discharged to land at the Kepler Block, then subsequently discharged via the aquifer to the Waiau River. A change in water quality in the Waiau River is expected to be undetectable but still, in an absolute sense, will be present. This scheme is proposed to replace the current discharge of treated wastewater to the Upukoroa River, which discharges to Lake Te Anau. From the lake, water flows to the Waiau River upstream of the location to which the nitrogen plume from the proposed land disposal scheme will discharge. Therefore, a direct discharge to surface water is replaced with an indirect discharge, via land and aquifer with reduced contaminants, to the same river network.

27 These examples could represent a significant improvement in overall water quality of the water body or system against relevant water quality objectives, particularly protection of public health and nutrient reduction. The discharges could be treated prior to discharge to land or through the land application system, such that the relevant Plan standards and other objectives of the receiving water body are met after reasonable mixing. However, the discharge of the treated

wastewater to land or water would result in a reduction in water quality, when viewed absolutely.

28 I note that the geographic extent of the water body to be considered in this assessment is not specified in the objective. In the examples I gave above, if the specific reach of the river into which the new discharge occurs is considered in isolation, then an absolute change in water quality may occur. However, if the water system is viewed at a wider geographical extent, including both the currently affected areas and the areas potentially affected by the new discharge, the overall water quality may be maintained or, typically, improved.

29 The relevance of this consideration will depend upon the nature of the effect. I consider that toxicity effects and risks to public health are properly assessed in the vicinity of the discharge. However, nutrient impacts that do not result in specific local impacts, but instead result in a cumulative addition to the catchment load to downstream reaches and/or the estuary, may be better viewed at a wider geographical scale. Whether water quality is maintained or improved is therefore subject to interpretation and, in my view, should be dependent upon the nature of the discharge, the resultant effects that may occur, and the water body being considered.

30 In summary, most wastewater and stormwater discharges cannot achieve no reduction in water quality, even after reasonable mixing, when viewed absolutely.

Objective 13B

31 Forest and Bird has requested in its appeal that Objective 13B be changed to read: "*the discharge of contaminants to land or water that have ~~significant~~ adverse and cumulative effects on human health and recreation are avoided*".

32 As I discussed above, any discharge of wastewater to land or water is highly likely to result in a degree of adverse effect on human health, in that it will increase the absolute risk of exposure to contaminants even if that increase in risk is very small. Given that there will generally be other sources of contaminants into the water body, any discharge would also contribute to the cumulative adverse effects on human health, even if this is to a minimal degree.

Objective 18

33 Objective 18 states that "*All activities operate in accordance with "good management practice" or better to optimise efficient resource use, safeguard the life supporting capacity of the region's land and soils, and maintain or improve the quality and quantity of the region's water resources.*"

34 In its appeal, Alliance has requested that the Objective be revised to include reference to “Best Practicable Option” or BPO with respect to infrastructure. Whilst BPO is defined in the RMA[2], “good management practice” is not defined for infrastructure. In selecting the wastewater or stormwater scheme for which consents will be sought, it is possible that a scheme which addresses the various adverse effects may not be the BPO. In effect, the BPO is a higher bar than may be required to sufficiently address adverse effects. In my experience in assisting TAs to seek consents for infrastructure discharges, there is pressure for wastewater and stormwater schemes to achieve the highest level of treatment possible, such that the treated liquid discharge is as “clean” as possible. This can have unintended consequences in terms of the overall effects of the scheme.

35 The implications of providing additional treatment include the potential production of by-products whose disposal can result in a further, different set of effects that require management. Examples include the generation of increased quantities of sludge from a wastewater treatment plant which require separate management and disposal; or the production of brine from a Reverse Osmosis (**RO**) process, which can be significant in terms of quantity and problematic to dispose of, particularly in a freshwater environment.

36 Additional treatment can also result in increased resource consumption. Examples include:

(a) Increased electricity usage for ultraviolet (**UV**) disinfection, aeration or other mechanical treatment processes;

(b) Increased consumables such as addition of a carbon source to the waste stream to achieve denitrification processes for wastewater, chemicals (such as coagulants), or replacement parts (such as UV lamps) which may need to be imported; and

(c) The need for quantities of concrete and other construction material to build and house new process units.

37 For stormwater, many stormwater schemes were developed without the inclusion of treatment systems. The retrofitting of treatment into such systems can be problematic for the reasons described later in my evidence. Treatment of stormwater consists of the removal of contaminants (both particulate and for

[2] Resource Management Act 1991, section 2 "**best practicable option**, in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to— (a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and (b) the financial implications, and the effects on the environment, of that option when compared with other options; and (c) the current state of technical knowledge and the likelihood that the option can be successfully applied"

more advanced systems dissolved) from the stormwater discharge. As for wastewater, this results in a separate waste stream that must be managed and disposed of. This may be appropriate for sources of stormwater from high contaminant source land uses or activities but may not be appropriate to be applied across all land uses in the catchment of the scheme.

38 Increasing levels of wastewater and stormwater treatment will increase the costs of providing these services, both in terms of initial capital costs but also ongoing operating costs.

39 Fish and Game has requested that "*… maintain **or** improve …*" in the last part of Objective 13A be changed to "*… maintain **and** improve …*" (**my emphasis added**). The status of water quality in the Southland Region is described in the evidence of Mr Rodway, Mr Ward and Mr Hodson for Environment Southland. This summary of water quality was further developed in the evidence of Ms McArthur, Professor Death, and Dr Kitson.

40 The evidence of all these parties is generally consistent in identifying that there are areas of the Southland Region with significantly degraded water quality, particularly with respect to its impact on ecosystem health and human health. This is consistent with my experience in undertaking assessments of environmental effects for various activities in the Region. I agree that water quality in these areas would need to be improved to ensure that the required values are provided for.

41 In addition to the specific reach of river or stream being considered, the impact of the resultant loads being delivered to downstream reaches and the mouth of the river, particularly if a sensitive estuary is impacted, should also be considered in determining whether water quality needs to be improved or maintained.

42 However, there are also areas within the Southland Region with good water quality, which protects the values of the water body, such as ecosystem health and public health. In these areas, generally I consider that water quality should be maintained to ensure that the values continue to be supported, although I would caution against an absolute interpretation of maintenance, or "no change in water quality", as I discussed earlier.

43 Therefore, dependent upon the area being considered, water quality should either be improved or maintained dependent upon the existing water quality of the water body under consideration. In my opinion to change the "or" to "and" creates confusion, as it implies that in all cases, water quality should be both maintained and improved, which is not possible.

Effects of stormwater and wastewater schemes

Wastewater

44 Municipal wastewater schemes have a number of beneficial effects, including improved public health and water quality. Typically, a scheme will provide significant benefits over individual on-site treatment and disposal systems by centralising wastewater treatment and discharge to a single location. The implementation of a scheme is typically in areas where individual on-site treatment and disposal systems are failing. The scheme will reduce the discharge of partially treated wastewater to drains, surface water bodies and / or groundwater. The discharge of partially treated wastewater can result in risks to public health, water quality and ecosystems which are reduced by the wastewater scheme.

45 The centralisation of wastewater treatment also allows for upgrades of treatment to reduce water quality effects, which would generally be less achievable for an equivalent distributed system based on individual on-site treatment and disposal systems.

46 The effects of discharges from municipal wastewater schemes depend upon the nature of the catchment served, the degree of treatment achieved, and the nature of the receiving environment.

47 These effects can vary, especially on a seasonal basis, both in terms of the treated wastewater quality and the ability of the receiving environment to assimilate the discharge. Municipal wastewater contains a variety of contaminants which can have a range of effects in the receiving environment. Many of these contaminants are considerably reduced through the existing wastewater treatment plants.

48 Wastewater discharges contain dissolved and solid organic matter, which can reduce the available oxygen in the water body, and the solids can also smother benthic communities.

49 Wastewater can cause toxicity effects, both through direct exposure or through accumulation in sediments or the food chain. The primary toxicant in wastewater discharges is ammonia, and its potential toxicity effect is usually limited to a relatively small mixing zone. Metals and synthetic organic compounds may also be present and can exert toxicity impacts.

50 Wastewater discharges can contribute to nutrient concentrations and loads in water bodies, mainly nitrogen and phosphorus. The elevation of nutrient concentrations is a recognised issue in Southland rivers, lakes and groundwater as identified in evidence from Environment Southland and various appellants.

Their evidence generally identified that most nutrients are sourced from agricultural sources, but municipal wastewater also contains nutrients. The relative contribution from wastewater compared to agricultural sources is dependent upon the nature of the wastewater scheme, and the nature of the water body and its catchment.

51 Wastewater can contain pathogens which can result in a risk to public health. This is due to human exposure to pathogens in the discharged wastewater. Pathogens are agents that can cause disease and include bacteria (e.g. salmonella), viruses (e.g. norovirus) and protozoa (e.g. giardia). The risks occur when water downstream of the discharge is used for drinking water, food collection and consumption, or recreational activities, such as swimming, fishing or boating. The potential presence of pathogens and hence the risk of exposure is typically represented by the concentration of indicators, such as *E.coli* or Enterococci. Mr Hodson's evidence presents the concentrations of *E.coli* in the surface water in the region, which he refers to as microbes. It should be noted that *E.coli* does not specifically indicate human faecal contamination, but is present in the faeces of many animals, including stock and birds. Therefore, its presence indicates the degree of faecal contamination in a surface water body from both human and animal sources, rather than specific human health risk.

52 A potentially significant effect from the discharge of wastewater is the cultural impact. Whilst I am not an expert in cultural matters, from my experience in wastewater projects, I understand that the discharge of treated wastewater directly to surface water is abhorrent to iwi, who have a strong preference for discharge to land.

53 In my experience, the discharge of wastewater to land is strongly preferred by communities, not only iwi. The discharge of treated wastewater to land will result in the further treatment of the wastewater as it passes through the soil profile, where sufficient depth to groundwater and suitable soil is available. The degree of treatment achieved by the land is discussed later in my evidence. As I discussed earlier, the discharge of wastewater to land can result in the discharge of some contaminants to the underlying groundwater which can then be transmitted to surface water. This should be recognised and assessed in any scheme with a discharge to land.

Stormwater

54 The effects of discharges from municipal stormwater schemes depend upon the nature of the land use and contaminant sources within the catchment of the scheme. These can be highly variable spatially between catchments with different land uses, and temporally, dependent upon the duration between rain events, the

intensity of the rainfall and the variability in activities undertaken in the period between discharges.

55 It should be noted that many stormwater schemes in Southland act as a groundwater drainage network as well as a stormwater collection network and hence discharges are not limited to rainfall events but will be impacted by them.

56 There are a number of beneficial effects that result from a stormwater scheme including the enabling of land use, protection of public health and improvement in water quality. A stormwater scheme removes shallow groundwater and rainfall from ponding, flooding and stagnating within the urban area, enabling urban development and its continued presence.

57 The water quality benefits of a stormwater scheme include the reduction of prolonged flooding of unsealed areas which would result in destabilisation of the soil and its erosion into the impacted water body. This destabilisation could lead to significant discharges of sediment into the water body. This could result in decreased clarity in the water body, and an increase in the sediment load.

58 The reduction in flooding and standing water from a stormwater scheme reduces the transmission of water borne disease to the public. The reduction in flooding also reduces the strain on the sewer network, as inflow and infiltration of surface water and groundwater to the sewer network would be significantly lower than would occur if the stormwater scheme was not in place, or was inadequate. Surface flooding can both result in and transfer a greater amount of debris and rubbish which would enter both the sewer and stormwater schemes. Both the increased flow rates, debris and rubbish would lead to a substantially higher rate of surcharging and blockages which would result in higher incidence of sewer overflows and the public health and environmental risks associated with such discharges.

59 The adverse impacts of a stormwater scheme result from the stormwater picking up a range of contaminants as it flows over urban surfaces before entering the stormwater network. These include mineral and organic solids, dissolved and particulate metals, nutrients, and potentially synthetic organic compounds, especially fertilisers, herbicides, and pesticides used in urban parks and gardens, and chemicals used by residents and businesses for cleaning and other uses which may enter the stormwater networks.

60 The primary sources of contamination in residential and commercial areas are roofs and roads. Dependent upon the nature and condition of the roof, these can be a source of zinc and copper. Roads, particularly high traffic and braking areas, can be a source of copper from brake linings and petroleum hydrocarbons.

61 Trade premises, including industries, will also have connections to the stormwater network and yard practices may result in discharge of contaminants to the stormwater network. Contaminated sites, both current and historical, within the catchment may also be connected to the stormwater network either directly or via drainage water or overland flow. This may transmit contaminants from these sites to the network.

62 The presence of raw wastewater in stormwater due to illegal connections to the scheme, cross contamination between the networks, and overflows from the wastewater network into the stormwater network is a significant concern. The primary effect from the presence of raw wastewater is the risk to public health from exposure to pathogens for users of the receiving water body. Dependent upon the scale of the discharges, the raw wastewater can also result in effects similar to those discussed above for the discharge of treated wastewater.

63 Whilst the presence of raw wastewater will increase the concentrations of indicators (i.e. *E.coli*) in the discharges, the presence of *E.coli* in stormwater discharges is not solely attributable to raw wastewater, as evidenced by the monitoring of a range of stormwater discharges which was required by the conditions of the consent granted in 2011 for the discharges from the Invercargill Stormwater scheme to freshwater. I analysed this data for the 2016 application for consent for the continued discharges from the (**ICC**) stormwater scheme to freshwater[3].

64 Both dry weather and wet weather samples were required by the previous consent conditions. As I mentioned before, this recognises that more than stormwater runs through these systems. There were a number of discharges where highly elevated concentrations of *E.coli* were recorded. These sites also had elevated ammoniacal nitrogen in comparison to other sites, which is also an indicator of the presence of raw wastewater. Figure 1 in Appendix A presents the range of *E.coli* data from this monitoring as compared to the nationally available data from URQIS[4] in 2016, which represented the national data set.

65 Whilst not as elevated as the ICC stormwater discharges which included some raw wastewater[5], the ICC wet weather, and to a lesser extent the ICC dry

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[3] "Stormwater Discharges – Application Document" Prepared for the Invercargill City Council by MWH (now Stantec), September 2016

[4] http://urqis.niwa.co.nz/. URQIS is a resource developed in 2012 that provides stormwater and urban stream quality data to the public by accessing a database of urban runoff quality data collected from all over New Zealand, compiled by NIWA. The database includes data supplied by Councils, Transport Agencies, Research Institutes and Universities across New Zealand.

[5] Whilst elevated, the *E.coli* concentrtaions recorded are significantly less than that expected in undiluted raw wastewater which would typically be in the range 100,000 CFU/100mL to 10,000,000 CFU/100mL.

weather, discharges have elevated *E.coli* concentrations for a number of discharges, indicating the typically elevated concentrations in stormwater as a result of contamination from surface run-off, even where raw wastewater is not indicated as being present. It is important to note that the concentrations in the ICC stormwater discharges as indicated by Figure 1 are similar to that in the national database, which indicates that these elevated concentrations are typical and expected.

66 Essentially, the quality of the discharges from a municipal stormwater scheme is highly dependent upon the nature of the activities undertaken within its catchment.

67 The contaminants in stormwater and their effects are similar to those described above for wastewater, with the primary effects being their contribution to the accumulation of metals and synthetic organic contaminants in sediment and the public health impacts of the presence of raw wastewater.

Options to upgrade infrastructure

Wastewater

68 The effects from wastewater discharges depend upon the concentrations of various contaminants in the wastewater and the ability of the receiving environment to assimilate the discharge.

69 Options to upgrade wastewater discharges relate to reducing the concentrations of the various contaminants in the wastewater prior to discharge, and/or changing the discharge location or conditions. This could be an increase in the level of treatment to reduce contaminants of concern, change in the discharge location to achieve greater dispersion and/or dilution, cease discharges during low flow conditions, or change the nature of the discharge environment (i.e. from surface water to land).

70 As part of the Southland Economic Project, I was involved with identifying a range of potential upgrades to the existing wastewater treatment plants for a number of case study towns in the Southland Region. This included a range of scenarios which resulted in improvements to the quality of the discharges for continued discharge to surface water and considered discharges to land, both rapid rate infiltration and slow rate irrigation.

71 The project focused on the parameters relating to the primary effects which I discussed earlier in my evidence, namely total suspended solids, biochemical oxygen demand (**BOD**), total nitrogen, total phosphorus, and *E.coli*.

72 The performance of the existing wastewater treatment plants was assessed and then a range of upgrade scenarios were developed to achieve further reductions

in contaminants from those achieved by the existing systems. The various scenarios ranged in complexity from contaminant specific upgrades which added unit processes to the existing oxidation ponds through to full replacement of the existing ponds with mechanical processes with significant reductions in a range of contaminants. The upgrade scenarios included:

(a) Nutrient reduction: addition of unit processes to reduce[6] the nitrogen and phosphorus concentrations by approximately 50% and 65% respectively, and reduction in solids and BOD but not *E.coli*;

(b) Pathogen reduction: addition of a disinfection step to reduce[6] pathogens only, as indicated by the *E.coli* concentrations in the discharge being reduced to the equivalent of a Grade A swimming beach[7];

(c) Phosphorus reduction: addition of unit processes to specifically reduce[6] phosphorus by approximately 65%;

(d) Nutrient and solids reduction: addition of further processes to reduce[6] nitrogen and phosphorus concentrations by approximately 55% and 65% respectively, and significantly reduce solids and BOD but not *E.coli*;

(e) Enhanced treatment: replacement of the oxidation ponds with a new mechanical system (a membrane bioreactor) to reduce[6] nitrogen and phosphorus concentrations by 75%, and significantly reduce solids, BOD, and *E.coli*;

(f) Tertiary treatment: replace the oxidation ponds with a treatment system which results in approximately 99% reduction[6] in nitrogen and phosphorus concentrations and significantly reduces solids, BOD, and *E.coli.* However, this treatment process also produces brine as a waste stream which is problematic to manage, particularly in a freshwater environment*;*

(g) Rapid rate infiltration: discharge of the oxidation pond effluent to land via rapid infiltration basins. This results in significant reductions[6] in all contaminants when considered at the point of discharge to the aquifer, dependent upon conditions; and

(h) Slow rate irrigation: discharge of the oxidation pond effluent to land via slow irrigation. This results in higher degree of reduction[6] in all

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[6] Reductions in contaminant concentratoin achieved by the upgrade scenarios are expressed as the percentage of concentrations achieved by existing systems rather than of raw wastewater concentration.

[7] Grade A limit in the Microbiological Assessment Category (MAC) in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas Published in June 2002 by the Ministry for the Environment, Updated in June 2003

contaminants compared to rapid rate infiltration when considered at the point of discharge to the aquifer, dependent upon conditions.

73 There are many different unit processes and combinations of processes that can be used to achieve the targeted discharge quality in the various upgrade scenarios. The purpose of the Southland Economic Project was not to review all the available wastewater treatment processes to achieve the various target discharge qualities, but to develop typical upgrade types and associated costs. Therefore, for each upgrade scenario, a single "upgrade" was developed, and indicative costs identified.

74 The target discharge quality for each of the treatment scenarios that were developed for the Gore wastewater treatment plant are shown in Figure 2 to Figure 5 in Appendix A. A smaller polygon represents better or higher quality treated wastewater associated with lower concentrations of contaminants. Except for phosphorus, the concentrations of contaminants were transformed[8] before being plotted to make it possible to include all five contaminants on the same graph.

75 The existing Gore wastewater treatment plant has an Actiflo system which specifically reduces the solids and phosphorus concentrations, in addition to the treatment achieved by the remainder of the scheme. It is used during periods of low flow in the Mataura River only (i.e. not all the time), such that there are two sets of treated wastewater concentrations for the existing system dependent upon whether this system is in operation.

76 As shown, the various upgrade scenarios result in different treated wastewater concentrations and hence the degree of effect in the receiving environment. None of the scenarios modelled would result in treated wastewater which is free from all modelled contaminants, and all scenarios would result in some change in water quality upon discharge to the water body. The capital and operating costs associated with each of these scenarios was also estimated for each case study town, with the scenarios with "better/higher" discharge quality costing more.

77 It should be noted that the discharge to land scenarios assumed that there would be sufficient depth of soil between the surface and the aquifer (the "unsaturated zone") to achieve the level of treatment assumed. Given the spatial and temporal variability in groundwater level in Southland, especially between seasons, the required depth of unsaturated zone and hence degree of treatment may not be achieved at all times. Also, the assessment assumed that soil suitable for land discharge was available. This may not be the case in some parts of the Southland region.

[8] The *E.coli* concentrations was log transformed and those for BOD, SS and TN were ln transformed.

78 As I have outlined, there are many options available to upgrade the quality of the discharge from a wastewater treatment plant and reduce the potential effects. The key requirements when designing an upgrade are the nature of the existing influent and treatment processes and the sensitivity of the receiving environment, and hence the treated wastewater quality to be achieved. This will vary considerably between locations.

Stormwater

79 The wastewater for a town is typically connected to a single treatment location prior to discharge. Therefore, improvement of the quality of the discharge can be targeted to this one location. However, stormwater schemes for a single town generally have a number of different discharge locations, even for small towns. Invercargill has over 200 separate discharges to freshwater and the Coastal Marine Area. Therefore, improvements to discharge quality through addition, or upgrading, of treatment is more problematic than for wastewater.

80 Improvements in the quality of stormwater discharges require a wide variety of measures intended to reduce the contamination of the stormwater entering the system, as well as potential treatment of specific discharges. Generally, it requires a whole of catchment approach involving a package of measures designed to improve the discharges, rather than a specific technical upgrade.

81 In association with ICC staff, I recently led the development of the Stormwater Quality Management Plan[9] (**SQMP**) required by the consent held by ICC to discharge from the stormwater scheme to freshwater[10] which was granted by Environmental Southland in 2017. The SQMP is required to be reviewed every three years, and hence this first issue provides the works to be undertaken in this initial phase of the consent. The SQMP describes the various measures that will be implemented to improve the quality of the discharges, which include:

(a) The statutory framework provided by the Invercargill District Plan which includes rules which allow consideration of the impact of activities on stormwater quantity and quality as part of the assessment of applications for consent. ICC also has a bylaw for land development and subdivision infrastructure based on NZ standard NZS 4404:2010, which stipulates the stormwater infrastructure required to be provided for new sub-divisions,

[9] "Stormwater Quality Management Plan" prepared for Invercargill City Council by Stantec, dated December 2017

[10] Discharge Permit AUTH-20168843: To discharge water, stormwater, and contaminants to water from the Invercargill City Council reticulated stormwater network from 30 November 2017.

including consideration of Low Impact Design[11]. Consideration will be given to whether a stormwater bylaw is required to enforce changes;

(b) An education and awareness plan to raise awareness of the issues so that the community can change behaviours, such as not undertaking any of the following: washing cars on sealed surfaces connected to the network rather than on grassed areas; discharging fuel to stormwater drains from overfilling tanks or incorrectly putting diesel into petrol cars; littering and other activities that result in discharges of various contaminants or blockages of to the stormwater or wastewater networks;

(c) Operations and maintenance programmes undertaken by ICC to manage the schemes, including inspections, sump cleaning, litter collection, and responding to specific blockages or other issues in both the sewerage and stormwater schemes;

(d) Audits of trade premises and contaminated sites which may discharge contaminants to the stormwater network to review yard practices and storage and bunding facilities to identify improvements that could be made to reduce risk of the discharge of contaminants to the network from the sites;

(e) Renewals and upgrades of both the stormwater and wastewater schemes. These involve replacement of parts of the systems and can include upgrading to increase the capacity of the schemes. The aim is to progressively reduce inflow, infiltration and cross connections between the networks, which can result in contamination of the stormwater discharges, and high flows to the treatment plant which can result in bypasses of treatment processes. Improving the capacity of the schemes reduces the incidence of flooding and overflows, which also reduces the potential for contamination;

(f) A specific programme targeting sources of raw wastewater to the stormwater network. This includes surveillance monitoring throughout the term of the consent to identify potential wastewater contamination and investigation and its removal from the stormwater network;

(g) Contaminant load modelling to indicate the primary sources of specific contaminants to the system to enable the prioritisation of potential mitigation measures or treatment; and

[11] Low Impact Design is defined by NZS4404:2010 as “An approach to land development and stormwater management that recognises the value of natural systems in order to mitigate environmental impacts and enhance local amenity and ecological values.

(h) A monitoring programme involving: characterisation of the impact of the discharges on receiving water and sediment quality; a cultural monitoring programme which is being developed and implemented in conjunction with Te Ao Marama Inc; survey of shellfish and fish flesh contamination in the Orēti/New River Estuary; and survey of recreational uses of the water bodies.

82 Further to these approaches, there are a range of potential management options / interventions that can be applied to reduce contaminants both at source and at the end of the pipe prior to discharge to freshwater. The reductions in the four primary contaminants for stormwater systems (namely solids, copper, zinc, and petroleum hydrocarbons) for each of these measures is provided in the Contaminant Load Model User's Manual prepared by Auckland Regional Council[12]. An extract from the User's Manual for the model which identifies the typical reduction in contaminant load for each measure is included in Appendix B to this evidence.

83 Whilst some of these options result in significant reductions in contaminants, none result in complete removal of contaminants from the stormwater, and hence, even with implementation of these measures, some residual contamination will remain in the stormwater which will result in changes in water quality after discharge.

Sue Bennett

[12] Auckland Regional Council (2010) Contaminant Load Model User's Manual. Auckland Regional Council Technical Report TR2010/003.

Appendix A: Figures

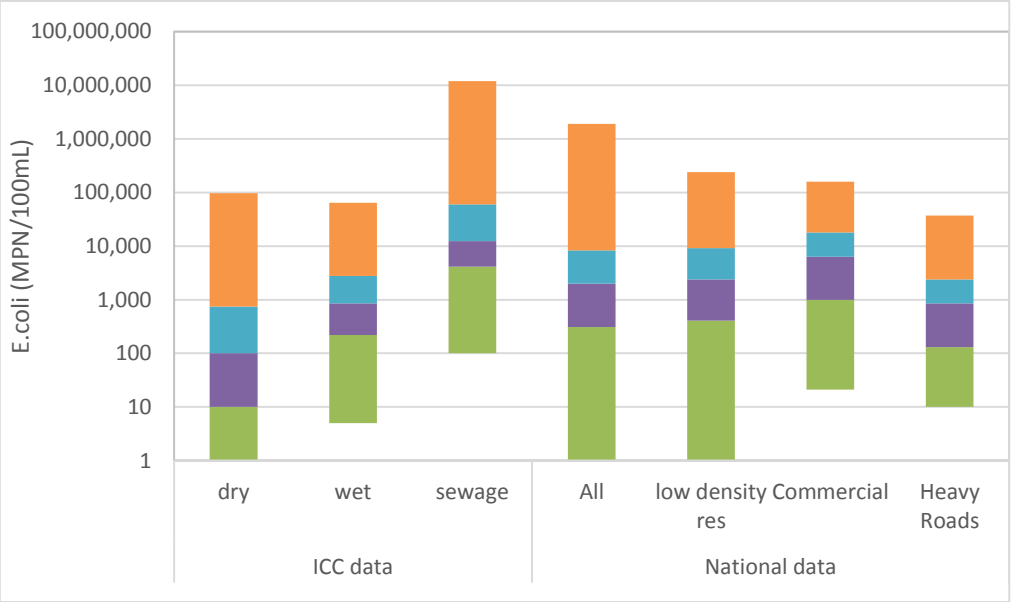

Figure 1: Comparison of Invercargill City Council *E.coli* concentrations in stormwater[13] discharges against national data[14]

[13] "Sewage" graph is for data from stormwater discharges which potentially include a portion of raw wastewater, and is not raw wastewater only which would be in order to 100,000 CFU/100mL to 10,000,000 CFU/100mL

[14] Each quartile of the data sets are shown in a different colour, i.e. the lowest 25% of each data set is in the green band. The interface between the blue and purple band is the median and the orange band is the top 25% of the data.

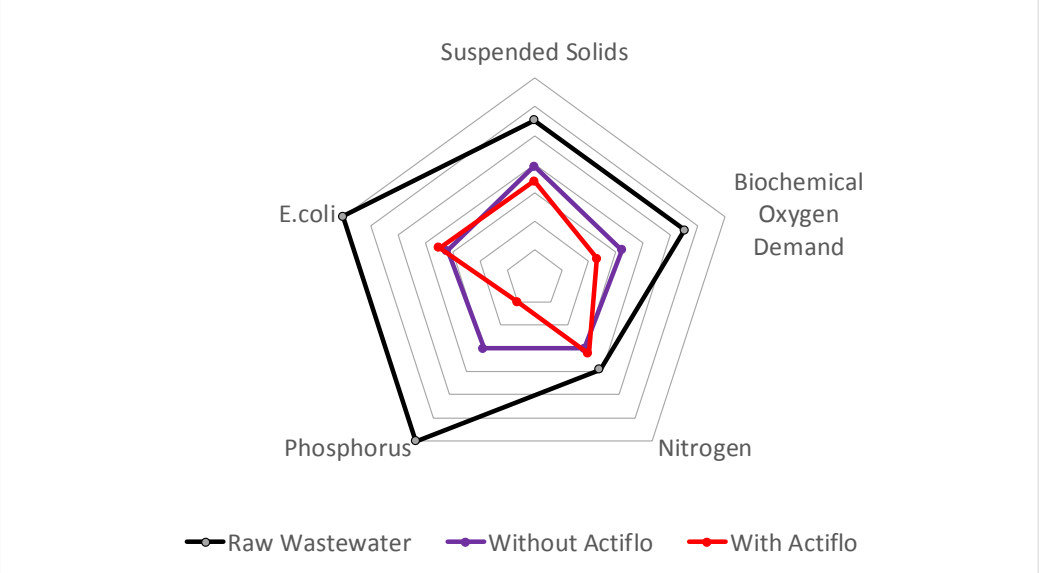

Figure 2: Raw wastewater and treated wastewater quality[15] from the existing Gore Wastewater Treatment Plant

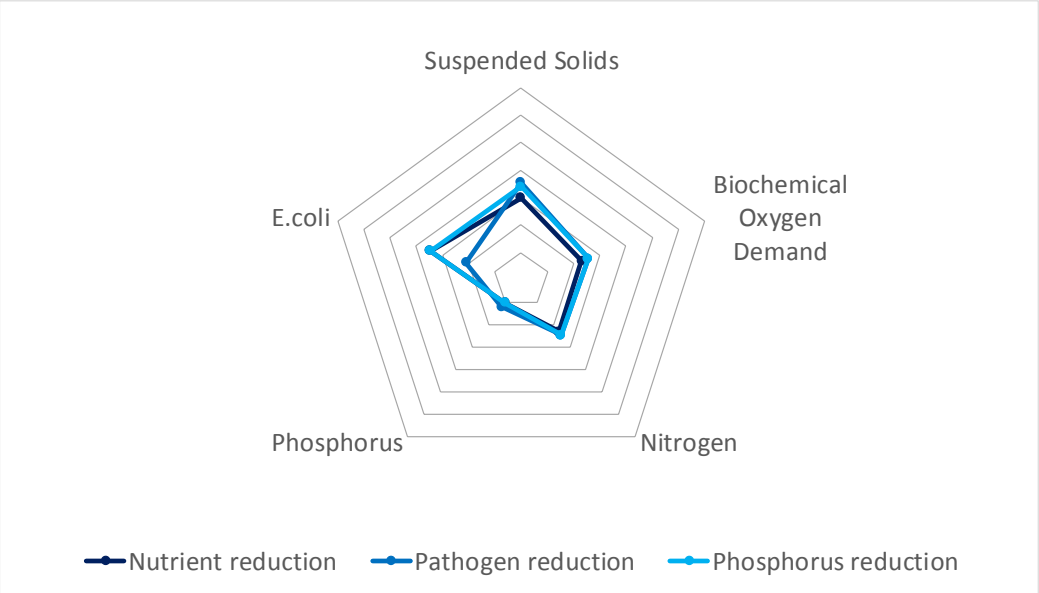

Figure 3: Predicted Treated Wastewater Quality[15] from "Discharge to Water" Scenarios for Gore Wastewater Treatment Plant

[15] The *E.coli* concentrations was log transformed and those for BOD, SS and TN were ln transformed.

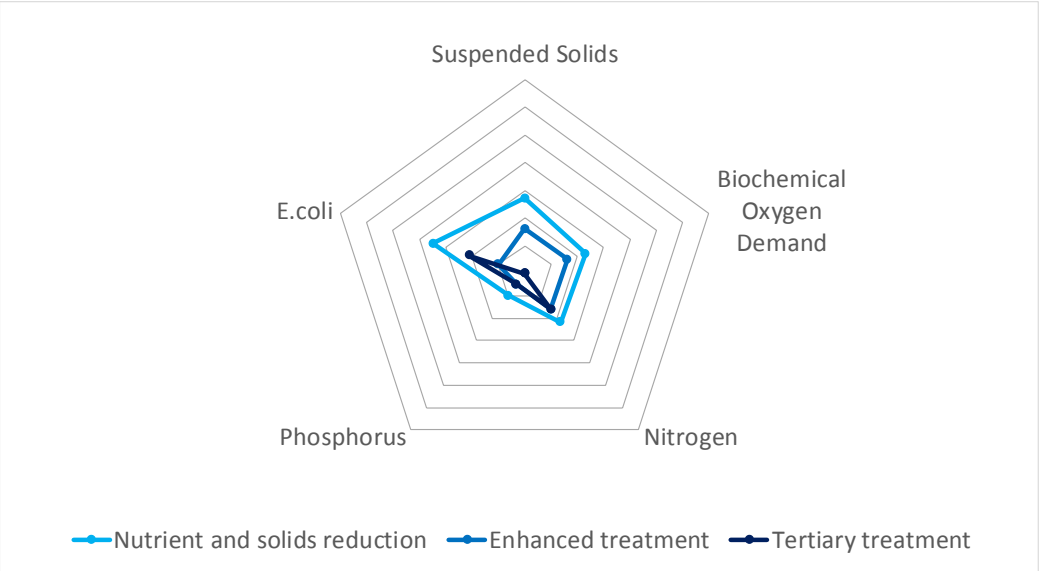

Figure 4: Predicted treated wastewater quality[15] from further "Discharge to Water" Scenarios for Gore Wastewater Treatment Plant

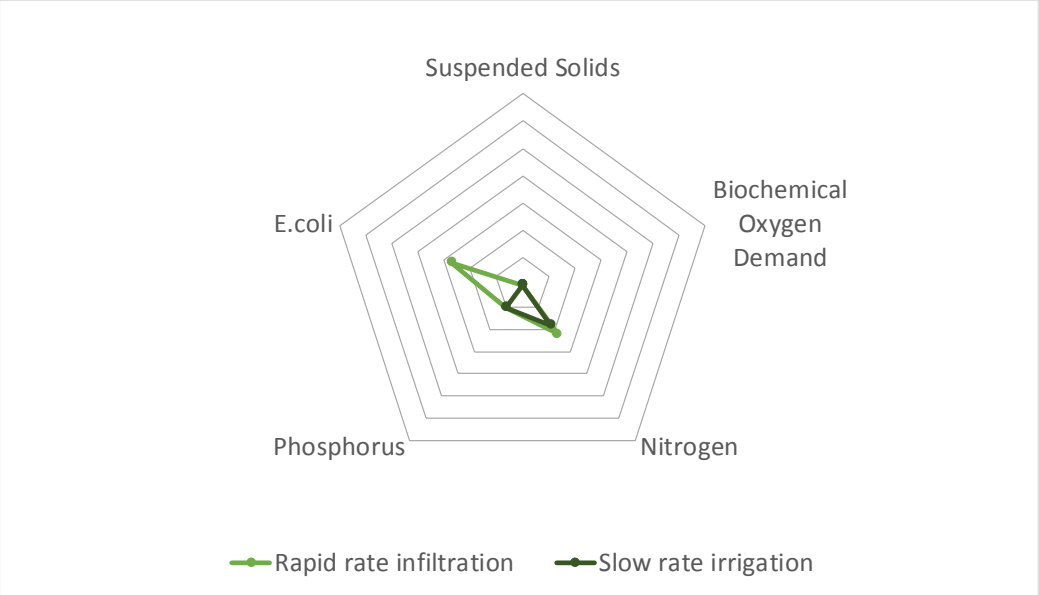

Figure 5: Predicted treated wastewater quality[15] at the point of discharge to groundwater from "Discharge to Land" Scenarios for Gore Wastewater Treatment Plant

Appendix B: Typical reductions in contaminant loads from various stormwater management options

Source: Auckland Regional Council (2010) Contaminant Load Model User's Manual. Auckland Regional Council Technical Report TR2010/003, Appendix C: Load reduction factors.

Appendix C: Load reduction factors

The term "load reduction factor" (LRF) refers to the proportion by which contaminant loads can be reduced by management options that include source control measures such as roof painting and stream bank stabilisation, as well as stormwater treatment. For stormwater treatment devices the LRFs are the treatment or contaminant retention efficiencies. The CLM includes a full set of default LRF for all management options as shown in Table C.1. These LRFs were chosen to be the highest load reductions likely to be achieved by a correctly designed, implemented (or installed for an engineered device), and maintained management option. The LRF for an option train can be changed by the model user as explained in Section 5.4.

Table C.1. Load reduction factors used for the CLM management options irrespective of the option position in the management train

Roofs

	Load reduction factor			
Treatment Option	**TSS**	**Zn**	**Cu**	**TPH**
Biomedia filtration	0.75	0.60	0.70	0.00
Constructed wetland	0.50	0.25	0.30	0.00
Dry pond	0.10	0.05	0.05	0.00
Painting	0.00	0.90	0.90	0.00
Rain garden	0.70	0.60	0.70	0.00
Sand-filter	0.50	0.10	0.15	0.00
Storm-filter	0.50	0.15	0.20	0.00
Swale	0.30	0.15	0.20	0.00
Vegetative filter strips	0.20	0.10	0.20	0.00
Wet extended pond	0.20	0.10	0.10	0.00
Wet pond	0.10	0.05	0.05	0.00
Wet pond with flocculation	0.80	0.40	0.60	0.00

Roads and other paved surfaces

	Load reduction factor			
Treatment Option	**TSS**	**Zn**	**Cu**	**TPH**
Biomedia filtration	0.75	0.60	0.70	0.70
Catchpit filter	0.40	0.20	0.25	0.30
Catchpits	0.20	0.11	0.15	0.15
Constructed wetland	0.80	0.60	0.70	0.60
Dry pond	0.60	0.20	0.30	0.10

Porous paving	0.50	0.30	0.40	0.50
Rain garden	0.75	0.70	0.75	0.80
Sand-filter	0.75	0.30	0.40	0.70
Storm-filter	0.75	0.40	0.65	0.75
Swale	0.75	0.40	0.50	0.40
Vegetative filter strips	0.30	0.10	0.20	0.30
Wet extended pond	0.80	0.40	0.50	0.20
Wet pond	0.75	0.30	0.40	0.15
Wet pond with flocculation	0.80	0.50	0.60	0.50

Urban grasslands and trees, construction sites and bottom-of-site

	Load reduction factor			
Treatment Option	**TSS**	**Zn**	**Cu**	**TPH**
Biomedia filtration	0.75			
Catchpit filter	0.40			
Catchpits	0.20			
Constructed wetland	0.80			
Dry pond	0.60			
Porous paving	0.50			
Rain garden	0.75			
Sand-filter	0.75			
Storm-filter	0.75			
Swale	0.75			
Vegetative filter strips	0.30			
Wet extended pond	0.80			
Wet pond	0.75			
Wet pond with flocculation	0.80			

Stream Channels

	Load reduction factor			
Treatment Option	**TSS**	**Zn**	**Cu**	**TPH**
Concrete Channel	1.00			
Enclose (pipe)	1.00			
Rock, timber bank protection	0.75			