Before the Proposed Plan Change One Hearings Panel
In Wellington

Under	the Resource Management Act 1991 (the Act)
In the matter of	the Proposed Plan Change One to the Natural Resources Plan – Hearing Stream 2: Objectives, ecosystem health policies, and wastewater.
Between	**Greater Wellington Regional Council** Local authority
And	**Wellington Water Limited** Submitter 151 and Further Submitter FS039

Statement of evidence of Liam Alexander Foster for Wellington Water Limited

Stormwater

Dated 14 March 2025

DENTONS

40 Bowen Street
PO Box 10246
Wellington 6143

P +64 4 472 7877
F +64 4 472 2291
DX SP26517

Solicitor: E Hudspith/S Fowler
E ezekiel.hudspith@dentons.com/samantha.fowler@dentons.com

13077127.1

Statement of Evidence of Liam Alexander Foster

1 Introduction

1.1 My full name is Liam Alexander Foster.

1.2 I am a Technical Principal – Water for WSP New Zealand Ltd.

1.3 I am a Fellow of the Chartered Institution of Water and Environmental Management, a Chartered Water and Environmental Manager, Chartered Scientist and Environmentalist and have been since 2007. I hold a Master of Science Degree. I have over 25 years of experience in stormwater, catchment and flood risk management

1.4 My expertise is in the development of stormwater management strategies and catchment management planning for Territorial Local Authorities around New Zealand and have been working in an advisory capacity, supporting Wellington Water Ltd ('WWL') since March 2022.

1.5 Of relevance to this evidence is my role leading the delivery of the Draft Stormwater Management Strategy (SMS) through to May 2023 to support the application for the Global Stormwater Consent for WWL.

1.6 The SMS involved working closely with the Chief Advisor – Stormwater and Climate Change and the Network Discharge Consent team within Wellington Water. Several workshops were held to include and incorporate the key functional requirements across the departments of Wellington Water including the Strategy & Planning, Development & Delivery and Customer & Operations groups.

1.7 This evidence focuses on the provisions of Plan Change 1 ('PC1') that relate to the implications of the objectives and ecosystem health implications for WWL as the stormwater service provider on behalf of its client councils.

1.8 I have been engaged by WWL to give this evidence.

2 Code of Conduct

2.1 Although this matter is not before the Environment Court, I confirm that I have read the 'Code of Conduct for Expert Witnesses' in the Environment Court Practice Note 2023, and agree to comply with it.

2.2 I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions I express. Unless I state otherwise, this evidence is within my sphere of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

3 Summary of evidence

3.1 The purpose of this evidence is to explain generally how WWL provides stormwater services on behalf of the four client councils contained within the relevant Whaitua areas, where stormwater is managed so that water quality within the natural waterways entering the harbours is improved over time.

3.2 The evidence examines the local authority stormwater network, contaminant sources, the gap between current and desired water quality, and measures to achieve targets. It specifically addresses likely implications of the proposed plan change on WWL as the stormwater services provider.

3.3 The network is designed primarily for flood protection, but it also conveys contaminants from urban surfaces. WWL manages a large network of pipes, pump stations, and other assets, but is reliant on council funding to deliver the functions required.

3.4 I also note that private and other organisations (such as the New Zealand Transport Authority / Waka Kotahi (NZTA)) and other large land holdings (like schools, hospitals and industry / commercial units) have ‘private’ stormwater networks and devices that also contribute contaminants to the receiving environment.

3.5 Major contaminants include heavy metals (copper, zinc), faecal matter, nutrients, hydrocarbons, microplastics, and sediment. The major sources include building materials, vehicles, pet waste, and general urban runoff, for which WWL are not able to control through current regulatory systems and approaches.

3.6 Significant reductions in copper and zinc loads are needed to meet target water quality objectives in rivers and coastal areas, with the changes proposed in both the notified PC1 document and revisions incorporated in the Section 42A (**S42A**) reports. There are some waterways that have data gaps that hinder accurate assessment of baseline conditions.

3.7 The difference between the current state, and the target state, creates a large challenge. Strategies to bridge this gap include minimising impacts from new development, retrofitting urban treatment through implementing investigations such as catchment management plans, and promoting source control through education and behaviour change. Both structural (e.g., wetlands, swales) and non-structural (e.g., policy, education) options are considered as options that can support the overall goal of improving stormwater discharges.

3.8 In my opinion, most of the activities that can support reductions of contaminants being generated are within the control of organisations other than WWL, including property owners, Local Authorities, other infrastructure providers and the Regional Council. WWL does not have direct control over how the contributions of contaminants from these other parties can be achieved.

3.9 WWL provides guidance on appropriate treatment devices, but retrofitting solutions into existing urban areas presents challenges that reduce the ability to achieve the required quality objectives. Additionally, the effectiveness of treatment solutions varies depending on factors like contaminant type, system design, and maintenance. In my opinion, retrofitting stormwater treatment into existing urban environments requires compromises, that are likely to make the targets near impossible for WWL to be responsible for.

3.10 It is my understanding that WWL does not currently have access to the data or analytical tools required to assess the correlation between contaminant load out of a pipe and contaminant concentrations (i.e. TAS) in the receiving environment.

3.11 My evidence highlights the complexities of managing urban stormwater and the significant effort required to improve water quality. In my opinion, the need for collaborative action (across councils, other stormwater network owners, mana whenua, and industry bodies) and strategic investment is the most effective manner for delivering the long-term expectations for improved water environments.

3.12 Management Plans are a key tool for developing integrated catchment management approaches, collating and reviewing the available information to prioritise interventions to have the greatest impact. This helps to guide the requests to councils for future funding decisions and to provide evidence of the role that other organisations would need to deliver on to support PC1 objectives.

3.13 I consider that an overarching approach that enables and, where required, enforces responsible parties to all play their part in improving outcomes as opposed to targeting a network service provider as being responsible for water quality implications for receiving water environments is appropriate as presently.

3.14 It is my opinion that as WWL is not able to control the generation of the contaminants, it will require other mechanisms to be delivered to control source inputs (such as changes to district plan rules, or specific council bylaws to require the use of inert building materials discharging to stormwater networks) to deliver improvements.

3.15 If there is no ability to control the source, recognised as being difficult, time-consuming and expensive then WWL will be required to address the improvements at the discharge point.

3.16 The current practices and techniques available require land to be set aside for the function of treatment, are equally costly and time consuming to deliver and the effectiveness of these devices to reduce the dissolved contaminant state means that there is the potential to not achieve the TAS requirements within the timeframes as currently proposed.

3.17 WWL will comment on the full package in HS4 as that will give more time to digest the impact of the changes in the TAS/CWO numbers alongside the broader proposed planning framework.

4 Scope of evidence

4.1 My evidence addresses the following:

- The local authority stormwater network within Whaitua Te Whanganui-a-Tara and Te Awarua-o-Porirua Whaitua;
- The different sources or causes of contaminants entering the local authority stormwater network;
- The current 'gap' between baseline state of the environment and target attribute states ('TAS') and coastal water objectives ('CWO') under PC1, as relevant to stormwater management;
- Measures available to contribute to meeting the TAS and CWO, with a focus on:

  a Which of these are within WWL's control;

  b The likely efficiency or effectiveness of different options; and

  c High level cost of these options.

4.2 The purpose of my evidence is to describe the potential implications of the proposed plan change, as they relate to stormwater management, on WWL, as the stormwater service provider on behalf of its client councils.

4.3 I have referred to the following documents when preparing my evidence:

- S42A Report – Objectives, 28 February 2025
- S42A report - - Ecosystem Health & Water Quality policies, 28 February 2025
- Evidence of Dr Michael Greer, dated 28 February 2025
- Wellington Water Ltd – Stormwater Management Framework V2.0 October 2023

4.4 In this statement of evidence, I do not repeat the description of the plan change and refer to the summary of the plan change in the Council's S42A report.

5 The stormwater network within Whaitua Te Whanganui-a-Tara and Te Awarua-o-Porirua Whaitua

5.1 'Stormwater' is defined in PC1 as 'runoff that has been intercepted, channelled, diverted, intensified or accelerated by human modification of a land surface, or runoff from the external surface of any structure, as a result of precipitation and including any contaminants contained therein'.

5.2 In addition, PC1 defines the 'stormwater network' as:

> The network of devices designed to capture, detain, treat, transport or discharge stormwater, including but not limited to stormwater treatment systems, kerbs, intake structures, pipes, soak pits, sumps, swales and constructed ponds and wetlands, and that serves a road or more than one property.

5.3 When land use is converted to urban, the increase in imperviousness gives rise to a significant change in the quantity and quality of the runoff. As a result, the network collects and conveys contaminants that build up on these impermeable surfaces (sediment, metals and other organic/inorganic matter).

5.4 The stormwater network serves a critical function in managing stormwater within the urban areas and has traditionally been designed with the primary objective of safeguarding people, property and infrastructure from flood hazards (rather than a focus on water quality).

5.5 In essence, the stormwater network has been designed to effectively collect and convey regular rainfall runoff away from urban properties and roads to reduce the risk of flooding.

5.6 The networks include infrastructure that connects surface water (stormwater) and sub-surface water (groundwater), by intercepting stormwater and discharging it into the ground or providing a pathway for groundwater to discharge onto the surface.

5.7 There are systems that direct stormwater into the ground (and therefore also into groundwater) – these are typically known as infiltration or soakage systems.

5.8 A review of WWL's Stormwater Management Framework[1] identifies that management of stormwater integrates and overlaps with several different organisations and activities.

5.9 Figure 1 summarises the split and interfaces between these different organisations and individuals. For the purposes of PC1 the client councils include Wellington City Council, Porirua City Council, Hutt City Council, and Upper Hutt City Council.

5.10 Landowners are responsible for:

- Private, built stormwater assets on their land. This includes
  - i Sumps
  - ii Grates
  - iii Laterals (up to the connection to the public main)
  - iv Attenuation devises
  - v Streams and watercourses on their land
  - vi Channels on their land
- Private access structures, e.g. bridges, that cross streams and watercourses.

5.11 WWL is responsible, in general, for

- the client council-owned and public, built stormwater assets, including those located on private land that collects (not including local authority roading assets), conveys, and discharges stormwater on behalf of our client councils. These include:

[1] WWL (2023) Stormwater Management Framework. Version 2.0 October 2023.

i Pipes,

ii Pump stations,

iii Attenuation devices,

iv Intakes and outlets (including on private land)

- The area around the intakes and outlets including the stream immediately upstream or downstream of the structure.

- Investigation of local authority road drainage assets where these are insufficient or in poor condition and are causing flooding issues.

5.12 The councils are responsible for:

- Streams and watercourses in Local Authority owned land, often managed by the Parks and Reserves teams.
- Road Drainage assets, which are managed by the roading teams, including sumps, sump leads, strip drains.
- Public bridges that cross rivers or streams.

5.13 The Regional Council are responsible for

- Consenting of works in or discharges to watercourses

- 'Large' rivers as determined in each Watercourses Agreement (summarised into Table 1 below).

Table 1: GWRC Managed Rivers

Local Authority Area	GWRC Managed Rivers
Hutt City	Hutt River Wainuiomata River Waiwhetu Stream
Porirua	Porirua Stream
Upper Hutt	Mangaroa River Pinehaven Stream
Wellington	None

- In addition to being responsible for the rivers listed in Table 1, the Regional Council undertake maintenance work on sections of other rivers and streams that are the responsibility of client councils per the Watercourses

Agreement. The Regional council charges the client council for this work through WWL.

- Further clarity on Regional Council's role in the management, maintenance and regulation of watercourses can be found on their website[2]

5.14 The network represents assets that lie within the boundaries of the urban zone as identified across the four Councils' District Plans, with WWL supporting the councils though:

- Obtaining and complying with regional consents for stormwater network discharges (the subject of this SMS)
- Carrying out works in the beds of some urban streams and channels, such as clearing channels to improve flows and protecting banks from erosion.
- Processing applications for new or modified connections to the network (to support new and modified buildings) for some of the client councils.
- Undertaking the role of engineering approval of extensions to the public networks (to support subdivision and new roads)
- Undertaking investigations, modelling, design and installation of network replacements, upgrades, and improvements.
- Operations and maintenance of the existing public networks, including monitoring of discharges.
- Data management.
- Asset management, including providing recommendations to councils for funding to achieve the above and the required levels of service.

[2] Website: Floodplain Management Plans & Strategies (GWRC) (accessed 05/03/2025)

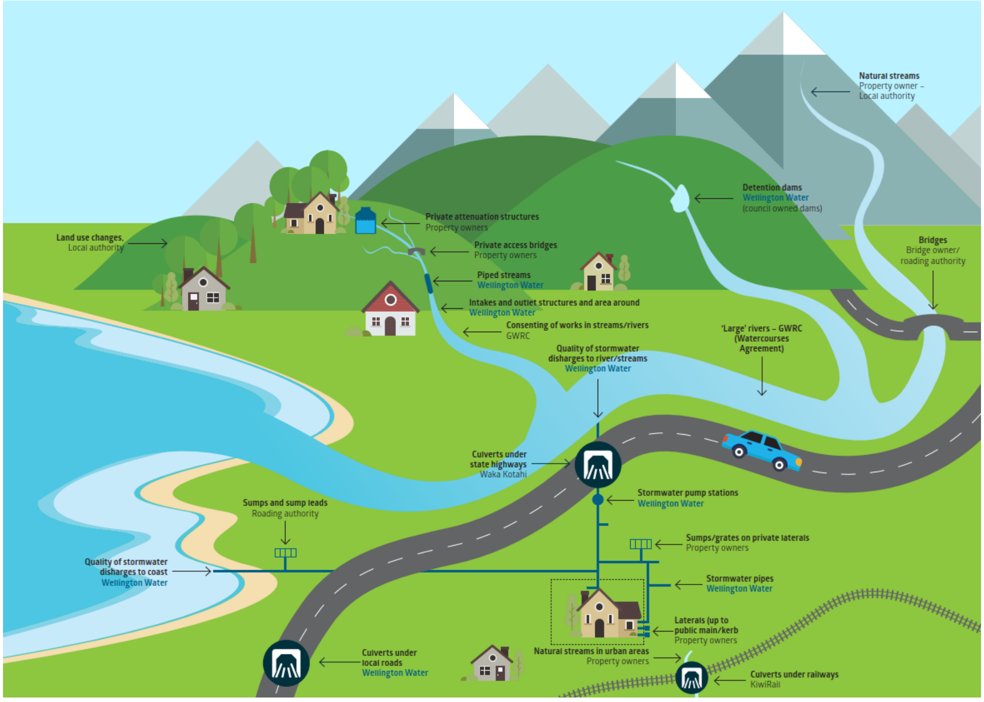


Figure 1 – Stormwater Management - Roles and responsibilities.

5.15 WWLs activities are based on councils' provision of a primary level of service comprised of pipes, formed drainage channels and soakage systems designed and managed to carry rainwater away from buildings and properties. The network receives local authority runoff through the Council operated assets (sumps, grates and sump leads) into the WWL controlled stormwater system.

5.16 WWL's activities also includes for the provision of a secondary level of service comprised of overland flow paths and along road surfaces to protect people and properties from the flood hazards from larger rain events.

5.17 I understand that WWL is reliant on the provision of funding to undertake these activities on behalf of its client councils through the councils' Long-Term Plan (LTP) processes. I am also aware that WWL's role is to provide advice to the councils, through the LTP process, on the capital and operating expenditure anticipated to be needed to deliver on our role in managing the stormwater network (and others) and to meet customer expectations and regulatory requirements.

WWL manages an extensive list of stormwater assets including over 1600 km of stormwater pipes, over 20 pump stations, and numerous associated fittings and other assets. The control of quantity and quality regarding stormwater often need to go hand in hand to achieve optimal benefit and value.

Table 2: Stormwater assets currently management by WWL

Client Council	**Stormwater Network Asset Quantity (as of August 2020)**
Hutt City Council	454 km of pipes 13,500+ associated fittings 5 Detention Dams 12 pump stations
Upper Hutt City Council	155 km of pipes 3800 Fittings 7 Pump Stations
Porirua City Council	294 km of pipes 9100 fittings
Wellington City Council	729 km of pipes 27,800 fittings 3km tunnels 2 pump stations

Receiving Environments

5.18 Natural rivers or stream tributaries are often informally considered as being part of the stormwater network (though they are not included in the PC1 definition above); as identified above they perform a catchment function in enabling the passage of water from mountain to sea collecting runoff from stormwater networks and rural land. These assets are not considered to be part of WWLs stormwater network as WWL is not responsible for their operation or maintenance.

5.19 There is a potential that the effects of the discharges from all private stormwater systems that discharge directly into the rivers or stream tributaries. From my experience, there are typically thousands of outfalls across an urban environment, which bypass the 'public' or Council reticulated networks and discharge directly into a receiving environment.

5.20 Work that has commenced to trial a stormwater catchment plan for the Black Creek sub-catchment, part of the Wainuiomata Urban Streams FMU, identifies that there are approximately 150 outfalls that are identified as being part of the public network. Additionally, there are many others that discharge directly from unknown sources, along approximately 5 – 6 km of waterway within the urban land use zone. Work I supported Christchurch City Council with during 2015 - 2017, undertaken post-earthquake could only link roughly 80% of the outfalls across over 500km of waterways to the public network.

5.21 This represents a challenge for both the consent holder and the regulatory authority given that across typical urban environments there are many more 'private' outfalls than those that the councils own and WWL is responsible for. This includes other 'stormwater network' operators, such as the Wellington International Airport Limited (WIAL) and the NZTA highway networks that either discharge directly to the receiving environment or contribute flows to a council owned network that WWL is responsible for.

These other contributions are likely to make difficult to discern the extent to which WWL controlled stormwater discharges are responsible for target attribute states not being met, or in determining 'commensurate' reductions in contaminant load.

6 Stormwater contaminants entering the stormwater network

6.1 There are different sources or causes of stormwater contaminants entering the stormwater network. When I refer to contaminants entering the stormwater network, I mean through the primary entry points being roof gutters and sumps.

6.2 Urban surfaces tend to have either a form of coating (such as paint, galvanising, asphalt, etc) and / or a layer of more temporary substance (such as airborne deposits or cleaning products for instance). These substances and coatings over time can become fully or partially soluble. Rainwater carries these in either a dissolved or particulate form into the network through the entry points, where they are determined to be contaminants. These include:

- a Heavy metals (such as zinc and copper) which come from building materials (such as rooves) and brake pads;
- b Faecal matter (E. coli and Enterococci) which comes from pet waste and waterfowl;
- c Nutrients (Nitrogen, Phosphorus) from gardens and landscaping;
- d Heavy metals, hydrocarbon and emerging pollutants which come from roadways, vehicles, and household activities such as car washing or driveway cleaning;
- e Gross pollutants and microplastics which come from litter;
- f Sediment due to development activities, and;

g Various other contaminants (such as a group of emerging chemicals of concern) of organic chemicals and products that are in day which can come from spills and land contaminated by historical land uses (HAIL sites).

6.3 Increased temperature, and increased volumes, of stormwater generated from urban surfaces may also impact on receiving environments.

6.4 In my opinion, most of the activities that can support reductions of contaminants being generated are within the control of organisations other than WWL, including property owners, Local Authorities, other infrastructure providers and the Regional Council. WWL does not have direct control over how the contributions of contaminants from these other parties can be achieved.

6.5 Plan Change 1 sets out a requirement to reduce the discharge, among other things, of sediment, copper, zinc and *E. coli* from the networks. These are major contaminants found across the region's receiving environments. They are often found in stormwater and contribute a range of concentrations of contaminants that are found in receiving waters. Several factors influence this concentration, including extent of urban network upstream, state and condition of the receiving environment and the proportion of surfaces that contribute contaminants.

Sediment

6.6 Sediment, often referred to as Total Suspended Sediments (TSS) come from any surface, from either natural processes (wind deposition, weathering etc) or through deliberate application. There are multiple sources across the catchment and the relative contributions have not specifically been quantified, but based on national and international studies then construction site sediment, vehicle particulates and road abrasion are significant sources.

6.7 Sediments are a core contaminant of interest both due to the physical impact on aquatic life and the receiving environment, but also because sediment from urban runoff often carry other contaminants and pollutants.

6.8 For the purposes of this evidence, I concentrate mainly on the requirements associated with meeting target attribute states for both Copper and Zinc as activities associated with their removal reduce sediment levels effectively as well

Copper

6.9 International and NZ experience is that the main sources of copper are vehicle brake pads[3]. Other sources include copper such as guttering and downpipes, cooling water discharges, fungicides and soils (Kennedy & Sutherland, 2008).

Zinc

6.10 Zinc is a key metal of interest in urban street runoff (Shaver et al. 2007). Additionally, urbanised areas, especially industrial areas, tend to have galvanised metal roofs, a significant source of zinc in urban runoff (Clark et al. 2008). Residential areas typically have painted or tile roof, but many of these have older paint coatings in poor condition, with these roofs being shown to be a large source of zinc, being between 50 – 75 % (ARC, 2008[4])

6.11 Zinc is also found as vulcanising catalyst (zinc oxide) within car tyres. Tyre wear releases zinc onto the roads, contributing to a significant zinc load being released into the environment.

6.12 Other galvanised metal surfaces common in the urban environment include ductwork, heating/ventilation/air-conditioning (HVAC) equipment, ventilation fans, turbines, pipes, roof gutters/downspouts, fencing, and guardrails.

6.13 Out of the pollution sources listed above, only a small number of these are managed under existing regulations, such as that through land use change, Industrial sites discharging to the stormwater network. The extent to which changes in the above actions can be manged is partially reliant upon strong policy and regulations within the client councils and enforcing the applicable development standards through planning and consenting requirements for buildings and subdivision. These activities are largely outside the control of client councils and WWL.

6.14 I note for completeness that wastewater entering the stormwater network (either from public and private cross connections or exfiltration) is also a source of contaminants. However, those contaminants fall within the scope of the wastewater network discharge applications, rather than the global stormwater application, and

[3] https://www.gw.govt.nz/assets/Documents/2022/05/REPORT-Issues-Paper-Zinc-and-Copper-TAoPW-Committee-Workshop-4.10.18.pdf
[4] Auckland Regional Council (2008) – Urban sources of Copper, Lead & Zinc (TR2008/023)

is addressed in the evidence of Mr Steve Hutchison. Accordingly, I do not comment on these sources of contaminants further in my evidence.

7 The current gap between target attribute states and actual environmental baseline state

Rivers

7.1 Work undertaken by Stantec during 2025 (presented in Appendix 1), indicates that to meet the TAS presented with the notified version of PC1:

a A large reduction in copper loads (50 to 99%) would be required in 10 of the 37 sub-catchments These catchments include Kaiwharawhara, Duck Creek, Taupo, Waiwhetū, Stokes Valley, Hulls and other Te Awa Kairangi urban catchments.

b Smaller reductions in copper (4%) would be required in an additional 9 sub-catchments including the Ngauranga, Karori, and Wellington urban catchments.

c A large reduction in zinc loads (40 to 76%) would be required in the same 10 sub-catchments as listed for copper.

d Smaller zinc reductions (8%) would be required in an additional 12 sub-catchments including Black Creek, Porirua, and the Wellington urban catchments.

7.2 It is my understanding that the work presented above and received is consistent with that of Dr Michael Greer's evidence.

7.3 I note from the Tables in Appendix 4 of the S42A objectives report that there have been some recommended changes to the TAS in certain FMUs, taken from the evidence of Dr Michael Greer – as such the required reductions in copper and zinc loads may differ from that presented here in my evidence.

Lakes

7.4 PC1 defines freshwater management units for lakes Kohangapiripiri and Kohangatera. As there is no local authority stormwater infrastructure managed by WWL within these catchments, I will not consider them further.

Coast

7.5 PC1 defines seven coastal management units (**CMUs**), these being Onepoto Arm, Pauatahanui Inlet, Open Coast (Porirua), Te Whanganui-a-Tara harbour and estuaries, Makara Estuary, Wainuiomata Estuary, and Wai Tai. PC1 also includes a series of 'Coastal Water Objectives' (**CWO**) and requires that the CWO's are met by 2040. Work by Stantec (2025) shared in Appendix 1 shows how the CMUs align with their contributing sub-catchments.

7.6 The policies identified within PC1 to achieve the CWO's, include a 40% reduction in copper and zinc baseline loads to Pauatahanui Inlet and Onepoto Arm.[5] Should mitigations be able to achieve the load reductions necessary to achieve the rivers part-FMU TAS from the stormwater network, then the network derived commensurate load reduction necessary to align with the Te Awarua o Porirua CMU policies will also likely be achieved.

7.7 For the other CMUs, PC1 does not set specific contaminant load reductions for copper or zinc, then there would be an expectation to reduce copper, and zinc loads to contribute to meeting the coastal water objectives to maintain or improve.

Discussion

7.8 A number of PC1 provisions for stormwater refer to making reductions of copper and zinc (rules WH.R9, P.R8, and Schedule 31), that are "commensurate with what is required in the receiving environment to meet the target attribute state" (or similar wording).

7.9 It is my understanding that WWL does not currently have access to the data or analytical tools required to assess the correlation between contaminant load out of a pipe and contaminant concentrations (i.e. TAS) in the receiving environment.

7.10 While WWL can model the contaminant load (e.g. total kilograms of copper and zinc from the stormwater network), how that translates to concentrations in the receiving environment is dependent on factors such as stream flows and ocean currents (which affect dilution and therefore concentration).

7.11 There is a gap between the target attribute states in PC1 and actual environmental baseline state. For example, the evidence shared in Appendix 1 shows that the notified PC1, requires dissolved copper and zinc to move from C (the baseline state) to B (TAS) in the Te Awa Kairangi urban streams. Paragraphs 8 onwards share potential approaches and investments required to improve the attribute state as required, and discuss the implications of this for WWL.

7.12 I note from the work referred to within the evidence of Mr Greer, that there are some changes proposed to the proposed target future state. While the changes to TAS recommended in the S42A report have narrowed that gap between TAS and current state in some cases. WWL will comment on the full package in HS4 as that

[5] Policy P.P4 sets contaminant load reductions for the Plan. Policy P.P12 then provides more specific direction for stormwater discharges from local authority networks (15% for copper and 40% for zinc) to contribute towards meeting the target attribute states and coastal water objectives for copper and zinc in the Onepoto Arm and Pāuatahanui Inlet.

will give more time to digest the impact of the changes in the TAS/CWO numbers alongside the broader proposed planning framework

8 Available measures to contribute to meeting the TAS and CWO

8.1 Stormwater can be managed at a range of scales in the urban environment. WWL is currently reviewing the approaches that it can take to support the outcomes sought. Previous work, that requires further review, to respond to the outcomes of the PC1 process, resulted in the draft Stormwater Management Strategy (**SMS**)[6], submitted with Wellington Water's Global Stormwater Stage 2 application. The SMS identifies a series of approaches to support the progressive improvement over time of receiving water environments.

8.2 The SMS lists a range of interventions (represented in Appendix 4) that could support achievement of the receiving environment objectives and targets. The Draft SMS included an improvement programme, positioned over multiple Long-Term Plans from Councils to reverse the historical environmental impact over time.

8.3 To reverse the impacts of over 150 years of development, will take a concerted effort and require the consolidation of many forms of investment to give the best chance for the outcomes to be achieved.

8.4 Stormwater treatment facilities (such as bioretention devices, wetlands and proprietary devices etc) that are incorporated into new developments are not capable of removing 100% of their development impacts on water quality (as discussed in Paragraph 8.16 onwards). Therefore, work is required over time to reduce the load of contaminants from our existing urban environment to be able to improve the quality of the receiving environment. New development alone will not be able to do this and will over time add to the catchment load.

8.5 To support an improvement in the receiving environment, it is therefore essential that the Councils work with and fund WWL to provide stormwater facilities that treat runoff from existing urban areas to improve the overall quality of stormwater discharges.

Options available for WWL to follow

[6] Wellington Water Ltd (July 2023) He Rautaki Wai Āwhātanga | Stormwater Management Strategy – for lodgement of Stage 2 Global Stormwater Consent application with Greater Wellington Regional Council. Prepared by Connect Water for Wellington Water. Taken from https://www.wellingtonwater.co.nz/assets/Resources/Stormwater/July-2023-proposed-SMS.pdf

8.6 There are many pathways to improving and minimising the effects of stormwater on waterbodies. Methods for targeting improvements may include:

a ***Minimising the effects / impacts of new development*** – Stopping the cycle of degradation – through the application of Water Sensitive Design to capture contaminants, where generated as part of the development design phase.

b Delivery of Catchment Management Plans and subsequent targeted improvement activities (see below for further details) across our existing stormwater networks – largely targeted towards delivering ***Retrofit Stormwater***.

c Working collaboratively with others to lift our overall relationship with water through education programmes and to change behaviours to shift towards ***Source Control***, as a key requirement to meet TAS and CWO requirements.

8.7 Crossing across each of these three approaches, there are further options /approaches that can be undertaken to manage contaminants in stormwater. These options can support all three of these generalised approaches set out above are presented in Appendix XXX. Broadly, these include:

a **Structural options** (such as vegetated swales, wetlands, rain gardens, gross pollutant traps, riparian buffers, and storage and detention systems) which are effectively physical changes to the network.

The efficiency of these devices to manage flooding, scour and removal of contaminants from stormwater is dependent on the characteristics of the site where they are implemented such as local topography and scale, as well as the specific design features of the management device.

b **Non-structural options** are essential to support the journey to wai-ora and are complementary to structural approaches, and involve shifting mindsets and behaviour through policy, planning, education, and engagement, such as awareness programs, government regulation and policy or economic incentives (these could include for example a roof policy, Stormwater Design Guidelines, target rates through stormwater bylaws, copper-free or reduced copper brake pads, and education and engagement campaigns). Other organisations could sensibly lead these initiatives or policy changes.

Good management practice evolves through time and results in continuous improvement as new information, technology and awareness of issues are developed and disseminated.

*WWL guidance for accepted devic**es for new development***

8.8 Guidance for new developments on the methods and techniques used for the mitigation of stormwater is provided in several documents, predominantly WWL's Treatment Device Design Guideline (TDDG)[7]. The TDDG describes the types of systems acceptable for connecting new development to the public stormwater devices (to be owned and operated by WWL on behalf of their respective Councils). Other approaches are acceptable as well in negotiation with relevant WWL departments.

8.9 Notably TDDG does not seek to 'focus on the design of devices to be retrofitted into existing urban areas. These applications require specialist design to ensure that treatment outcomes are met'.

8.10 The guideline covers four specific types of treatment devices, with others being able to be used but requiring consultation with WWL. The four captured devices are Wetlands, Bioretention, Swales and Pervious Paving with Table 3 of the TTDG sharing the treatment and water quantity roles anticipated for each application. The first three of these have been the predominant items

8.11 WWL accepts through its stormwater authorisations process for new connections and redevelopment sites some other types of devices and systems able to be used on private sites. I consider that these devices provide an equivalent water quality or quantity mitigation function, but either do not adhere to the WSD aspirations to water management or require additional specialised maintenance that WWL may not be able to maintain without specific funding agreements.

8.12 The nominated water quality treatment systems are designed around the concept of the 'first flush', with the TTDG requiring that assets are sized to treat approximately 90% of all annual stormwater runoff, typically known as the Water Quality Volume (WQV). This volume will allow for the treatment of the 'first flush', known to be the most contaminated portion of flows.

8.13 It is my opinion, that the types and designs of stormwater mitigation facilities described in the TTDG, and other documents used by the WWL reflect international best practice and are appropriate for the Wellington region's climate, its geological and hydrological environments.

8.14 Further iterations of the TDDG may be required to facilitate the overall outcome for achieving TAS, further devices or amendments to the devices currently included in

[7] WWL (2019) - Water Sensitive Design for Stormwater: Treatment Device Design Guideline (Version 1.1) – December 2019

the guide may be needed to enhance the opportunity for improving stormwater discharges to support TAS outcomes in specific catchments.

8.15 I further note that given the existing urbanised nature across many of the catchments, further analysis will be required into other forms of treatment, including proprietary devices. The lack of available space in appropriate locations through the urban catchments requires alternative approaches to achieve the TAS and CWO, and overtime be incorporated into future revisions of the TDDG. These are likely to present additional challenges in delivery and ongoing life cycle costs.

Relative efficiencies of treatment solutions.

8.16 Stormwater treatment refers to the removal of contaminants which are both particulate and dissolved. In the past, best practice has targeted particle removal on the basis that these were perceived to contain the greatest proportion of contaminants. However, Charters, 2016, shares that most roof-sourced zinc is likely to be dissolved, and approximately 50% of road-sourced zinc and 40% of road-sourced copper are likely to be dissolved.

8.17 Particles are removed by settlement when held in a calm state for long enough, or through filtration through soil or a manufactured filter, or by adhesion to biofilms or uptake in plant matter.

8.18 Dissolved contaminants are captured via chemical reactions or adhesion of atoms, ions or molecules to a filter medium. Filter media include soil, selected filter particles and biofilms.

8.19 There are several factors that can affect the efficacy of stormwater treatment devices, including:

a Suitability of the treatment type to contaminants;

b Adequacy of sizing;

c The size of the storm and the amount;

d Adequacy of maintenance;

e Influent stormwater quality; and

f Stormwater pH.

8.20 Of the options that are available to WWL, I have undertaken a preliminary review of them considering the feasibility of deploying them (e.g. physical space for them in urban environments, access issues, consequences for the network of end of pipe treatment, etc), and their effectiveness when they can be used (e.g. what proportion of heavy metal contaminant load are they able to remove).

8.21 Appendix 2 shares this review of the options available, their feasibility and projected treatment effectiveness, with Appendix 3 showing the relevant sections, taken from the 2020 International Best Management Practices database summary report and key findings. Table 3 below shares the summary data for treatment efficiencies for the four approved interventions from within WWL guidance document against the main contaminants of concern here.

Table 3 - Median of average treatment efficiencies[8] (%) summarised from International BMP Database[9], 2020.

	Wetland (n > 250)	Bioretention (n > 450)	Grass Swale (n > 350)	Porous Pavement (n > 300)
TSS	61	77	52	71
Total Copper	55	46	43	36
Dissolved Copper	42	-10	13	-2
Total Zinc	62	79	43	67
Dissolved Zinc	63	40	42	77

n = number of devices included in summary statistical analysis.

8.22 Use of each of the above options would require a thorough engineering feasibility assessment that captures the constraints and opportunities for delivery of the assets in that specific spatial location. This would typically occur through a structured catchment management planning process. However, I have highlighted the key fundamentals for successful deployment on the understanding that the other key elements are conducive to delivery for consideration

8.23 Comparing the average treatment efficiencies and the proposed reductions required to support the achievement of the TAS within the notified PC1, would suggest that multiple device types would likely need to drive the contaminant load reductions necessary to achieve the TAS within the receiving waters. Paragraph 8.32 onwards, talk to the likely outcome that the dissolved nature of contaminants represent a challenge to achieve the identified standards.

8.24 WWL seeks for all new development to follow good practice through both the water quantity and quality guidelines shared.

Retrofit Stormwater into Urban Areas

8.25 I support an approach that moves the industry towards achieving an integrated approach to catchment management. Delivery of area planning would facilitate this and target investigations to the areas of greatest improvement opportunity. This approach would help to deliver a prioritised response for the resulting capital delivery programme. It is worth noting that the area or proportion of catchment

[8] Refers to the Median % removal of a particular contaminant for a specific intervention (taken from the WRF database (see foot note 7) from the samples shared with the database.

[9] Water Research Foundation (2020) – Project No 4968: Internation Stormwater BMP Database: 2020 Summary Statistics. Downloaded from https://www.waterrf.org/system/files/resource/2020-11/DRPT-4968_0.pdf on 28th February 2025.

might be different through this area planning process to allow flexibility in how to prioritise investment to target better outcomes for the stormwater funding.

8.26 The intent of the area planning is also to identify management activities and options that will support stormwater discharge improved water quality across an appropriate management area (catchment, sub-catchment or even distributed to focus on specific land use types).

8.27 These plans will:

a share how through using good management practice, taking a source control and treatment train approach, by implementing WSD, and managing localised adverse effects, the planned activities will support the delivery of improvements to the receiving waterbodies;

b need to consider the context of the wider catchment issues and values such as environmental, social, and cultural. Infrastructure planning is tuned specifically to the catchment's unique water quantity and water quality issues (opportunities and constraints) and targeting improvements; and

c guide the councils in determining future capital budget requirements. The details that coordinate implementation of any sub catchment management plan with each Council LTP will be laid out in the future activities to schedule the investigations, consenting and capital delivery over the required period.

8.28 A trial Sub Catchment level Management Plan is currently in development for the Black Creek subcatchment of the Wainuiomata urban Streams FMU.

8.29 Retrofitting stormwater infrastructure into existing urban infrastructure, results in a series of compromises around the size, design and cost tend to mean that 100% performance is often not achieved.

8.30 The sizing and location of facilities would be preliminary in nature and may be changed by the Councils following land zoning decisions, land acquisition, opportunities not previously available and the completion of more detailed design processes. Through delivery of the sub catchment or other spatial scale / area management plans, Councils may also change the number and size of facilities (increase or decrease) to support other objectives and enable or support water quantity mitigation requirements.

8.31 The investigations and planning process can take several years to complete to be able to rely on the evidence contained within to make substantive and targeted water quality improvements. This would be the case with an unlimited budget, such that interventions are delivered that enhance the water quality without impacting third parties. Similarly, the design, consenting and capital delivery for each of the potential interventions can take several years to complete, particularly in areas where the land is not owned by the councils. The scale, quantum and range of interventions required across the four local authority areas would likely create a delivery and programme issue given the capacity issues within the engineering and design industry, as covered in the evidence of Mr Norman.

Source Control

8.32 Contaminant sources are widespread, therefore in my opinion an effective mitigation strategy should have catchment-wide coverage, for example a catchment-scale treatment basin. Unfortunately, large treatment facilities (such as swales, bioretention devices and wetlands:

a Are only practicable in greenfields catchments where land can be purchased for their construction. Approximately 80% of the city area is built-up, with land unavailable for treatment facilities; and

b Remove only a proportion of the contaminants passing through for both the particulate and dissolved state (Table 3 shares the average treatment effectiveness), with these facilities showing to be more effective at reducing particulate loads not dissolved).

8.33 As a result, and to support further reductions for the dissolved contaminants (given current measures are at best only partially effective in removal), further effort is required to avoid or better control the production of contaminants at source. Conceptually, this can be achieved either by stopping contaminant emissions or by exposing only contaminant-free surfaces to the environment. Source control is an attractive strategy because:

a It prevents having to recapture contaminants once they are released;

b The identified interventions are only moderately effective; and

c It incentivises a search for cleaner alternatives.

8.34 Of the three major contaminants in stormwater:

a Copper could be greatly reduced by legislation limiting the copper content in brake pads. Such legislation has been enacted in parts of the United States of America and as such the trend toward reducing this contaminant is underway. New Zealand could develop its own set of regulatory tools to increase the pace of adoption;

b Zinc emissions can be substantially reduced when bare zinc roofs are substituted with zinc-free materials. This is being partially achieved in new and replacement roofing by pre-painted aluminium/zinc sheet products and concrete tiles. However, the effectiveness of this as a strategy will be tested and perhaps diminished as paint coatings age and expose substrates to the atmosphere. Preserving the efficiency of any contaminant reduction device through maintenance will be an ongoing challenge;

c Zinc oxide is a component of tyre manufacturing. At present, despite ongoing international research a substitute has not been found, and tyre zinc seems unlikely to be controlled in the foreseeable future.

d Sediment can be controlled on construction sites, and to some extent on eroding landscapes. Other sources such as road surface abrasion, windblown dust and organic matter are not susceptible to source control.

8.35 From the available studies, both zinc and sediment are, for now, an unfortunate consequence of a road network and represent a continuing challenge for stormwater network providers to deliver mitigations for their adverse effects on the receiving environment.

8.36 The implementation of the source controls discussed above (or other controls) would take time to achieve, likely require the cooperation of several agencies, and is out of WWL's immediate control.

9 A step change in delivery is required

Timeframe & implications on delivery programme

9.1 For each of the contaminants noted, it can take some time after the work has been completed for the improvements to materialise. The time taken to derive statistically significant improvements in the state to be observed post environmental enhancement (Collier at al, 2002), may not be apparent by 2040, even if all the work was able to completed by then.

9.2 To demonstrate the time required to lead to improvements of watercourses it is worth noting the ideal and usual phases required to make and observe improvements to parameters, which are as follows: -

a Confirm statistically robust trends and identify sub-catchments where parameters contribute to failure of TAS

b Identify sources of contamination, including who is responsible for the contamination

c Identify actions to reduce contamination (e.g. policy change, infrastructure improvement, action against third party)

d Prioritise actions

e Develop business plan for these actions

f Secure necessary funding

g Develop and implement actions

h A period for improvements to be shown and to fix any issues with the effectiveness of implementation.

i Undertake monitoring over a suitable period to confirm the state, post improvements.

9.3 To achieve improvements in stormwater quality, the following actions will need to be undertaken:

a Catchment investigations, undertaking audits of high-risk sites, monitoring and modelling to support the identification of suitable locations for interventions to be placed.

b Programme and project management resources to support the efficient delivery of the enhanced capital programme to meet the water quality improvements. This work will require integration of modelling and mapping with operational activities in each catchment to then lead the delivery of capital solutions that close the gap to the TAS/CWO.

c Technical staff with stormwater design experience to validate the capital interventions that are suitable, including the need to abide by appropriate standards and can achieve the expected outcomes. This includes skilled enforcement and compliance officers, given the powers to direct the right outcomes on sites.

d Communications and Engagement teams to support the public educational requirements for appropriate activities/behaviours and to help inform the community of activities ongoing across the council areas.

e The design, consenting and construction of each of the potential interventions across each catchment. It is worth noting that these can have a significant impact on the delivery programme to identify suitable locations and deliver on them.

f A step change in funding from the client councils would be required to enable WWL to fulfil their responsibilities to carry out ***this programme of work.***

9.4 Using the required percentage reductions in contaminant load work (Stantec, 2025), I undertook a review the potential approaches for WWL to support the attainment of the TAS and CWO as per the notified PC1 report. This work assumes that WWL would undertake the work to capture and improve the quality of the discharges within the available network alone. The assessment does not include for the other parties and approaches to improve stormwater quality that may be better placed to deliver tangible improvements, such as national policy changes or through encouraging the use of more inert materials.

9.5 Central to this analysis is the recognition that this has been applied at a high level given the steps that would be required understand and implement changes to improve the quality of the stormwater discharges from the network.

9.6 The approach taken to create these preliminary estimates across the four council areas, has prioritised the use of the three accepted interventions (from within the WWL guideline documents). It uses a combination of swales, bioretention, and wetlands as mechanisms to reduce the contributions of contaminants from existing impermeable areas.

9.7 These three interventions have been prioritised at this time to provide the opportunity for integrated stormwater management alongside improvements in water quantity management and the potential to accrue other societal, cultural and environmental outcomes.

9.8 Other interventions such as proprietary devices e.g. Tetra Traps, StormFilter, etc, may be a cost-effective solution for end of pipe controls where space is limited. However, proprietary devices have not been approved for vesting to WWL at the time of writing.

9.9 My assessment has taken a top-level approach to looking at the percentage land requirements that could be required to capture and enhance water quality from these impermeable areas around the urban environments. No specific contaminant load modelling has been undertaken to support this programme level assessment, as this is not currently available. Supporting geospatial analysis spatially distributed the impermeable areas across the urban environments into WWL stormwater subcatchments, Freshwater Management Units (FMU) and territorial local authority boundaries.

9.10 Table 4 shares the prioritisation of investment ONLY into the FMUs requiring improvements to the TAS, results in a preliminary and high-level figure of $3.3B of investment. This would represent an **annual** capital programme of between $100m and $220m depending on the target date applied for the TAS.

Table 4: Potential investment per council in Stormwater Treatment.

Council	$B
Lower Hutt City	1.6
Porirua City	0.45
Upper Hutt City	0.7

Wellington City	0.6
Grand Total	**3.35**
Per annum for 2040 target	**0.22**
Per annum for 2060 target	**0.1**

9.11 Several assumptions made within the assessment are presented below. These assumptions at this stage reflect the status of the assessments as being based on principles shared elsewhere (Auckland Council and their GD01 document). They are a conservative assessment of the potential investment requirements to envelope the potential costs for the treatment systems alone.

9.12 The key assumptions are:

a Treatment of 100% of the impermeable area (roads and roofs) within FMUs that require a contaminant reduction. This is unlikely to be able to be achieved in practice and may not be required if high risk activities can be targeted (high traffic road corridors or areas with ageing metal roofs).

b Proportional allowances of device area required to treat the impermeable area, with larger requirements for areas of greatest load reduction such that for example, if an FMU requires more than 75% reduction, then a conservative 12.5% of the impermeable area could deliver enhance outcomes. Areas requiring less than 25% reduction would result in 2% of the impermeable area being allocated to treatment devices. This presents a total area for retrofitting treatment devices that is roughly 5% of the calculated impermeable area across all four councils.

c The resulting area is then proportioned to enable spatial distribution of the assets within the FMU, with an allowance for 20% allocated to swales, 30% to bioretention devices and 50% to wetlands.

d The proportional water quality treatment area values are higher than those presented in Auckland Council's GD01 for new development. As such they represent a high-level valuation to envelope the potential costs.

e At this point, no specific analysis of land costs has been incorporated within the presented values, but the conservative parameters used above enable flexibility and freeboard for land purchase to be incorporated.

f Unit costs per m2 for each device type were collected from a range of sources available from national, international interventions.

g Given that there is no certainty over the locations or designs at this point the capital costs were increased by 94% to account for optimism bias, internal and external fees and preliminary and general set up activities.

h This analysis has not investigated the specific spatial distribution of the assets across the urban landscape within each FMU, as such it is likely that further spatial investigation could identify opportunities for rationalising and optimising the distribution of assets across each catchment, through WWL wide investigations and modelling or through catchment Plans.

9.13 I do note, however, that given the relatively small catchments from ridgeline to each estuary or the sea that these assets will likely be distributed across multiple sub-catchments and hence the efficiencies of aggregation at the scale presented below may not be achieved.

9.14 In addition to the assessment presented above, I have assessed the potential costs associated with applying treatment to all urban areas, capturing 100% of the impermeable areas within the Freshwater Management Units. This would represent a likely investment in the order of $6.6b, with a range of $3.3b - $8.3b and an annual programme of between $190m (targeting 2060) – $440m (targeting 2040) across all four councils collectively.

9.15 The 3-year programme (2024-27) for WWL indicates in the order of $60m of capital investment allocated to stormwater, with the predominant focus of these allocations targeted to water quantity level of service and growth activities. The overall council approved three waters capital programme for the 10 year period is over $3b.

9.16 The increased water quality programme for stormwater would be a significant increase on the stormwater capital programme currently under delivery, requiring the step change in delivery focus.

As such, an integrated approach is required to achieve the TAS and CWO

9.17 Many of the community aspirations around the water quality of our waterways and harbours are not solely under the control of WWL, nor indeed the client councils. Although both these organisations have a significant role, there are other important stakeholders who will add to the overall delivery of these important values such as the Crown, industry and the public.

9.18 In my opinion, an integrated approach is required that has clear definition of the roles and responsibilities for each of those stakeholders or influencers on the stormwater quality, shown in Figure 1. This would then allow for appropriate funding regimes, policy interventions/changes and material change to support the successful delivery of improvements.

9.19 In addition to the measures above discharge of contaminants from stormwater and networks in urban areas could be further enhanced through:

a using land use change and redevelopment opportunities to reduce existing adverse effects;

b controlling the extent of impervious surfaces to minimise adverse effects;

c controlling stormwater volumes and runoff from land use development in areas that discharge to rivers and streams that are identified as being susceptible to the adverse effects of increased stormwater flows (hydrological controls)

d minimising the generation and discharge of stormwater and contaminants;

e adopting the best practicable option to manage discharges from public stormwater networks.

Liam Alexander Foster

14 March 2025

<u>References</u>

Charters, F. (2016). Storm-water contaminant load monitoring and modelling of the Addington Brook Catchment.

Kennedy, P.; Sutherland, S. (2008). Urban Sources of Copper, Lead and Zinc. Prepared by Organisation for Auckland Regional Council. Auckland Regional Council Technical Report 2008/023.

APPENDIX 1 – Stantec Memo (2025)

APPENDIX 2 – Review of potential options/measures available and discussion on effectiveness, ease of implementation and responsibility

Option	Within WWL control	Feasibility of deployment	Laboratory condition effectiveness (heavy metal removal)
Vegetated Swales – Quality and/or Quantity	Limited influence.	Requires collaboration with council and available land in the right location	20-60% (based on theoretical values from WWDG)
Filter Strips - Quality and/or Quantity	Limited influence.	Requires collaboration with council and available land in the right location	20-60% (based on theoretical values from WWDG)
Pervious Pavement	Limited influence.	Can be implemented on WW sites, requires collaboration and policy changes to enforce elsewhere	10-50% (experimental rates)
Infiltration Trenches and Site Wide Infiltration	Limited influence.	Requires collaboration with council and available land in the right location	30-80%
Bioretention: Raingarden, tree pits, planter boxes – Quality	Limited influence.	Requires collaboration with council and available land in the right location	30-80%
Gross Pollutant Trap	High level of influence for installation within existing network	Proprietary devices designed to be retrofitted into existing infrastructure could be deployed but represent a challenge to deliver outcomes across the whole urban environment. The distributed nature of these assets tend to result in an ongoing operational burden and cost that is not insubstantial.	0-10%
Sand Filters – Quality	Limited influence.	Requires collaboration with council and available land in the right location	30-80%

Hydrocarbon Management / Oil and Water Separator	High level of influence for installation within existing network	Proprietary devices designed to be retrofitted into existing infrastructure could be deployed but represent a challenge to deliver outcomes across the whole urban environment. The distributed nature of these assets tend to result in an ongoing operational burden and cost that is not insubstantial.	0-10%
Wetlands	Limited influence.	Requires collaboration with council and available land in the right location	60-100% (based on theoretical values from WWDG)
Dry Detention Ponds (with extended detention)	Limited influence.	Requires collaboration with council and available land in the right location	0-40% (based on theoretical values from WWDG)
Wet Retention Ponds	Limited influence.	Requires collaboration with council and available land in the right location	40-80% (based on theoretical values from WWDG)
Riparian Buffers	Moderate influence	Requires collaboration with regional council	30-80%
Living Streams	Moderate influence	Requires collaboration with regional council	30-80%
Stream Daylighting	Limited influence.	Requires collaboration with council and available land in the right location.	0-80%

APPENDIX 3 – Tables from the 2020 International Best Practice Management Database (https://bmpdatabase.org/urban) Summary Report

Glossary & descriptions of devices included

Table 1-2. BMP Categories Included in 2020 Performance Analysis.

BMP Category	Code	Description
Detention Basin	DB	Dry extended detention grass-lined and concrete lined basins that empty out after a storm.
Retention Pond	RP	Surface wet pond with a permanent pool of water, may include underground wet vaults.
Wetland Basin	WB	Similar to a retention pond (with a permanent pool of water), typically with more than 50 of its surface covered by emergent wetland vegetation.
Wetland Channel	WC	A continuously wet channel with wetland vegetation and slow velocities.
Grass Swale	BS	Shallow, vegetated channel, also called bioswale or vegetated swale.
Grass Strip	BI	Vegetated areas designed to accept laterally distributed sheet flow from adjacent impervious areas, also called buffer strips or vegetated buffers.
Bioretention	BR	Shallow, vegetated basins with a variety of planting/filtration media and often including underdrains. Also called rain gardens and biofiltration.
Media Filter	MF	Filter bed with granular media, typically sand.
High Rate Biofiltration	HRBF	Manufactured devices with high rate filtration media that support plants.
High Rate Media Filtration	HRMF	Manufactured devices with high rate filtration media consisting of a variety of inert and sorptive media types and configurations (e.g., cartridge filters, upflow filters, membrane filters, vertical bed filters).
Hydrodynamic Separation Devices	HDS	Manufactured devices providing gravitational settling using swirl concentrators, screens, and baffles.
Oil/Grit Separators and Baffle Boxes	OGS	Manufactured devices including oil/water separators and baffle chambers designed for removing floatables and coarse solids.
Permeable Friction Course (Overlay)	PF	Open-graded bituminous mixture placed over an impervious road base.
Porous Pavement	PP	Full-depth pervious concrete, porous asphalt, paving stones or bricks, reinforced turf rings, and other permeable surface designed to replace traditional pavement.

Note: Additional BMP types are included in the BMP Database. This table represents BMP types with sufficient data for inclusion in category-level, pollutant concentration focused statistical analysis.

Performance Data Summary for Total Suspended Solids (TSS) & Total Dissolved Solids (TDS) - Showing good proportional reductions in TSS through treatment devices and poor performance reducing TDS.

Analysis for solids focused on total suspended solids (TSS) and total dissolved solids (TDS). Other solids can also be retrieved and analyzed through the BMPDB. Tables 2-2 and 2-3 provide influent/effluent summary statistics for TSS and TDS, respectively. Figures 2-2 and 2-3 provide graphical representations of these data.

Table 2-2. Influent/Effluent Summary Statistics for TSS (mg/L).

BMP Category	Study & Sample Count (% ND)		Interquartile Range ($25^{th} – 75^{th}$ %tiles)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	44; 575 (0.7%)	46; 611 (0.7%)	24.4 - 131	10.0 - 49.0	65.1 (57.0, 74.0)	22.0 (17.1, 22.5)	▼▼▼
Retention Pond	72; 1199 (1.1%)	74; 1191 (3.0%)	15.0 - 150	5.00 - 32.9	49.0 (41.0, 54.0)	12.0 (11.0, 13.0)	▼▼▼
Wetland Basin	31; 601 (0.3%)	30; 563 (3.0%)	14.0 - 89.0	4.69 - 32.0	35.5 (29.7, 40.0)	14.0 (11.5, 15.2)	▼▼▼
Wetland Channel	15; 269 (0.0%)	13; 219 (0.0%)	14.0 - 81.0	10.0 - 70.5	25.7 (20.5, 32.0)	24.0 (17.0, 28.0)	◇◇▼
Grass Swale	35; 582 (0.2%)	40; 656 (0.3%)	10.4 - 62.0	6.00 - 34.7	26.0 (22.0, 28.1)	13.7 (12.0, 14.9)	▼▼▼
Grass Strip	52; 920 (0.1%)	52; 711 (2.8%)	24.0 - 95.0	10.0 - 49.0	48.0 (43.0, 50.0)	23.0 (20.0, 24.0)	▼▼▼
Bioretention	43; 840 (0.0%)	41; 685 (5.3%)	16.0 - 119	4.00 - 20.0	44.0 (38.0, 48.0)	10.0 (8.00, 10.0)	▼▼▼
Media Filter	35; 533 (0.6%)	39; 563 (8.7%)	19.6 - 105	2.82 - 18.6	44.0 (37.0, 49.1)	7.20 (6.00, 8.00)	▼▼▼
HRBF	6; 104 (0.0%)	6; 104 (1.0%)	15.8 - 55.2	2.5 - 6.0	30.8 (21.0; 35.2)	3.80 (3.00; 4.15)	▼▼▼
HRMF	18; 392 (0.5%)	18; 392 (3.8%)	20.0 - 100	8.15 - 32.6	44.0 (37.0, 53.5)	18.0 (15.0, 19.0)	▼▼▼
HDS	27; 488 (0.4%)	27; 452 (1.1%)	26.6 - 162	15.9 - 87.0	63.9 (56.6, 73.0)	39.0 (33.0, 43.8)	▼▼▼
OGS	16; 261 (0.4%)	16; 216 (1.9%)	11.0 - 88.0	4.38 - 44.2	36.0 (27.8, 42.0)	15.5 (11.2, 19.1)	▼▼▼
PFC	NA	6; 135 (0.0%)	NA	6.00 - 16.5	NA	9.00 (8.00, 10.0)	NA
Porous Pavement	16; 483 (0.8%)	24; 402 (2.2%)	23.0 - 226	10.1 - 43.9	77.0 (63.0; 90.0)	22.0 (18.0; 23.5)	▼▼▼

*Confidence interval about the median; computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
% ND percentage of non-detects
NA not available or less than three studies for BMP/constituent
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations
△ influent/effluent comparison test indicates significant *increase* in concentrations

Table 2-3. Influent/Effluent Summary Statistics for TDS (mg/L).

BMP Category	Study & Sample Count (% ND)		Interquartile Range ($25^{th} – 75^{th}$ %)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	14; 156 (0.0%)	14; 140 (0.0%)	65.6 - 193	65.1 - 192	109 (85.9; 130)	110 (83.5; 120)	◇◇◇
Retention Pond	16; 169 (0.0%)	16; 156 (0.0%)	69.0 - 180	78.3 - 364	122 (100; 130)	178 (158; 206)	△△△
Wetland Basin	5; 65 (1.5%)	5; 38 (2.6%)	77.0 - 197	92.0 - 238	127 (84.7; 152)	149 (92.0; 168)	◇◇△
Wetland Channel	7; 103 (0.0%)	7; 100 (1.0%)	194 - 670	216 - 695	389 (284; 482)	391 (270; 486)	◇◇◇
Grass Swale	14; 161 (0.0%)	13; 130 (0.0%)	48.0 - 102	44.8 - 123	76.5 (64.0; 79.0)	80.0 (67.0; 84.0)	◇◇◇
Grass Strip	34; 617 (5.8%)	33; 433 (3.2%)	28.0 - 96.0	50.0 - 120	56.0 (50.0; 56.0)	82.0 (74.0; 84.0)	△△△
Bioretention	4; 139 (0.0%)	7; 77 (0.0%)	30.1 - 141	61.7 - 541	58.8 (46.2; 68.5)	210 (175; 298)	△△◇
Media Filter	15; 196 (4.1%)	16; 193 (2.1%)	24.0 - 80.0	44.0 - 134	45.7 (37.0; 52.0)	75.7 (58.0; 89.2)	△△△
HRMF	6; 171 (45.0%)	6; 171 (43.3%)	31.5 - 75.0	28.2 - 75.0	47.6 (41.3; 51.1)	46.0 (38.9; 50.9)	◇◇◇
HDS	5; 106 (3.8%)	5; 105 (1.9%)	74.0 - 1,560	64.0 - 2,830	183 (110; 224)	208 (94.0; 238)	◇◇△
Porous Pavement	NA	3; 43 (0.0%)	NA	968 - 4,740	NA	2,300 (1,110; 3,080)	NA

*Confidence interval about the median; computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
% ND percentage of non-detects
NA not available or less than three studies for BMP/constituent
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations
△ influent/effluent comparison test indicates significant *increase* in concentrations

Summary commentary taken from BMP Summary Report 2020[6]

Primary observations for TSS include:

- Median influent TSS concentrations generally range between 26 and 77 mg/L.
- All BMPs with sufficient data for analysis show statistically significant reductions.
- The best performing BMPs are bioretention, media filters, and high rate biofiltration with effluent TSS concentrations ranging from 4 to 10 mg/L.
- Retention ponds and wetland basins performed similarly with effluent TSS concentrations in the 12- 14 mg/L range.

- Median influent concentrations for TSS varied considerably, with detention basins, porous pavement and hydrodynamic separators treating more elevated influent TSS relative to several other BMP categories. This observation is not a function of BMP type; it is simply an observation that some BMP categories had relatively clean influent, which may be related to land use or level of source control. This may affect interpretation of statistical tests. For example, out of the three statistical tests, only the Wilcoxon signed-rank test showed statistically significant reduction of TSS for wetland channels; however, the median inflow TSS was already relatively low at 26 mg/L.

Primary observations for TDS include:

- TDS data are more limited than TSS data for many BMP types.
- No BMP with sufficient data has statistically significant concentration reductions for TDS. Furthermore, retention ponds, wetland basins, grass strips, media filters, and hydrodynamic separators increase TDS.
- The HDS category had unusually high concentrations of TDS, which were also highly variable. Further review of the underlying studies in this category indicated the statistics are influenced by a USGS study at a city maintenance yard in Madison, WI. Waschbusch (1999) reports that the site may have unique conditions, particularly the presence of road sand and salt piles close to the system inlet. The Madison site's median inflow TDS was 3,858 mg/L, whereas median influent concentrations at the other three sites ranged from 44 to 118 mg/L.
- Without advanced treatment, volume reduction is likely the only effective method for reducing TDS loads to surface receiving waters, based on the BMP types currently analyzed in the BMPDB. Note that for mobile TDS fractions (i.e., road salt), volume reduction due to infiltration may cause groundwater or interflow issues; therefore, identification of potential source controls is particularly important for TDS.

<u>Performance Data Summary for Total Zinc and Dissolved Zinc</u> - Showing similar proportional reductions through treatment devices for both Types

Table 5-18. Influent/Effluent Summary Statistics for Total Zinc (µg/L).

BMP Category	Study & Sample Count (% ND)		Interquartile Range (25th – 75th %tiles)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	26; 393 (4.6%)	27; 430 (8.8%)	20.0 - 119	6.94 - 58.0	51.7 (40.4; 58.3)	17.3 (14.3; 21.7)	▼▼▼
Retention Pond	60; 1032 (7.1%)	63; 995 (11.8%)	27.3 - 100	10.0 - 40.0	50.0 (43.9; 50.1)	21.2 (20.0; 23.0)	▼▼▼
Wetland Basin	19; 342 (1.2%)	19; 308 (11.0%)	34.1 - 94.6	11.5 - 37.1	52.5 (45.3; 57.6)	20.1 (17.0; 23.0)	▼▼▼
Wetland Channel	9; 161 (6.8%)	9; 153 (10.5%)	14.0 - 50.0	10.0 - 36.0	27.0 (20.0; 30.0)	20.0 (13.0; 20.0)	◇▼▼
Grass Swale	27; 425 (10.8%)	31; 513 (23.6%)	22.0 - 109	16.0 - 50.0	45.6 (40.0; 51.0)	25.8 (22.6; 28.8)	▼▼▼
Grass Strip	42; 743 (0.5%)	41; 533 (2.8%)	46.0 - 240	15.0 - 74.0	110 (93.0; 115)	36.0 (30.0; 39.0)	▼▼▼
Bioretention	29; 500 (1.2%)	26; 454 (14.3%)	31.0 - 140	6.26 - 23.4	62.0 (52.4; 69.0)	12.8 (11.0; 14.0)	▼▼▼
Media Filter	31; 508 (3.0%)	34; 531 (13.6%)	24.0 - 126	4.43 - 30.1	62.3 (55.2; 69.5)	15.0 (12.7; 16.2)	▼▼▼
HRBF	5; 54 (0.0%)	5; 54 (11.1%)	53.2 - 388	20.0 - 112	178 (82.2; 228)	60.6 (25.0; 80.5)	▼▼▼
HRMF	19; 344 (2.0%)	19; 344 (2.6%)	32.0 - 152	20.0 - 79.2	59.8 (51.0; 69.0)	38.1 (32.6; 43.0)	▼▼▼
HDS	18; 268 (0.0%)	18; 262 (1.9%)	41.0 - 130	36.9 - 120	79.0 (67.3; 89.0)	62.2 (54.1; 69.2)	◇▼▼
OGS	10; 154 (0.0%)	10; 126 (0.0%)	35.0 - 232	35.2 - 166	97.9 (80.8; 138)	83.2 (65.1; 106)	◇◇▼
PFC	NA	3; 69 (0.0%)	NA	14.6 - 31.0	NA	21.2 (15.9; 23.1)	NA
Porous Pavement	16; 393 (7.6%)	22; 346 (30.1%)	30.1 - 121	9.70 - 34.0	60.0 (50.4; 62.5)	20.0 (14.5; 20.0)	▼▼▼

*Confidence interval about the median computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
NA not available or less than three studies for BMP/constituent
% ND percentage of non-detects
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations
△ influent/effluent comparison test indicates significant *increase* in concentrations

Table 5-19. Influent/Effluent Summary Statistics for Dissolved Zinc (µg/L).

BMP Category	Study & Sample Count (% ND)		Interquartile Range (25th – 75th %tiles)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	14; 258 (3.9%)	14; 271 (6.3%)	5.78 - 38.5	3.38 - 24.0	12.1 (9.15; 14.1)	9.38 (6.90; 10.4)	◇▼▼
Retention Pond	25; 431 (5.8%)	25; 413 (8.0%)	10.0 - 43.3	5.60 - 32.0	23.4 (20.0; 26.0)	16.0 (13.9; 17.6)	▼▼▼
Wetland Basin	9; 125 (3.2%)	8; 110 (3.6%)	13.7 - 35.8	4.32 - 14.8	22.6 (20.1; 25.0)	8.35 (6.62; 9.00)	▼▼▼
Wetland Channel	3; 64 (46.9%)	4; 59 (47.5%)	4.61 - 20.0	3.96 - 19.6	10.1 (6.37; 16.9)	10.0 (4.47; 10.0)	◇◇◇
Grass Swale	16; 174 (2.9%)	16; 141 (5.0%)	17.1 - 69.4	13.3 - 32.0	34.2 (27.3; 35.8)	19.8 (16.7; 21.7)	▼▼▼
Grass Strip	37; 669 (5.4%)	36; 478 (12.8%)	13.0 - 79.0	7.62 - 33.0	33.6 (30.0; 39.0)	17.0 (15.0; 19.0)	▼▼▼
Bioretention	13; 292 (9.6%)	11; 215 (11.2%)	11.9 - 49.3	3.47 - 19.5	20.8 (16.9; 22.3)	12.5 (9.00; 13.8)	▼▼▼
Media Filter	13; 207 (1.0%)	15; 228 (17.1%)	12.0 - 88.5	2.20 - 19.0	32.0 (24.3; 37.2)	7.15 (4.49; 8.93)	▼▼▼
HRBF	4; 38 (0.0%)	4; 38 (7.9%)	109 - 377	28.2 - 212	189 (148; 312)	79.0 (53.5; 105)	▼▼▼
HRMF	14; 228 (0.4%)	14; 228 (1.8%)	9.00 - 35.2	11.0 - 38.5	16.2 (14.0; 18.6)	18.8 (15.7; 20.1)	◇◇◇
HDS	9; 122 (1.6%)	9; 123 (1.6%)	18.1 - 85.0	20.0 - 79.0	43.3 (31.4; 48.0)	42.0 (30.1; 52.0)	◇◇◇
OGS	5; 51 (0.0%)	5; 59 (0.0%)	18.1 - 146	31.4 - 159	31.9 (24.0; 58.0)	70.0 (44.8; 83.4)	◇◇◇
PFC	NA	3; 68 (0.0%)	NA	8.38 - 19.5	NA	13.1 (10.0; 16.4)	NA
Porous Pavement	9; 310 (11.3%)	10; 229 (50.2%)	10.8 - 30.0	1.60 - 11.6	17.8 (15.9; 19.9)	4.09 (3.05; 5.50)	▼▼▼

*Confidence interval about the median computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
NA not available or less than three studies for BMP/constituent
% ND percentage of non-detects
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations

Summary commentary taken from BMP Summary Report 2020

- Most BMP types show statistically significant reductions for both total zinc and many also reduced dissolved zinc.
- Bioretention, media filters, and detention basins are the top performers with total zinc median effluent concentrations of 13 to 17 µg/L. Retention ponds, wetland basins and channels, swales, and PFC are not far behind, with total median effluent concentrations less than 30 µg/L.
- Many BMP categories also removed dissolved zinc. Exceptions include wetland channels and manufactured device categories other than high rate biofiltration.
- Hydrodynamic separators and oil-grit separators are the lowest performers for dissolved zinc removal. Median concentrations for oil-grit separators more than doubled between the inflow and outflow, indicating there may be a source of zinc in some of these devices, potentially certain construction materials used in the device.

<u>Performance Data Summary for Total Copper and Dissolved Copper</u> - Showing similar proportional reductions through treatment devices for both types .

Table 5-10. Influent/Effluent Summary Statistics for Total Copper (µg/L).

BMP Category	Study & Sample Count (% ND)		Interquartile Range (25th – 75th %tiles)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	23; 359 (6.4%)	23; 370 (19.5%)	4.04 - 23.5	2.00 - 12.5	8.75 (7.25; 10.0)	4.58 (3.74; 5.48)	▼▼▼
Retention Pond	52; 934 (8.8%)	54; 922 (16.9%)	4.76 - 18.3	2.70 - 8.00	9.59 (8.95; 10.0)	4.90 (4.42; 5.00)	▼▼▼
Wetland Basin	14; 298 (8.1%)	14; 258 (18.2%)	4.27 - 11.8	2.00 - 6.00	7.40 (6.46; 8.22)	3.32 (3.00; 4.00)	▼▼▼
Wetland Channel	7; 123 (6.5%)	7; 120 (5.8%)	3.79 - 14.5	4.90 - 12.0	10.0 (5.40; 10.0)	10.0 (10.0; 10.0)	◇◇◇
Grass Swale	23; 378 (8.7%)	27; 476 (9.5%)	6.00 - 24.1	3.50 - 13.9	12.1 (10.2; 14.0)	6.90 (6.00; 7.80)	▼▼▼
Grass Strip	41; 745 (0.4%)	40; 526 (0.4%)	12.0 - 52.0	5.44 - 25.0	25.0 (22.0; 26.0)	12.0 (10.0; 13.0)	▼▼▼
Bioretention	30; 512 (0.4%)	27; 469 (2.6%)	6.40 - 30.0	4.12 - 14.0	13.1 (11.4; 15.1)	7.13 (6.40; 8.20)	▼▼▼
Media Filter	27; 434 (6.9%)	30; 458 (12.7%)	5.77 - 18.0	2.30 - 9.27	10.0 (9.50; 11.0)	4.65 (4.00; 5.21)	▼▼▼
HRBF	4; 46 (2.2%)	4; 46 (6.5%)	4.33 - 11.3	3.03 - 5.57	7.95 (5.40; 8.90)	3.75 (3.20; 4.80)	▼▼▼
HRMF	15; 278 (2.2%)	15; 278 (5.8%)	6.22 - 30.8	4.00 - 16.1	12.0 (9.58; 13.2)	8.14 (6.75; 9.14)	▼▼▼
HDS	14; 215 (0.5%)	14; 209 (1.0%)	8.38 - 22.0	7.72 - 22.0	14.6 (12.0; 16.0)	13.0 (11.1; 14.2)	◇◇▼
OGS	11; 155 (0.0%)	11; 128 (0.8%)	4.90 - 25.8	3.80 - 18.4	12.8 (8.72; 15.2)	11.1 (6.25; 13.6)	◇▼▼
PFC	NA	3; 69 (0.0%)	NA	7.42 - 14.7	NA	11.2 (8.94; 13.2)	NA
Porous Pavement	14; 368 (2.2%)	17; 313 (14.1%)	8.40 - 27.8	5.00 - 14.5	12.9 (11.8; 14.3)	8.30 (7.70; 9.00)	▼▼▼

*Confidence interval about median computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
% ND percentage of non-detects
NA not available or less than three studies for BMP/constituent
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations
△ influent/effluent comparison test indicates significant *increase* in concentrations

Table 5-11. Influent/Effluent Summary Statistics for Dissolved Copper (µg/L).

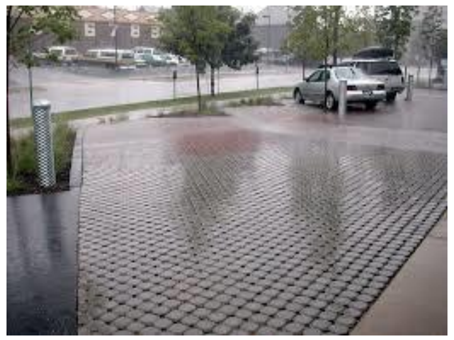
BMP Category	Study & Sample Count (% ND)		Interquartile Range (25th – 75th %tiles)		Median (95% Conf. Interval)*		In vs Out**
	In	Out	In	Out	In	Out	
Detention Basin	14; 258 (14.3%)	14; 270 (23.0%)	2.01 - 9.40	1.41 - 8.07	3.96 (3.56; 5.00)	2.99 (2.22; 3.20)	▼▼▼
Retention Pond	22; 432 (6.9%)	22; 424 (9.0%)	3.11 - 8.00	2.40 - 5.30	5.08 (4.60; 5.50)	3.50 (3.19; 3.80)	▼▼▼
Wetland Basin	9; 125 (10.4%)	8; 110 (20.9%)	2.65 - 5.90	1.24 - 4.23	3.95 (3.33; 4.30)	2.29 (1.77; 3.33)	◇▼◇
Grass Swale	16; 174 (4.0%)	16; 141 (2.1%)	3.30 - 13.7	3.56 - 9.46	6.50 (5.00; 7.80)	5.63 (4.83; 6.74)	◇◇▼
Grass Strip	39; 717 (2.1%)	38; 515 (4.1%)	5.30 - 23.0	3.60 - 14.0	12.0 (9.57; 12.0)	7.40 (6.60; 8.30)	▼▼▼
Bioretention	16; 360 (2.8%)	14; 261 (7.3%)	4.07 - 14.3	3.41 - 19.0	6.85 (5.99; 7.87)	7.54 (6.50; 8.40)	◇◇△
Media Filter	14; 210 (5.2%)	16; 233 (5.6%)	1.75 - 7.98	1.50 - 6.50	3.86 (2.99; 4.49)	3.00 (2.30; 3.50)	◇▼▼
HRBF	4; 38 (10.5%)	4; 38 (7.9%)	2.92 - 6.65	2.00 - 4.15	4.50 (2.93; 5.00)	3.40 (2.30; 3.84)	◇▼▼
HRMF	13; 217 (12.0%)	13; 217 (11.1%)	2.00 - 7.70	2.00 - 8.00	4.00 (3.58; 4.60)	4.38 (3.41; 5.00)	◇◇◇
HDS	9; 123 (4.9%)	9; 123 (4.1%)	4.75 - 14.7	4.60 - 13.0	9.00 (6.80; 9.80)	8.50 (6.50; 10.0)	◇◇▼
OGS	5; 52 (0.0%)	5; 58 (0.0%)	3.85 - 23.6	5.82 - 17.0	11.0 (7.86; 14.6)	10.1 (7.23; 14.0)	◇◇◇
PFC	NA	3; 69 (0.0%)	NA	4.88 - 11.8	NA	8.40 (5.93; 9.33)	NA
Porous Pavement	9; 310 (10.3%)	10; 229 (4.4%)	3.60 - 8.60	3.80 - 8.00	5.60 (5.10; 5.85)	5.70 (5.05; 6.00)	◇◇△

*Confidence interval about the media computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
** Each symbol represents an influent/effluent comparison test. Left position compares overlap of 95% confidence intervals around influent/effluent medians. Middle position compares Mann-Whitney rank-sum hypothesis test P-value to a significance value of 0.05. Right position compares Wilcoxon signed-rank hypothesis test P-value to a significance value of 0.05.
% ND percentage of non-detects
NA not available or less than three studies for BMP/constituent
◇ influent/effluent comparison test indicates no significant difference in concentrations
▼ influent/effluent comparison test indicates significant reduction in concentrations
△ influent/effluent comparison test indicates significant *increase* in concentrations

Summary commentary taken from BMP Summary Report 2020

- Many BMP types show statistically significant reductions for both total and dissolved copper.
- With total median effluent concentrations less than 5 µg/L, the best performing BMPs are detention basins, retention ponds, wetland basins, media filters, and high rate biofiltration.
- The relatively poor dissolved copper removal performance for bioretention may be due to leaching of copper from sites that included a high percentage of compost in their media mixes. A study in Washington found that dissolved copper export was as high as 600% for bioretention cells containing 40% compost (Herrera Environmental Consultants 2012). While the export of copper is concerning, there is research that indicates that most of the dissolved copper leaching from bioretention systems is strongly bound to dissolved organic matter and is less bioavailable to aquatic organisms (Chahal et al. 2016).

APPENDIX 4 - Stormwater intervention options

Stormwater Management Option – structural options		**Type of Option & Applicability**		**Example of Implementation**	**Effectiveness** **L=Low M=Medium H=High**						**Source Pathway Receptor**	**Location Suitability**	**Benefit**	**Drawback**
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
STORMWATER ASSET MANAGEMENT: Enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities, through the combination of concrete and natural structures that involve minimal construction or earthworks, and planting vegetation to reduce or delay stormwater flow and or remove pollutants to increase the overall stormwater quality. With the goal to build maintain and improve these stormwater management assets through implementation of WSD.														
INFILTRATION SOAKAGE														
Vegetated Swales – Quality an/or Quantity	Vegetated swales can be mown grass or any vegetation types that is stable under stormwater flows. Convey and treat stormwater runoff.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		H	M	H	M	M	M	Source and Pathway	Mid-catchment High and low-density areas. Group residential and commercial land use	Filter sediments, nutrients, and other contaminants before discharge to receiving environments	Could be limited by space between properties and road.
Filter Strips - Quality an/or Quantity	Filter strips are gently sloping, vegetated areas adjacent to impervious surfaces. ("Vegetative Filter Strips—A Best Management Practice for Controlling ...") They are intended to reduce impacts of sheet flow and velocity of stormwater and improve its water quality.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		M	M	H	M	M	M	Source and Pathway	Mid-catchment High and low-density areas. Group residential and commercial land use	Integrated into existing or proposed landscape elements.	Limited by slope
Pervious Pavement	A pervious pavement is designed to facilitate and maximise rainfall infiltration through the pavement for stormwater benefit. Beneath the paved surface is an aggregate material that acts as a temporary reservoir, allowing for run-off to slowly infiltrate into the ground.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	L	H	L	H	M	Source	At source Individual residential and commercial land uses Small catchment areas with low traffic volumes such as residential streets,	Close to source management Filtration and sedimentation of contaminants	Not suitable on site with heavy commercial vehicles Regular inspection and maintenance

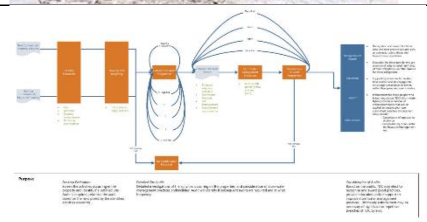
Stormwater Management Option – structural options		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway Receptor	Location Suitability	Benefit	Drawback
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
												driveways, and small carparks.		
Infiltration Trenches and Site Wide Infiltration	Trench containing gravels and provides treatment and disposal of stormwater. Some treatment is provided by gravel in the trench, but most treatment is provided by adjoining soil. Usually used in treatment train with filter strips.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	M	H	L	H	H	Source and Pathway	Mid-catchment All land use types	Contributes to reducing runoff rates and volumes while supporting baseflow and groundwater recharge processes.	Risk of slope instability due to infiltration Risk of groundwater flooding due to infiltration. Limited by ground conditions and soils
BIORETENTION														
Bioretention: Raingarden, tree pits, planter boxes - Quality	These practices use specific soils and plant materials to manage stormwater effects. Tree pits are essentially raingardens with a single tree rather than smaller foliage plants. Planter boxes are usually lined bioretention areas which receive point source runoff from rooftops or adjacent hard surfaces. ("Bioretention - Auckland Design Manual")	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		M	H	H	H	H	H	Source and Pathway	Mid-catchment Urban and high-density areas; often suitable for carparks and side street locations.	Treat stormwater through, sedimentation, filtration, infiltration, absorption, and biological processes. Soft engineering; adds amenity and ecological value to the landscape. Disperse device provide resilience against single device failure and supports integrated stormwater management.	Ongoing maintenance If private it relies on private property owner to undertake operation and maintenance
PROPRIETARY TREATMENT DEVICES														

Stormwater Management Option – structural options		**Type of Option & Applicability**		**Example of Implementation**	**Effectiveness L=Low M=Medium H=High**						**Source Pathway Receptor**	**Location Suitability**	**Benefit**	**Drawback**
Option	Description	Option	Wellington Water Applicability		Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
					Nitrogen	Phosphorus			Zinc	Copper				
Gross Pollutant Trap	Treats stormwater prior to filtration devices or discharging points into wetlands and ponds. Designed to capture large diameter sediments, plastic, litter, leaves and oils.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	L	M	L	L	L	Source	Base catchment Group residential, Commercial, and Industrial land use areas. Small to medium catchment sizes.	Removes large non-biodegradable pollutants. Can be used stand alone or in a treatment train. Pre-treatment to other options	Not suitable for removing fine sediment and dissolved pollutants. Regular maintenance to clear system
Sand Filters - Quality	Capture sediments, oils, and grease before solids before it is disposed to secure landfills.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		M	M	H	M	H	H	Pathway	Mid-catchment High density residential, commercial, and industrial areas where the percentage of impervious surface is high and there are space restraints. Best suited to catchments less than 4 ha.	Can be easily added to existing structures Groundwater recharge	
Hydrocarbon Management / Oil and Water Separator	Designed to separate hydrocarbons, oil, and grease from stormwater. Best used in combination with non-structural controls such as oxidation and biological microbial decomposition mechanisms	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	L	L	L	L	L	Pathway	Mid-catchment Commercial and industrial areas	Can be located underground to minimise visual impact	Not efficient in removing nutrients, sediment, and heavy metals.
STORAGE AND DETENTION SYSTEMS														

Stormwater Management Option – structural options		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway Receptor	Location Suitability	Benefit	Drawback
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
Wetlands	Mimics the treatment processes of natural wetlands for detention, fine filtration, and biological adsorption, to remove contaminants from stormwater runoff.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		M	M	H	M	H	H	Pathway and Receptor	Base catchment Group residential, Commercial, and Industrial areas. Suitable for large and low-density catchment areas with sufficient open space	Attenuation of flood flows, water quality treatment, and supports aquatic plants and wildlife. Provides biodiversity and habitat opportunities. Increases amenity and aesthetics	Requires a large area to receive and treat stormwater so not suitable for small and high-density catchment areas
Dry Detention Ponds (with extended detention)	Primarily used to store water during a particular storm event and slowly release the water over an extended period to alleviate peak flow	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	L	M	L	L	L	Pathway and Receptor	Base catchment Suitable for large low-density catchment areas with sufficient surface area. Group residential and Industrial	Helps to control volumes and flood risk in the downstream receiving environment.	Pre-treatment is needed to remove contaminants in the upstream network to assist with long-term operation and maintenance of these devices
Wet Retention Ponds	Natural means to store stormwater. Pond that holds stormwater runoff permanently. Contains, and holds runoff allowing stormwater to build up on site.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		L	M	H	M	N/A	N/A	Pathway and Receptor	Base catchment Suitable for large low-density catchment areas with sufficient surface area. Group residential and Industrial	Can cater to both quality and quantity management Can be used when groundwater is vulnerable High ecological, aesthetic and amenity benefits. Retention promotes pollutant	Not suitable for steep sides, due to requirement for high embankments Without proper maintenance, nutrients such as nitrogen and phosphorus that are typically found in stormwater runoff can accumulate in stormwater ponds and

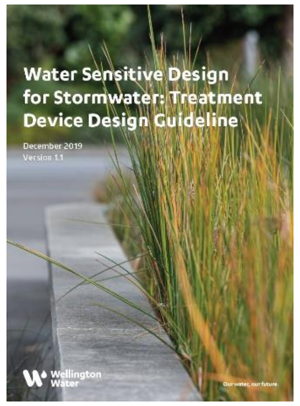
Stormwater Management Option – structural options		Type of Option & Applicability			Effectiveness L=Low M=Medium H=High									
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability	Example of Implementation	Nitrogen	Phosphorus			Zinc	Copper	Source Pathway Receptor	Location Suitability	Benefit	Drawback
													removal through sedimentation and the opportunity for biological uptake mechanisms.	wetlands leading to degraded conditions such as low dissolved oxygen, algae blooms, unsightly conditions, and odours.
CONVEYANCE SYSTEMS														
Riparian Buffers	Riparian buffers act as biological filters between catchments and receiving environments, intercepting a significant proportion of groundwater nutrients. Stormwater runoff is slowed and filtered, with direct uptake and transformation of contaminants by plants. Vegetation and humus layers attenuate significant volumes of water, promoting infiltration into the soil and releasing it over a longer time to contribute to stream base flows and to support riparian vegetation.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence through controlling access to network (Regional Standards)		H	H	M	H	H	H	Pathway and Receptor	Mid to base of the catchment Areas where streams and rivers have no buffer between the stream and infrastructure.	Biological filter between catchments and the receiving environment Greater width of buffer the more benefits to stream health. However, effectiveness is influenced by slope, soil composition and drainage patterns etc.	Need the area and room between the stream and associated infrastructure.
Living Streams	Constructed or retrofitted waterways that mimic the characteristics of natural streams. Usually come with riparian buffers that provides habitats for ecosystem health	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence key stakeholders and support Whaitua initiatives.		H	H	M	H	H	H	Pathway and Receptor	Mid-catchment Area with degraded natural streams or open drains with significant flows	Conveys runoff in highly urbanized areas and provide treatment. Healthy fringing and aquatic vegetation act as a biological filter. Organic and inorganic material can be filtered by living streams.	

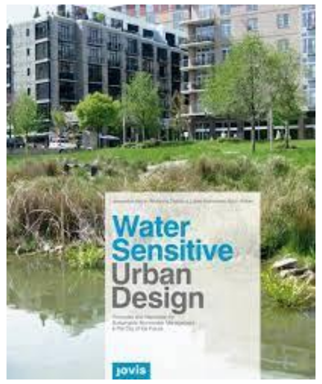
Stormwater Management Option – structural options		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway Receptor	Location Suitability	Benefit	Drawback
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
Stream Daylighting	Process of restoring a stream which was once diverted to its original channel aboveground. These streams were channeled underground to accommodate for the development of an area. Obstructions that cover a river or creek are removed and the waterway is restored to its previous condition.	Existing / New Assets (Projects)	Limited to WWL sites / projects. Influence key stakeholders and support Whaitua initiatives.		M	M	M	L	L	L	Pathway and Receptor	Mid-catchment Highly urbanised areas with remaining open space	Increases the area available for water to pass through an area which increases storage capacity and reduces peak flows Enhance nutrient retention, improve channel habitation, and restore floodplains	
ASSET MANAGEMENT / OPERATIONAL & MAINTENANCE PROGRAMMES														
Asset Investigation Programme	Inclusive of cleaning, repairs, and condition assessment. All WWL Assets	Program / A.M / Operations	High								ALL			
Street Cleaning	Sweeping & Sump cleansing of paved assets.	Program / A.M / Operations	Limited. Influence Road Controlling Authorities								Source & Pathway			
Modelling & Mapping Programmes	Comprehensive programme of modelling and mapping flood risk, water quality & water quantity	Program / A.M / Operations	High								ALL			
Urban Watercourse Assessment programme	Baseline information on the existing condition of waterways in both urban and rural settings.	Program / A.M / Operations	High Support erosion & sediment								ALL			

Stormwater Management Option – structural options		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway Receptor	Location Suitability	Benefit	Drawback
					Nutrients		Erosion (TSS (Total Suspended Solids))	*E. coli* (Bacteria)	Heavy metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
Green Infrastructure Maintenance Programmes	Inspection and ongoing maintenance of G.I assets – Cyclical renewal of asset	Program / A.M / Operations	Limited. Influence Asset Owners.								ALL			
Non-Residential Site Assessments	On site evaluation of Commercial & Industrial properties that have the potential to contribute to poor water quality in the stormwater discharges	Program / A.M / Operations	High. Controlled activity through Waste Permits		Need to look to high-risk sites and more frequently. Engagement survey approach to ensure a positive image of WWL. Potential way to measure success – 60% of all industrial sites are investigated annually.						Source			

Stormwater Management Option – non-structural		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway	Location Suitability	Benefit	Drawback
					Nutrients				Heavy Metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus	Erosion (TSS)	*E. coli* (Bacteria)	Zinc	Copper				
STRATEGIC POLICY, PLANNING AND REGULATIONS: Identification of framework of requirements, policy, and initiatives to enable good management practices for urban stormwater runoff through strategic planning, statutory controls, education, and regulatory actions. Set in place before physical works begin therefore providing clear direction and guidance which can prevent, minimise, or remedy adverse effects.														
STORMWATER DESIGN GUIDELINES														
Green Roofs Policy	Green roofs are a layer of living plants growing on top of a roof. A green roof is not a collection of individual plants but an extension of a conventional roof that involves installing a layer of membranes, substrate, and plants.	Policy / Program	Low Influence District Plan		H	H	H	L	L	L	Source	At source Suitable for any type of catchment. Good option for high density urban areas where there is less space for larger	Decrease urban temperature Low contaminant discharge potential and hence it is considered that runoff from these surfaces does not require water quality treatment.	Cost and supply to install Added structural design requirements. Potential fire risk if not designed properly. Building materials

Stormwater Management Option – non-structural		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway	Location Suitability	Benefit	Drawback
					Nutrients		Erosion (TSS)	*E. coli* (Bacteria)	Heavy Metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus			Zinc	Copper				
												treatment devices	Noise insulation, enhance air quality, reduced the energy demand of buildings Provides biodiversity and habitat opportunities Mana Whenua alignment.	needed for roofs to be suitable to hold plants and soil matter etc.
Roof Materials Policy	Painting galvanised iron roofs to prevent zinc entering stormwater, avoiding the use of copper roofing and guttering materials and those incorporating permanently exposed zinc coated surfaces	Policy / Program	Limited to WWL owned facilities. Influence District Plan		H	H	H	L	H	H	Source	At Source Residential, commercial, and industrial	Ideal in places where source control is likely to be a more appropriate option than providing treatment of stormwater practice Illuminates the source of heavy metals that usually come from corrugated iron roofs	Cost to implement and source roof materials. Buildings will have to be retrofitted with roof linings that can hold new materials etc.
Rainwater Harvesting Policy	Rainwater tanks attenuate and re-use stormwater from rooftops of buildings and landscape areas. Provides a non-potable source of water. Can be placed partially underground or underneath eaves of buildings.	Policy / Program	Limited to WWL owned facilities. Influence District Plan		M	L	H	M	H	H	Pathway	At source Below ground in high density areas as limited space Above ground in areas with more available space such as rural properties	Removes contaminants from roofs. Meet some the developments water demand, delivering sustainability and climate resilience benefits Reduces pressure on	Required periodic checking and maintenance Cost of the system, pump and the power required for the operation, especially if for private residential use.

Stormwater Management Option – non-structural		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway	Location Suitability	Benefit	Drawback
					Nutrients				Heavy Metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus	Erosion (TSS)	*E. coli* (Bacteria)	Zinc	Copper				
													existing Puna for water supply Reduced volume of runoff from a site.	
CODE OF PRACTICE														
Risk assessment and environment management systems by local authorities	Risk assessments and environmental management systems can identify, characterise, and manage the associated stormwater risks with each catchment.	Policy / Program	High Programme level		It is challenging to manage stormwater at the catchment or region wide scale due to the range of pollutant sources and resource limitations. Risk assessments involves assessing the different sources of pollutants, prioritising them and allocating resources to manage them. For example, using a risk-based approach to prioritise catchments.						Source, Pathway, and receptor	Everywhere in the catchment All land use types.	Identifies key risk and concern areas within the region/ catchment	
Develop stormwater management strategies at a "city scale"	Plans to guide decision- making on how stormwater quantity and quality is managed in a holistic and integrated matter in urban development, which is the over-arching purpose of this SMS.	Policy / Program	High Inform WWL activities		These strategies can then guide and inform the development of stormwater management plans which document the design proposed for a particular development area.						Source, Pathway, Receptor	Everywhere in the catchment All land use types.	Provides an integrated and holistic view towards stormwater management	
Stormwater Design Guidelines (For example: Water Sensitive Design for Stormwater: Treatment Device Design Guideline)	Communicates the requirements for the design of stormwater treatment devices in publicly owned assets and provides best practice guidance for the design of stormwater treatment devices where devices are to remain privately owned.	Guideline	High Influence through controlling connection to network		Supports the use of good management practices through the release of standards, guidelines, and technical practice. Provides guidance for the concept, preliminary and detailed design phases pf a stormwater treatment system Ensures new treatment devices are functional, optimised, maintainable, safely designed, and mindful of community values.						Source, Pathway and Receptor	Everywhere in the catchment. All land use types.	Incorporates WSD principles In alignment with Whaitua Documents and Mana Whenua.	

Stormwater Management Option – non-structural		Type of Option & Applicability		Example of Implementation	Effectiveness L=Low M=Medium H=High						Source Pathway	Location Suitability	Benefit	Drawback
					Nutrients				Heavy Metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus	Erosion (TSS)	*E. coli* (Bacteria)	Zinc	Copper				
Water Sensitive Design	Takes into consideration, Safety during construction, maintenance and operation, Integration with other design elements, Integration with and around other services, Constructability, Maintenance requirements, Whole of life considerations.	Guideline	High Influence through controlling connection to network		Seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities						Source, Pathway and Receptor	Everywhere in the catchment All land use types.	Incorporates water sensitive and low impact design principles Utilises stormwater management areas for multiple uses.	
Servicing and infrastructure standards	Servicing and infrastructure that is planned to service proposed development is to connect with the wider infrastructure network in an integrated, efficient, coordinated, and future proofed manner	Guideline	High Influence through controlling connection to networ		Standards within regional and district plans that for do not allow for use and development in areas where it is unable to be efficiently integrated within the existing infrastructure in an efficient and cost-effective manner.						Source, Pathway and	Everywhere in the catchment All land use types.		
OTHERS														
Target Rates through stormwater bylaws.	Setting target rates for operating devices and including them in SCaMPs (stormwater Sub-Catchment Management Plan). E.g., in Auckland, community elected to pay an additional stormwater tariff to invest in water quality	Policy / Program	Low Influence District Plan								Source, Pathway and Receptor	At Source Residential, industrial, and commercial	Helps mitigate a range of storm intensities and volumes Initiatives to decrease contamination of stormwater	Willingness of public to get behind – increase in costs may deter people
Copper-free or reduced copper brake pads	Metallic brake pads are commonplace throughout the world. Here in New Zealand most brake pads fitted to our vehicles contain copper and other heavy metals like mercury, lead, cadmium, and chromium. Low copper and copper-free friction materials used in brake	Policy / Program	Limited to WWL asset fleet procurement decisions. Influence National Policy and Direction.		N/A	N/A	N/A	N/A	H	H	Source	At source Suitable for all locations	Decrease in copper contaminants from vehicles Sustainable and resilient option	Supply demand. People not wanting to spend more

Stormwater Management Option – non-structural		**Type of Option & Applicability**		**Example of Implementation**	**Effectiveness L=Low M=Medium H=High**						**Source Pathway**	**Location Suitability**	**Benefit**	**Drawback**
					Nutrients				Heavy Metals					
Option	Description	Option	Wellington Water Applicability		Nitrogen	Phosphorus	Erosion (TSS)	*E. coli* (Bacteria)	Zinc	Copper				
	pads can now outperform other friction materials and they do not compromise vehicle safety or performance. (“The hidden pollutant in our brake pads - Environment Canterbury”) The cost of installing copper-free or reduced copper brake pads is only about $10-15 more expensive than traditional pads and they are easily available.													
Financial Levers, Incentives and Assistance	May involved but not limited to, rates rebates, grants and subsidies, targeted rating schemes, repayment schemes etc.	Policy / Program	Medium. Influence Funding regimes through negotiations with parent Councils.		Incentives based on ‘polluter pays’ and ‘user pays’ principles may be used to assist in implementing stormwater management controls. This should be decided upon through consultation with community groups to minimise resistance. Existing similar schemes include ‘warm wellington’ and the insultation grant schemes.						Source, Pathway and Receptor		Financial incentives or support may be useful in enabling privately owned infrastructure repairs replacement, or to incentivise uptake of new materials and technologies to replace dated infrastructure known to be prone to failure.	

Stormwater Management Option – education and engagement				Benefit	Drawback
Option	Type	Wellington Water Applicability	Description		
EDUCATION AND ENGAGEMENT: Education and participation programs are a catalyst for behavioural change and a tool to raise awareness for stormwater management and reconnect communities with their waterways. Leads to community led initiatives and volunteer effort. Can be developed through Open Databanks, Public outreach, and educational campaigns, and Educational WSD.					
EDUCATION					
Short course or training on aspects of stormwater management	Program / Capability	Medium	For volunteer residents or 'champions' that focus on source controls that minimise stormwater pollution, particularly nutrients. Topics that can be covered include water conservation, plant selection, fertilizer use, irrigation practices, composting and shallow groundwater reuse.	Programs/courses can range from community level to regional scales. Holistic approach to promote best practice in stormwater management. Community become aware/champions in different topics such as water conservation, plant selection, fertiliser use, irrigation practices, composting and shallow groundwater use	Cost of courses Willingness of the public to participate
Education campaign for residential property owners	Program / Public Outreach	Medium – Low	Awareness of potentially damaging household practices and opportunities such as stormwater capture. Aimed at informing to elicit a behaviour change and minimise pollution at source	Awareness of potentially damaging practices - with the aim of informing elicit behaviour change. Educational campaigns can encourage facilities to adopt environmental management and cleaner production techniques.	Willingness of the public and commercial and industrial premises to participate
Education campaign for commercial or industrial premises, and educational facilities	Program / Public Outreach	Medium – High	Specific to industries that have a significant risk of contaminating stormwater because of their activities. Training and environmental accreditation programs are undertaken to encourage facilities to adopt environmental management and cleaner production techniques.	Awareness of potentially damaging practices - with the aim of informing elicit behaviour change. Awareness of industries to the significant risk of contaminating stormwater because of their activities. Educational campaigns can encourage facilities to adopt environmental management and cleaner production techniques.	Willingness of the public and commercial and industrial premises to participate
Technical education on water sensitive urban design	Program / Capability	High	Capacity programs can range from community-level to regional scales. It is a holistic approach to promote good practice in stormwater management with communities, governments, and industry professionals.	Awareness of potentially damaging practices and origins of pollutants and contaminants. Awareness into WSD practices and how these could be incorporated at the individuals, residents, and commercial, industrial, and educational facilities.	Willingness of the public to participate
COMMUNITY GROUPS					
Encourage citizen participation by the community in all aspects of stormwater management	Program / Public Outreach	Medium / High	It is important for residents to understand the nature of stormwater pollution and ways to manage stormwater effectively. Allocating budget to engage with communities can lead to residents positively contributing to future stormwater management approaches. A 'bottom-up' approach has proven more effective in changing the behaviour and perceptions of communities.	Community awareness of the origin of contaminants and pollutants leading to positive contributions in the future. Behaviour changes	Willingness of the public to participate

Stormwater Management Option – education and engagement				Benefit	Drawback
Option	Type	Wellington Water Applicability	Description		
Identifying community groups or individuals to be champions for stormwater management	Program / Public Outreach	High	Community volunteers are valuable to ensuring stormwater management occurring at the local level. Community champions may assist in hosting community education programs to address stormwater management issues and represent the communities voice or opinions at council or local government meetings.	Community engagement and providing opportunities to build and transfer knowledge cultivates and grows institutional capacity and capabilities. Behaviour changes towards positive stormwater management.	Willingness of the public.