WATER SENSITIVE URBAN DESIGN

A GUIDE FOR WSUD STORMWATER MANAGEMENT IN WELLINGTON

Absolutely Positively **Wellington** City Council

Me Heke Ki Pōneke

ACKNOWLEDGMENT

Wellington City Council gratefully acknowledges the support of the project work group members; the people and organisations who took the time to make submissions and also the Environmental Reference Group for its overview and advice.

WORK IN PROGRESS

Please note that this guide is very much a work in progress, reflecting best practice in a fast moving and evolving field.

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OBJECTIVES OF THIS GUIDE

The guide aims to help large and small-scale developers – public and private – to understand the importance of incorporating water-sensitive urban design (WSUD) into future stormwater management projects. The background of WSUD, land-use considerations and the local Wellington context is provided in support of an overview of a range of WSUD systems that aim to:

- Stabilise water flows in streams
- Improve the quality of the water in our streams and harbours
- Reduce the frequency and severity of flooding in urban areas
- Reduce the quantity of stormwater entering the sewerage system
- Protect or enhance environmental, social and economic values
- Reduce demand on potable water supply
- Improve amenity in the urban environment: enhancing the 'liveability' of Wellington.

The design and construction of site-specific WSUD measures, as part of integrated water management, must be undertaken by experienced professionals with an understanding of the complexities and challenges involved. Specific design advice is not included in this document. Acceptable approaches to stormwater management, technical considerations and how these will be assessed are outlined in the WSUD chapter of Wellington City Council's Code of Practice for Land Development (COPLD).

WHO SHOULD READ THIS?

The successful implementation of WSUD requires consideration from the outset of projects and the support of a multidiscipline design team. By involving engineers, landscape architects, planners and the community, environmentally and economically viable solutions can be developed to reduce the pressure on existing drainage systems.

This guide is intended to provide some context to the planning for the implementation of WSUD and is therefore for, but not limited to:

- Developers
- Consultants
- Land owners
- Restoration and other community groups
- Council staff.

HOW TO USE THIS GUIDE

This guide should be read in conjunction with the more technically-oriented draft WSUD chapter of Wellington City's Code of Practice for Land Development (COPLD). It is recommended all users review both documents to become familiar with the concepts and devices in a Wellington context.

As well as this there is a vast array of other technical design documents from New Zealand and overseas.

This guide aims to introduce an integrated 'treatment train' approach to managing the city's stormwater. WSUD should, where practicable, be used within integrated catchment and asset management plans. All projects should identify and investigate WSUD opportunities at their various stages of its lifecycle: conception, initiation, planning, execution and operation, to deliver acceptable and workable WSUD results.

As designers become more familiar with the concepts they may want to refer to the step-by-step device selection procedures in the latter half of this document and then the technical considerations in the COPLD.

WHAT IS WSUD?

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

The urban water system includes potable water, wastewater and stormwater. This guide focuses, for now, primarily on stormwater, but in doing so will have positive effects on potable water demand and issues with unintended wastewater discharges.

A stormwater system allows the passage of runoff to avoid nuisance flooding and consequential damage to public and private property. A WSUD system must support this vital function.

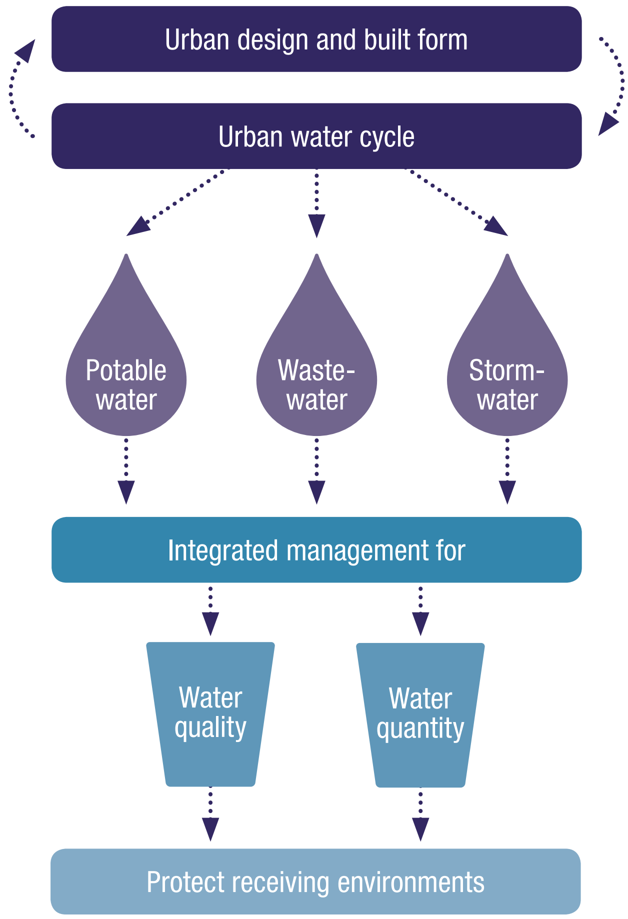
The overarching objectives of WSUD are:

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

Wellington's stormwater network is separate from the sewer system.

Stormwater is water that runs off urban hard surfaces such as roads, driveways, footpaths and rooftops, whether flowing overland or in channels, down sumps or pipes through a catchment.

WATER SENSITIVE URBAN DESIGN



Wastewater (sewage) is the liquid wastes from a community including toilet, bathroom, laundry and kitchen wastes and trade waste, before treatment.

WHY WSUD IN WELLINGTON?

An important part of Wellington's environment, recreation, heritage and economy are the harbours and the sea surrounding the city. Poor water quality sometimes closes beaches and affects our enjoyment of our natural environment. Data from Wellington and Porirua harbours show contaminants levels in excess of guidelines for aquatic life.

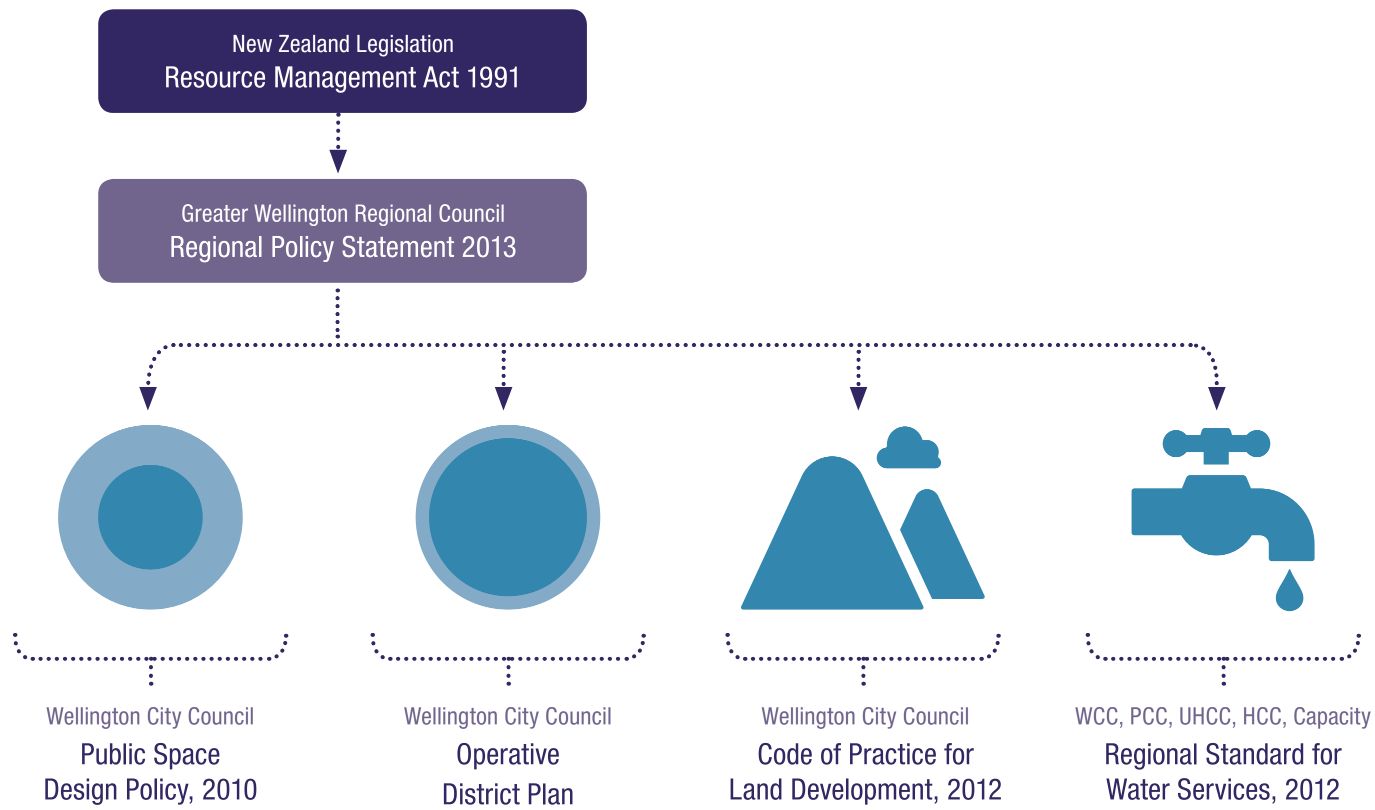
Stormwater is traditionally drained through an engineered pipe system designed to convey runoff and discharge to the nearest water body (either stream or harbour). These piped stormwater networks therefore also efficiently move contaminants generated by urban activities to these water bodies. During heavy and prolonged rain, cross-connections and under-capacity pipes can cause drainage systems to be overwhelmed and for sewage to overflow into harbours and coastal waters. Higher flows can also cause erosion and flooding of urban streams. Pipe networks, or grey infrastructure, are also expensive to build and maintain.

Using WSUD to treat stormwater, and reduce the existing impermeable areas of the city, will reduce the amount of rainwater in our drainage networks, thus reducing flooding and overflows of sewage in the streams and the sea, ensuring the water entering our harbours is less contaminated.

WSUD can effectively divert the greatest runoff volumes and pollutant loads to infiltration (where suitable), maintaining urban biodiversity and providing enhanced groundwater resource and baseflow to waterways.

To protect the environment and meet legislative requirements, the principles of WSUD should be applied in the development of new subdivisions, the retrofitting of city assets and neighbourhoods and the assessment of resource consents.

POLICY TREE



Most traditional 'grey' infrastructure has a single function. Green infrastructure, by contrast, is multi-functional. Aside from reducing pressure on the drainage network and filtering out pollutants from stormwater, WSUD can also bring more native flora and fauna into the heart of the city, creating shade, reducing carbon emissions and improving streetscapes. WSUD can also help realise the 'Blue Belt' vision of celebrating Wellington Harbour and the value it brings to the city by protecting marine habitats and making our sea safe for an array of recreational activities.

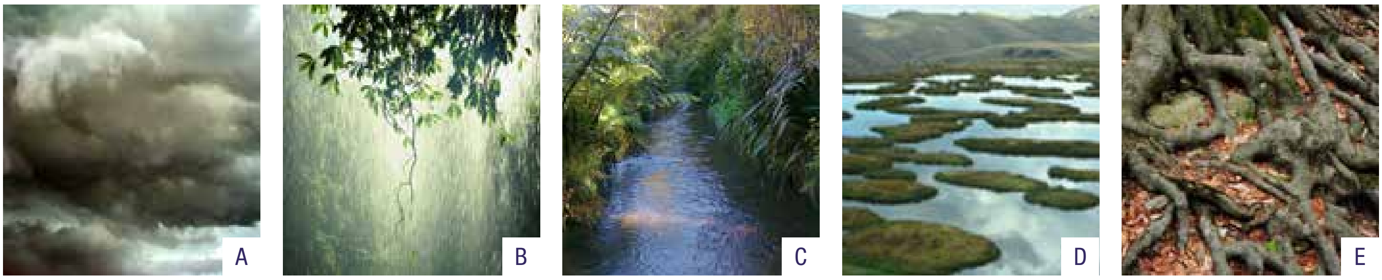
PART ONE
STORMWATER CYCLES

The natural water (hydrological) cycle describes the continuous movement of water at, and below, ground level. The water cycle is essential for the maintenance of most life and ecosystems on the planet.

A number of processes occur between rain falling and the water entering the sea. These processes occur in a number of ways at different points along the water's path. The processes include interception, infiltration, evapotranspiration, collection, transport, detention, retention and discharge to sea.

To manage these processes effectively in an urban setting requires a chain of intervention measures which effectively work in series to deliver multiple benefits for the overall system. Through the integration of WSUD elements into the urban stormwater system, the synergies between natural and engineered processes can yield significant efficiencies and resilience while improving the environment. This 'whole of cycle' approach is often referred to as a 'treatment train'.

NATURAL SYSTEMS



Precipitation | Interception | Attenuation and conveyance | Uptake

Collection | Treatment

In a natural system, rainfall is intercepted, absorbed and filtered by plants and the soil throughout the catchment. This infiltration keeps groundwater and soil moisture levels at reasonably stable levels and reduces the incidence of surface flows. Soil and vegetation operates like a sponge – retaining and releasing water, collecting and attenuating flows. Types of vegetation, soils, topography and land use all significantly affect the natural hydrological cycle with resulting changes in the frequency, volume and duration of runoff.

Additionally, stream margins, or riparian areas, are an important part of stream biodiversity – providing habitat and shelter for fish, increasing bird and insect life, improving water quality by filtering out some pollutants, moderating water temperature through shading and reducing erosion of stream banks.

Research shows that vegetation can increase water infiltration up to 60 times compared to bare ground.

ATTRIBUTES OF A NATURAL SYSTEM

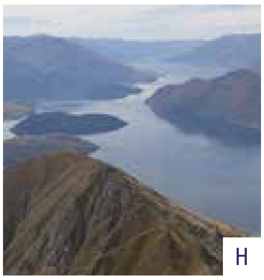
- Frequent flow attenuation
- Ecological complexity offering a range of ecosystem services
- Infiltration charges ground water storage and maintains soil moisture and baseflows
- Habitats for aquatic animals and plants (biodiversity)
- Nutrient recycling
- Reduces contaminant volumes discharged
- Natural beauty (aesthetics and amenity).

ISSUES TO HUMAN SETTLEMENT

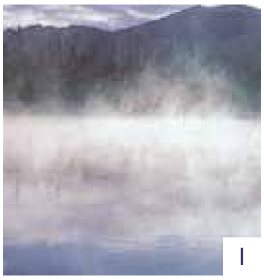
- Uncontrolled flooding on floodplains
- Challenges in integrating dynamic (natural) and rigid (man-made) structures.

Evapo-transpiration

Infiltration



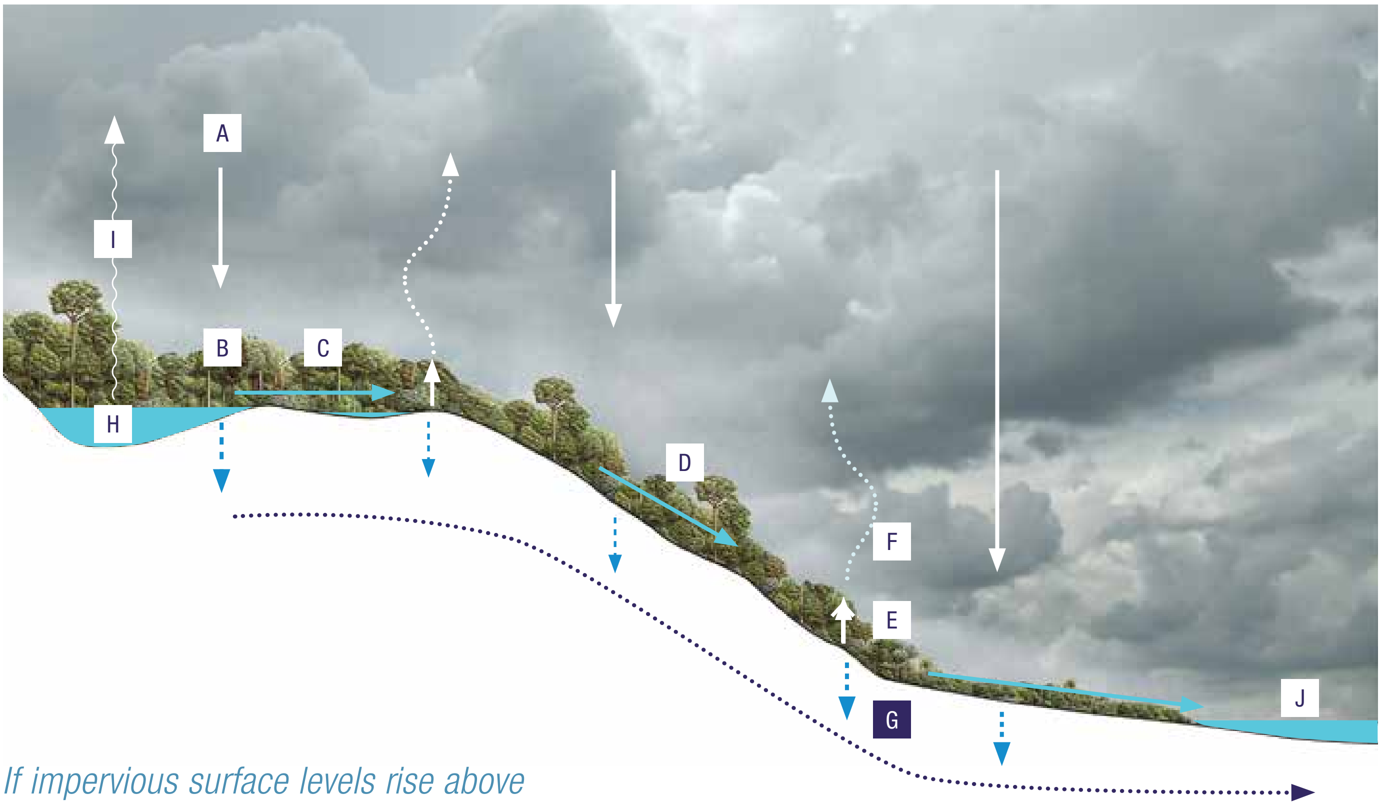
Retention



Evaporation

Discharge to receiving environment

Storage



If impervious surface levels rise above 7–10% of the catchment, stream 'flashiness' rises to such a point that habitat values are severely compromised.

CONVENTIONAL STORMWATER SYSTEMS

Precipitation | Interception | Uptake and evapo-transpiration | Conveyance

Collection

These systems have traditionally focused on flood management – collecting rainwater runoff from impervious surfaces and quickly discharging it to streams or the sea. In conventional urban centres impervious surfaces (such as roads, pavements, car parks and rooftops) do not allow water to soak into the ground and therefore increase the frequency and volumes of runoff.

As impervious surfaces spread across catchments, stormwater volumes and peak flow rates also increase. Following heavy rainfall, flow rates will rise rapidly and can result in incidence of localised flooding in open channels and streams. This differs from natural stream systems which are characterised by more gradual rise and fall in flow rates and water levels. These unnatural 'flashy' events can erode stream banks and channels, reduce habitat and diminish fish populations and variety.

When combined with pipes of limited capacity, this can cause flooding.

Hard surfaces reduce infiltration which reduces ground water and soil moisture content. This can cause soils to shrink, destabilising older built structures and infrastructure.

Conversely saturated soils and basecourse beneath a road surface can adversely affect the cohesive strength and integrity of the road.

Human and urban activities generate a wide range of contaminants. When it rains, contaminants are washed off hard surfaces and into the stormwater networks. This contamination of stormwater can result in public health risks, closing beaches and affecting recreation, shellfish gathering and cultural and tourism values as well as impacting on marine and freshwater biota and ecosystems.

Pollutants can include:

- Fine and coarse sediments from land development, disturbed vegetation and windblown sources
- Litter: especially cigarette butts and plastics
- Hydrocarbons and oil products from vehicles, road construction and unauthorised disposal in drains
- Nutrients (nitrogen and phosphorous)
- Pesticides, herbicides and fungicides from gardens
- Heavy metals including lead, zinc and copper (from vehicle wear, oils, buildings and paints)
- Human faecal matter: from sewer overflows
- Animal faecal matter from the likes of dogs, cats and birds.

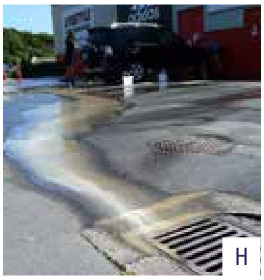
ATTRIBUTES OF CONVENTIONAL SYSTEMS

- Reduced land requirement (especially at surface)
- Efficient conveyance of flows to manage flood risks
- Pollutants transported away from urban areas
- Prevents over-saturation of soil.

Evaporation

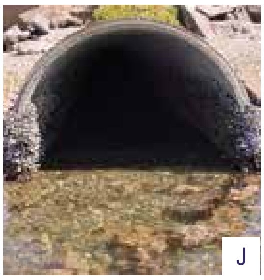
Infiltration

Storage

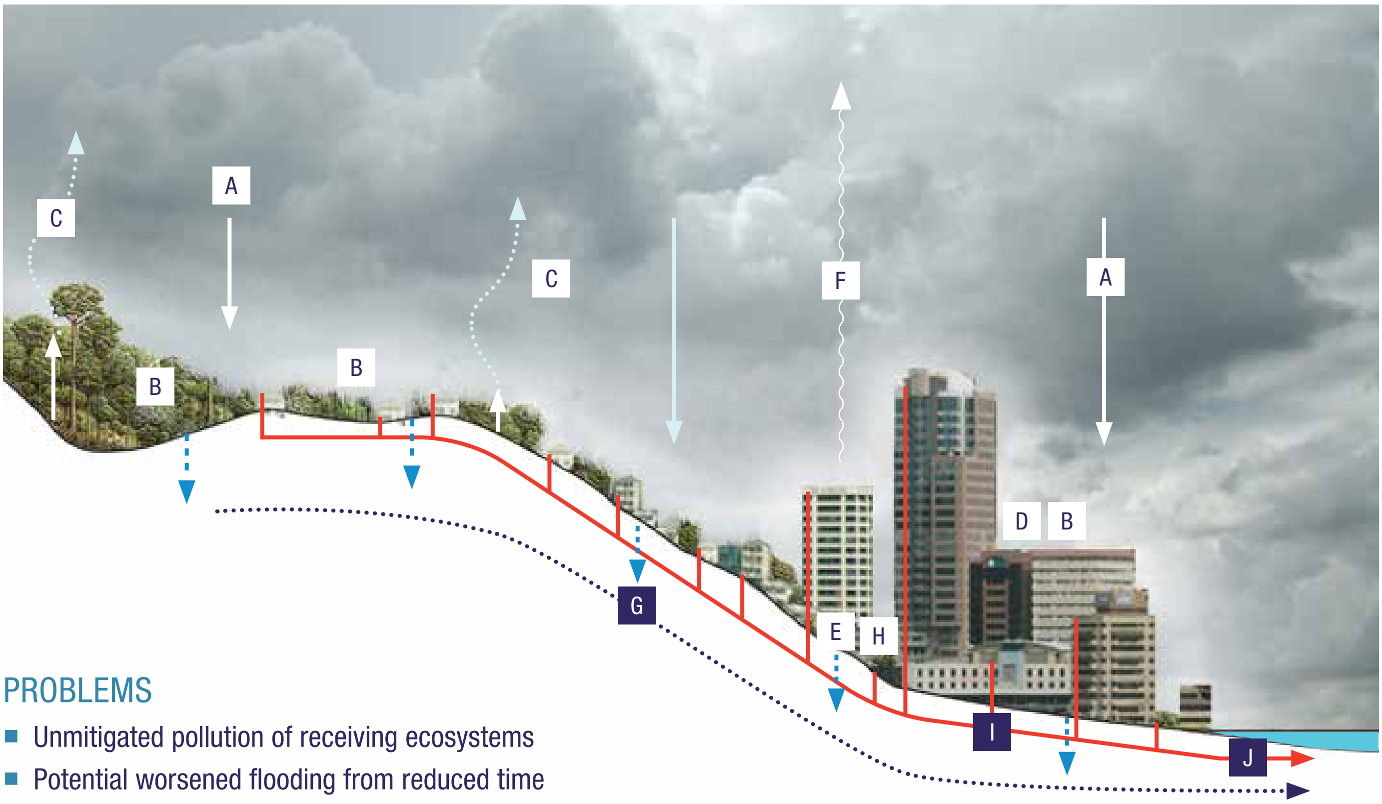


Sediment and litter collection

Conveyance



Discharge



PROBLEMS

- Unmitigated pollution of receiving ecosystems
- Potential worsened flooding from reduced time of concentrations
- Reduced recharge of ground water (and low lying streams)
- Reliance on unseen infrastructure with risk of element failure
- Reduced water for vegetation
- Disconnection of community with lost waterway and ecological resources.

AN INTEGRATED WSUD SYSTEM

Natural and urban stormwater systems each have their own attributes and issues. WSUD combines the positive attributes of the natural water cycle and urban-engineered network to design systems that use vegetation, soils and natural processes to reduce the volume, rate and peak flows of stormwater runoff and improve the water quality of discharges.

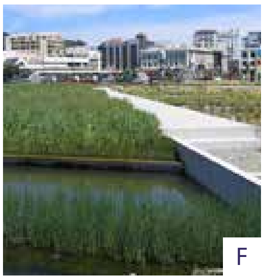
For Wellington City, WSUD is intended as a series of holistic design and development practices that:

- Work with, not against, natural systems – supporting integrated management of natural and physical resources
- Enhance ecosystem and human health
- Maximise on-site management of effects in order to minimise off-site effects
- Foster the efficient use of resources – creating opportunities to reduce, reuse and recycle thereby reducing energy demand and waste generation
- Recognise and provide for tangata whenua while fostering kaitiakitanga ('guardianship') through partnership
- Guide development so multiple social, cultural and environmental functions co-exist
- Promote economically efficient, practical solutions that consider total lifecycle cost and value to the community.

In Wellington a WSUD approach would help the piped networks cope with increasing frequency of heavy rain and reduce pollution of natural water bodies. The design measures shown in this document are examples of how this can be achieved.

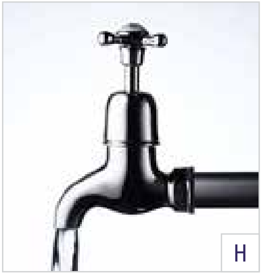
ATTRIBUTES

- Distributed stormwater management
- Protects or enhances water quality in downstream environments
- Reduces the incidence of frequent nuisance flood events
- Improves the visual and ecological amenity of sites and streets
- Reduces potable water use
- Improves urban ecology and habitat
- Provides passive irrigation to green infrastructure supporting passive cooling and landscape interest
- Celebrates water within the urban context to provide education and a pride of place.



Detention and retention

Evaporation



Reuse

Conveyance

Discharge

Storage

ISSUES

- Lack of technical understanding in the design, construction and operation
- Importance of components, such as soils and vegetation to long term performance
- Adjustment to standard maintenance requirements of drainage assets
- Need for strategic planning to optimise opportunities and cost benefit ratios
- Challenges with quantifying intangible benefits
- Public perception of increased pest habitats.

HARBOUR QUAYS, CENTREPORT – A WELLINGTON EXAMPLE

Private and public sites can collect, retain, treat, reuse and discharge clean water in a number of ways and contribute to the overall functionality and values of the urban system.

CentrePort's Harbour Quays development implements an integrated stormwater management strategy that deals with water quality and quantities at source.

The WSUD strategy for Harbour Quays focuses on the implementation of swales, raingardens, tree pits and roof water storage ponds. The design and location of these systems defines the character of the streets and open spaces.

WSUD MEASURES INCLUDE:

SWALES

'First-flush' stormwater run-off, the earliest and subsequently the most polluted component of rainfall, is directed towards a densely planted swale located either in the median or at the road edge. The swales have capacity to detain and filter run-off. Clean filtered water flows into slotted subsoil drains at the base of the swale and is then conveyed off site. During a big storm, excess water overflows into a raised sump, less polluted than 'first-flush' run off this water is conveyed directly into a conventional stormwater system.

RAINGARDENS

Raingardens occur within urban plazas and laneways to both improve stormwater runoff quality and visually augment these spaces.

TREE PITS

The majority of tree pits site wide filter stormwater run-off from roads and foot path pavements.

ROOF WATER STORAGE PONDS

Park spaces within the site have been designed to accommodate storage tanks and/or ponds for site-wide re-use in irrigation.

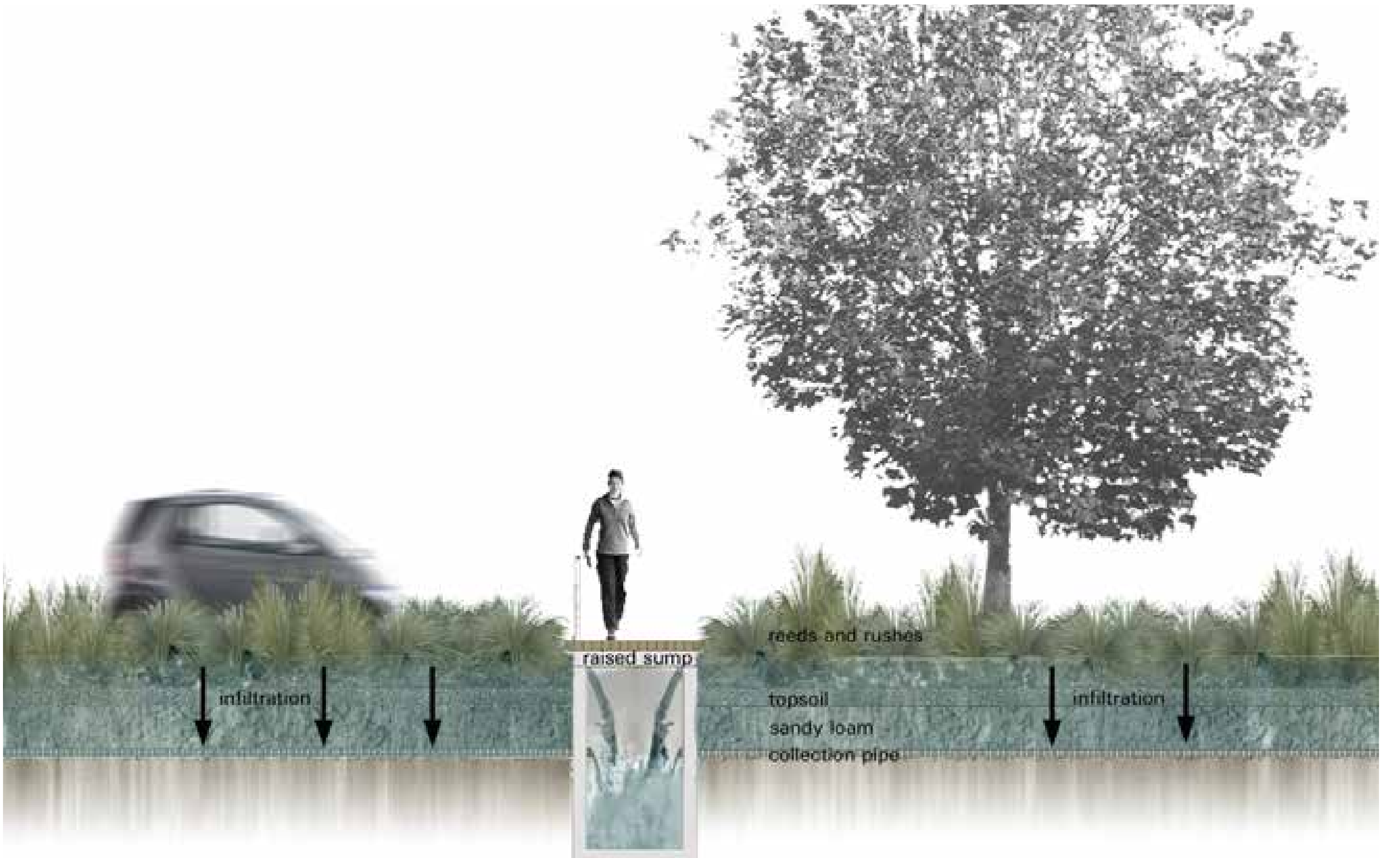
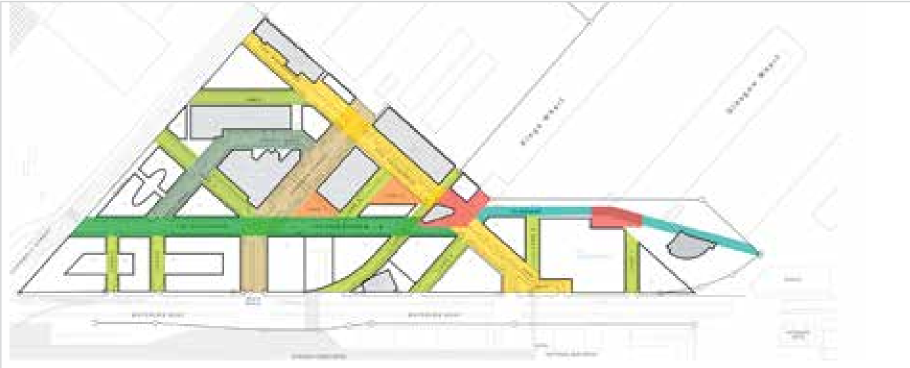
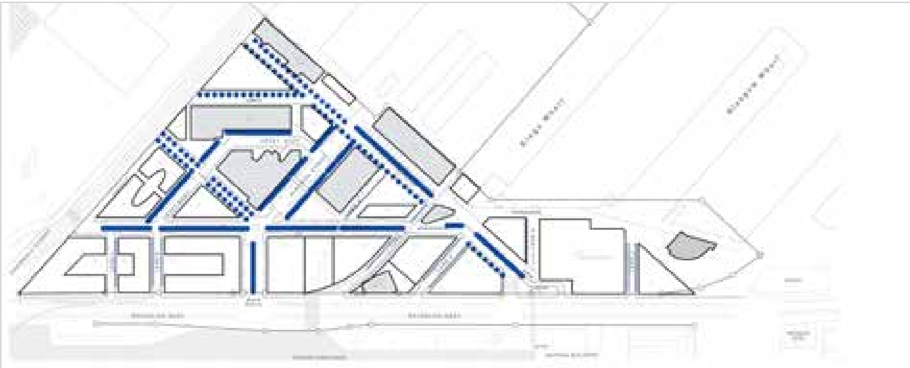


Image source: Wraight + Associates Ltd

HARBOUR QUAYS WSUD STRATEGY SHOWING STORMWATER SYSTEM INTEGRATED WITH URBAN DESIGN

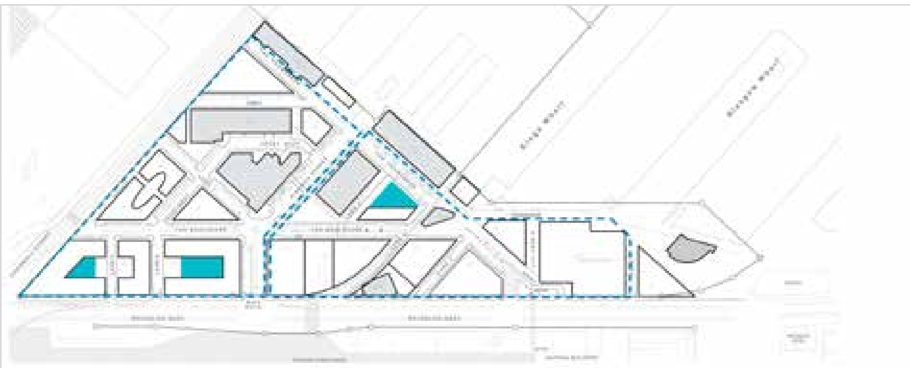


STREET NETWORK, SQUARES & PARKS



STORMWATER COLLECTION

STORMWATER STORAGE AND REUSE



STORMWATER INFILTRATION

Image source: Wraight + Associates Ltd

PART TWO
WELLINGTON

From the rugged, exposed south coast, to the harbour and its bays, to the Town Belt, ridgelines and hilltops – Wellington is a city where the natural and urban environments are intertwined.

An important part of Wellington's identity is the marine environment that surrounds the city. Our environment carries significant ecological, economic, social and cultural value, and creates economic opportunities for the city.

Like other cities and towns in New Zealand, Wellington was originally covered in native vegetation. The city was once cloaked by over 20,000 hectares of lowland broadleaf podocarp forest. The land has also been modified more than most other New Zealand cities by the uplift by earthquakes and reclamation of the shoreline as well as urban development filling in gullies, piping streams, and creating flat building platforms.

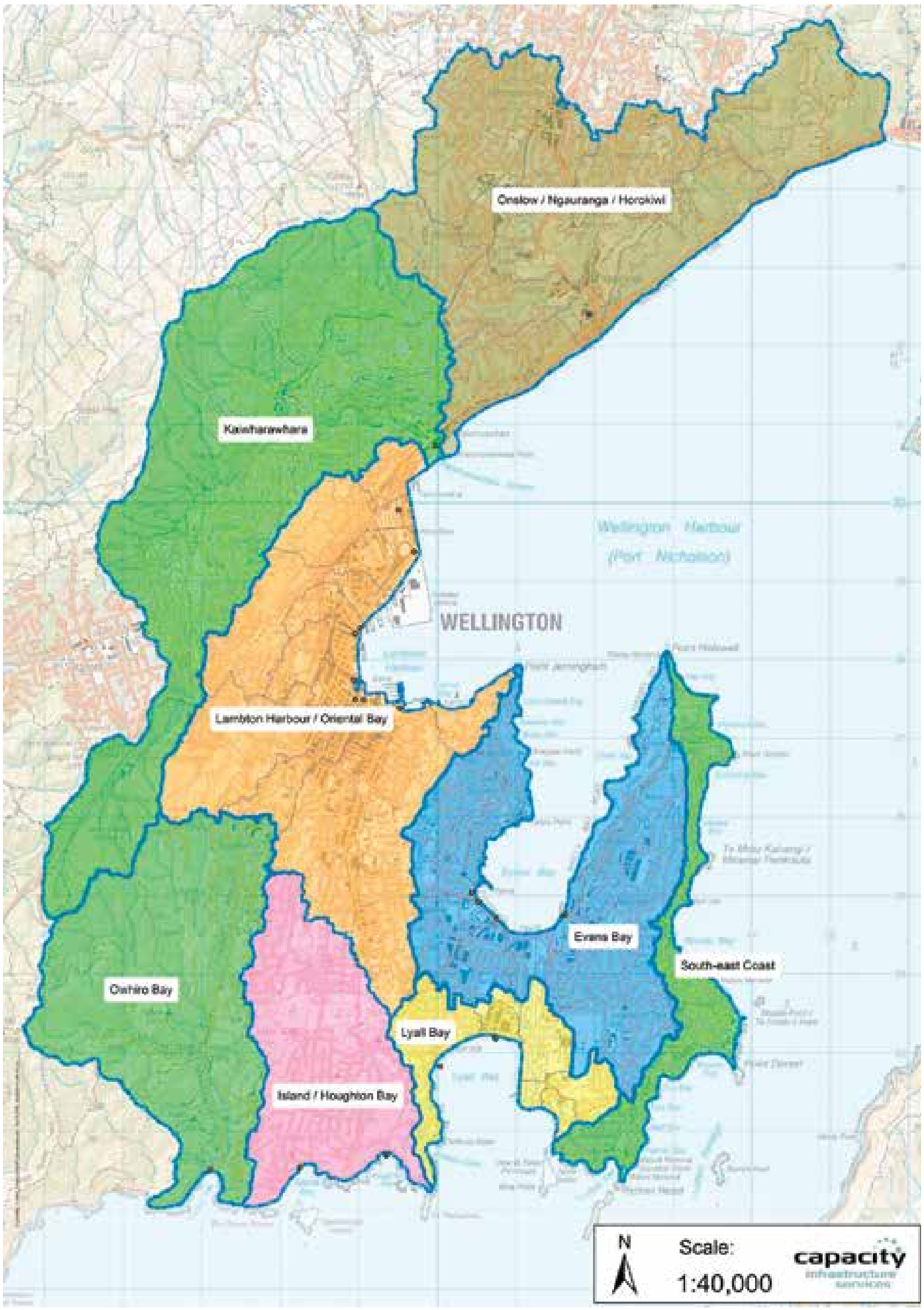
Wellington's topography, geology, urban layout and climate pose challenges for stormwater management which must be considered in the design of infrastructure. While this can limit opportunities for WSUD assets it does not preclude the implementation with site-specific design responses required.

CATCHMENTS

A water catchment is defined by topography. From ridgelines and hilltops headwater streams flow to successively larger streams, and eventually to a main stem stream, all draining the surrounding catchment of its surface water. The main stream ultimately drains to coastal waters either via direct discharge or tidal estuary.

Wellington's catchments are based on natural drainage characteristics. The urbanised part of the city comprises 34 individual catchments ranging in size and elevation from partly rural Kaiwharawhara (1917ha, maximum 440m above sea level) to smaller urban catchments such as Tory (44ha, maximum 8m above sea level).

THE MAIN STORMWATER CATCHMENTS



Surface water flows through these catchments in a combination of natural streams and stormwater pipes that discharge directly into the harbours (both Wellington and Porirua) or the south coast. The stormwater system has evolved with the development of the city. While there are still some remnants of streams, most areas are serviced by stormwater pipes.

The existing stormwater network comprises a gravity system of sumps, pipes, culverts, grit traps, overland flow paths and streams. There is some 550km of piped network and upwards of 25km of open semi-urban streams (excluding those in rural areas). Together they convey almost 80 million cubic metres of stormwater every year from buildings, roads, urban areas and open spaces into the city's coastal waters.

For catchment management purposes the 34 stormwater catchments are combined based on the receiving environment based on type of ecosystem and recreational use. These combined catchments are: Lambton Harbour, Evans Bay, Houghton and Island Bays, Lyall Bay, Eastern Bays, and the urban stream catchments: Porirua, Owhiro, Kaiwharawhara and Waitohi (Ngauranga) and Karori streams.

POLLUTION NEGATIVELY IMPACTS ON RECREATIONAL ACTIVITIES.

STREAMS

Streams are one of the Wellington region's threatened ecosystems. Urban streams have been, and still are being, heavily modified and influenced by development and urban activity.

Local watercourses and land features are highly significant to tangata whenua. Many sites are associated with iwi histories, traditions and tikanga.

Urban streams include Owhiro Stream, Kaiwharawhara, Waitohi (Ngauranga), Karori and Porirua Stream and tributaries, as well as the 'lost streams' of Te Aro, Thorndon, Houghton Valley, Island Bay and Miramar. Seven historical streams (around 5km) flow through pipes beneath the central city. They are Pipitea, Tiakiwai, Tutaenui, Waipiro, Kumutoto and Waitangi streams. These streams are largely forgotten, with most local people unaware of their existence. As Wellington developed, streams were piped by laying large stormwater pipes along the beds of the original streams to provide flat building surfaces, improve sanitation and to deal with flooding.

Modifications to streams, their associated vegetated margins (riparian areas) and the wider catchment have altered the relationship of Māori with these resources. The streams remain, albeit piped underground, but still carry mauri and are of significant importance to tangata whenua.

In the case of Wellington, the open sections of streams are generally narrow and restricted channels with overhanging vegetation. Streams have an average grade of 7.25% throughout the city – representing the steep Wellington topography and the tendency for streams to only remain in the steepest and more isolated areas of the city.

Streams provide habitat and food for plants and animals – from algae to eels. Although many of Wellington's streams are small, and some are even dry at certain times of the year, their biological health is important both for the species they support and also for the harbour and sea into which they flow.

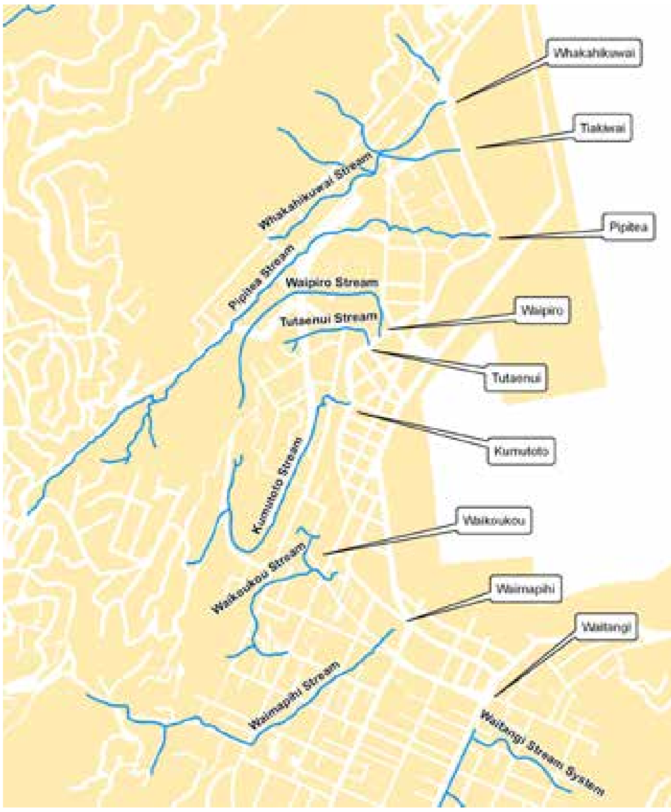
Stream margins, or riparian areas, are an important part of stream and catchment biodiversity; providing riparian habitat as well as improving water quality and habitat by providing shelter for fish, filtering out some pollutants, reducing erosion to stream banks and increasing bird and insect life.

Daylighting (opening up) the lost channels could provide valuable habitat, offer educational and recreational opportunities, enhance urban landscapes, and help to give a place a sense of identity. Where daylighting is not feasible, water-sensitive features can be constructed that reference their earlier presence.

Threatened species

Nearly all of New Zealand's freshwater fish species migrate between freshwater and the sea during their lives and this is an important part of their breeding cycle. This means that if streams are lost, or if there are barriers to fish passage, then fish will become extinct from that particular stream. Giant kokopu, long-finned eel and short-jawed kokopu are all nationally threatened fish present in Wellington.

WELLINGTONS HISTORIC STREAMS




NOW PIPED WAIMAPIHI STREAM


TE MAHANGA STREAM


WAITANGI PARK

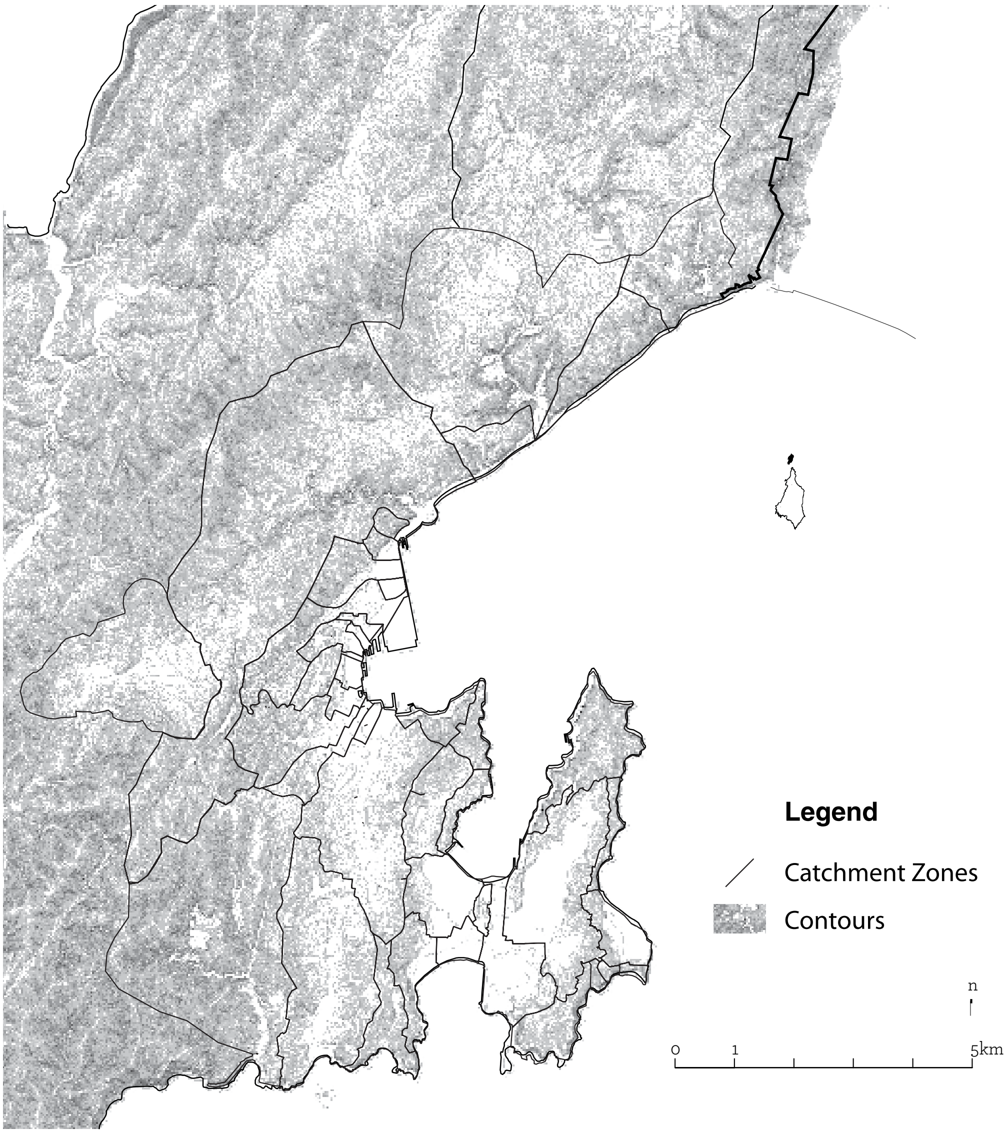
TOPOGRAPHY

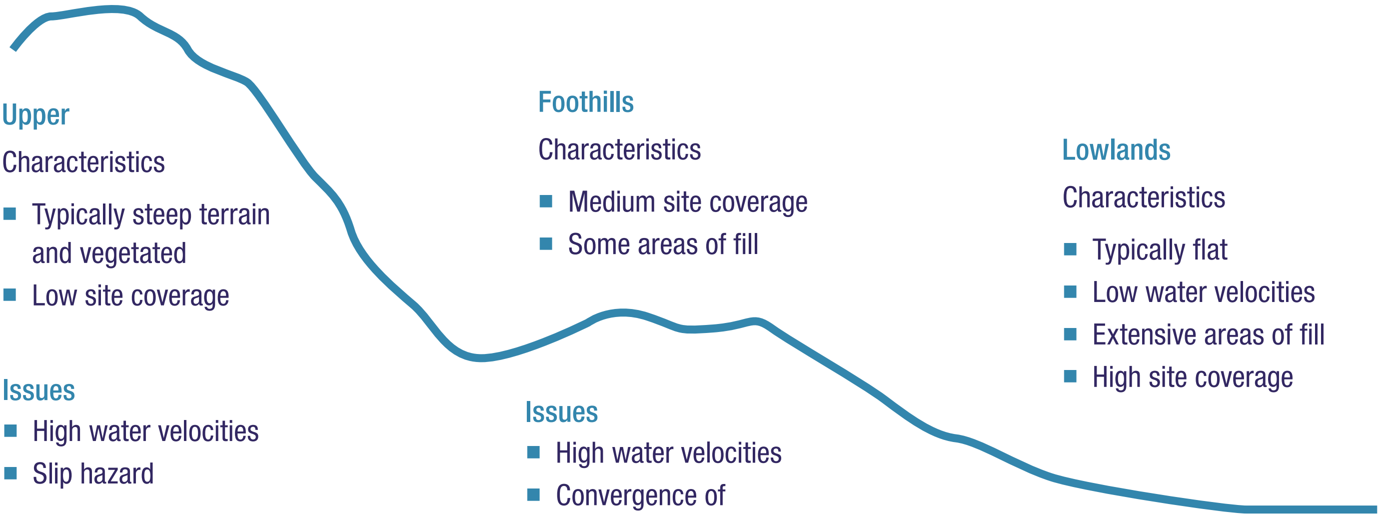
Wellington's topography is highly diverse, ranging from steep hills to lowland flats. The city's footprint is confined by hills around Wellington and Porirua harbours and the coast. Most of the city is characterised by steep slopes and gullies draining to the flat coastal edge. The northern suburbs are flatter, more undulating hillsides.

Many of the more densely-developed areas of the city are in the lowland areas, including the central city. Although this area is ideal for development, the flatter, lowland areas of the city have become more flood-prone as the wider catchments have been developed. This is because the piped system quickly and efficiently transfers stormwater from the impervious upper catchment areas downstream – increasing the likelihood of flooding.

If infiltration is maximised in the upstream and middle areas of catchments, it can help reduce the frequency of local and downstream floods, reduce erosion within remaining streams and improve water quality.

CONTOURS AND CATCHMENT BOUNDARY





Upper

Characteristics

- Typically steep terrain and vegetated
- Low site coverage

Issues

- High water velocities
- Slip hazard

Foothills

Characteristics

- Medium site coverage
- Some areas of fill

Issues

- High water velocities
- Convergence of tributaries – flooding

Lowlands

Characteristics

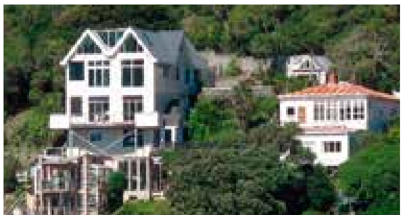
- Typically flat
- Low water velocities
- Extensive areas of fill
- High site coverage

Issues

- Flooding
- Tidal influences
- Limited open space

SLOPE TYPE

Wellington is characterised by steep hills and short flats connecting to a magnificent harbour or the wild coast.

	Characteristics	Issues	
Steep slope	Slope > 10° Typically shallow soil profile High water velocities	High slip risk Potential erosion risk	
Gentle slope	5° > Slope > 10°	Moderate slip risk Some flooding	
Flat	Slope < 5° Low water velocities	Flooding risk	

GEOLOGY, SOIL AND PERMEABILITY

Bedrock geology describes the rock formations that underlie an area. Soil is a mixture of mineral particles, organic matter, water and air. Soils are described in terms of their texture: e.g. sand, silt, clay.

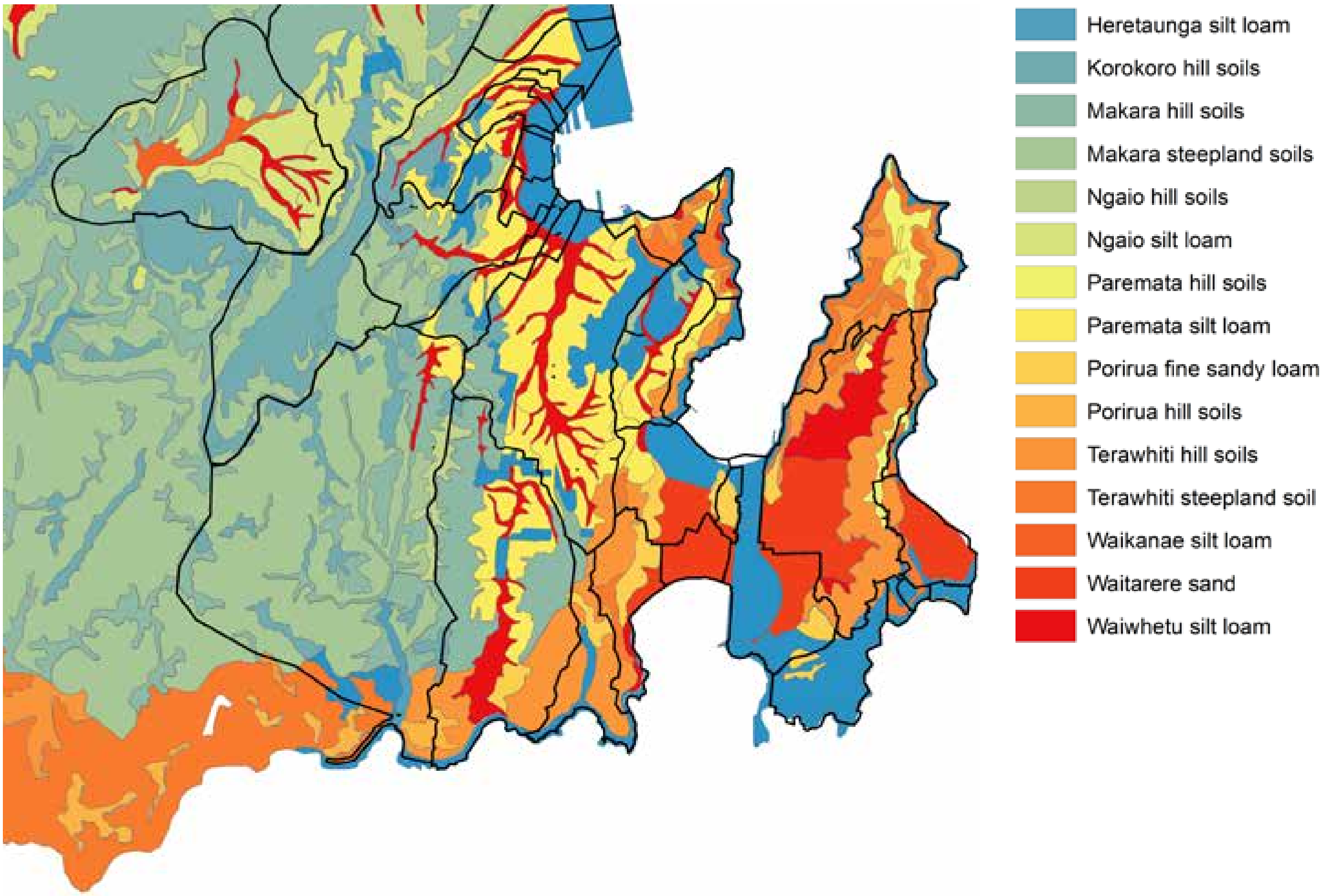
Bedrock and soils affect a variety of human activities; different soils are critical in determining viability of land for development, industry, agriculture and recreation.

Wellington is mostly underlain by greywacke (hardened sandstone and mudstone). Depth to bedrock is variable: sometimes it is more than 50m below the surface or can be exposed along the sides of roads and in stream beds. Shallow depth to bedrock typically impacts on infiltration.

Wellington greywacke produces silty, low-fertility, acidic soils with a high clay content. These clay soils are fine-grained, have low levels of permeability and are quickly saturated.

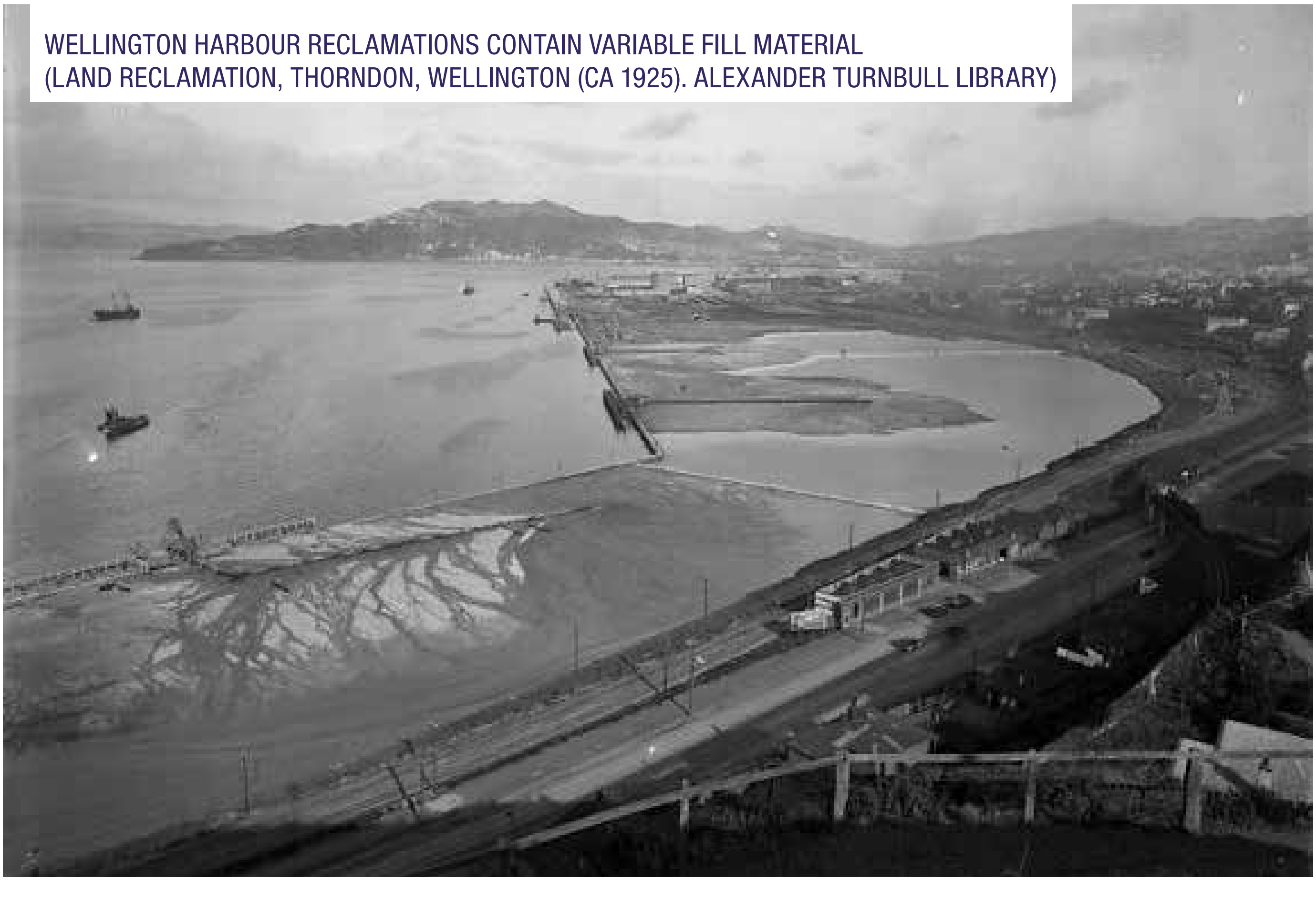
Loose, unconsolidated colluvial soils, ranging from silt to rock fragments, occur in the steeper valleys as a result of long-term land instability. These soils have variable infiltration characteristics but are often prone to instability when saturated. Coarser-grained sands typically underlie the coastal environments of Lyall Bay, Strathmore and Seatoun. These soils have larger spaces between each grain and allow water to infiltrate quickly.

WELLINGTON SOILS



The rate of infiltration is affected by soil characteristics including permeability, storage capacity and structure as well as depth to the water table and bedrock. Vegetation types and cover and rainfall intensity all play a role in controlling the infiltration rate and capacity. High water tables and lack of permeability can affect infiltration rate.

In urban areas, buildings and roads further restrict water infiltration resulting in increased surface runoff. The potentially high level of infiltration on sandy and colluvial soils is adversely affected by the quantity of impermeable surfaces on the flat coastal land.



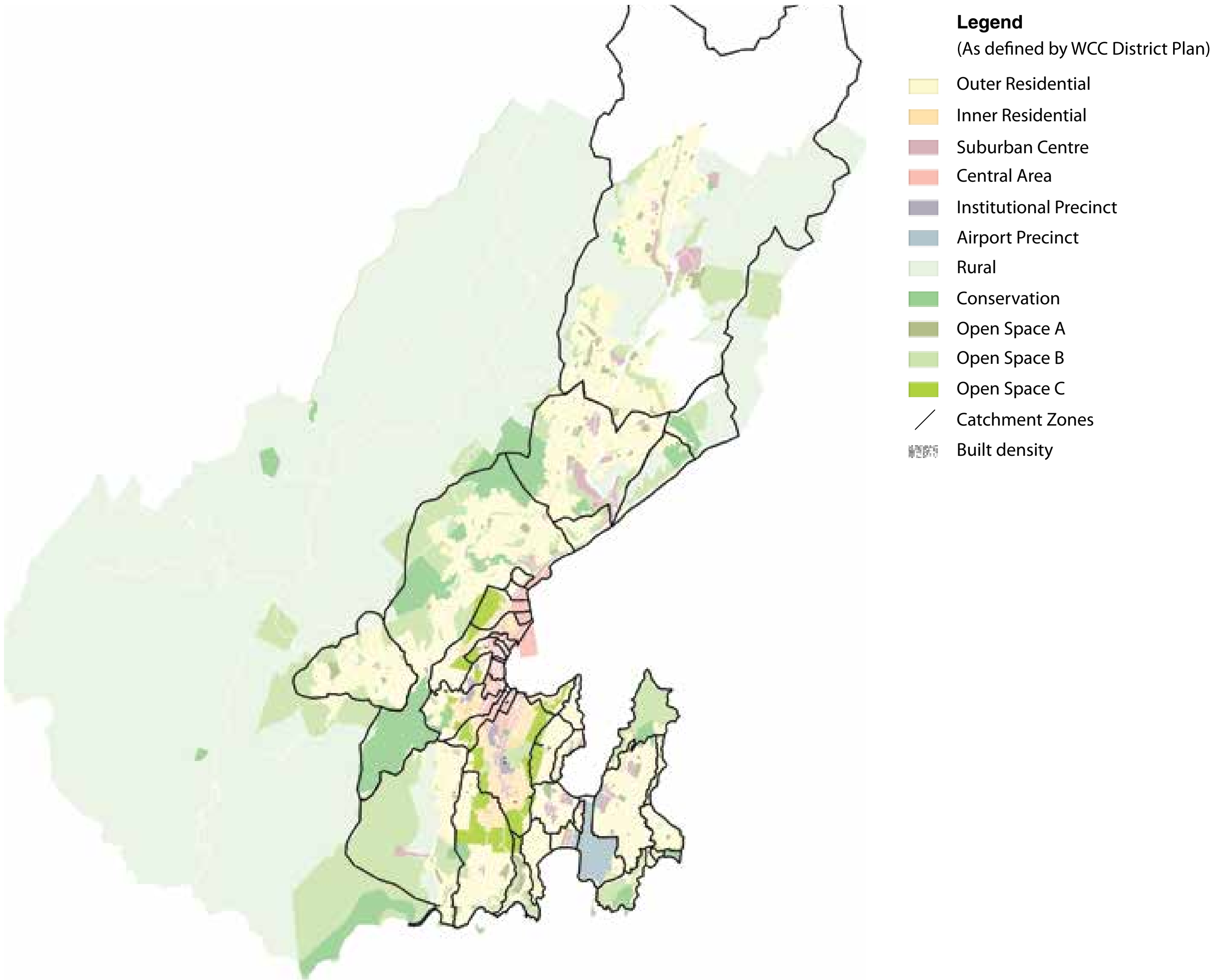
WELLINGTON HARBOUR RECLAMATIONS CONTAIN VARIABLE FILL MATERIAL
(LAND RECLAMATION, THORNDON, WELLINGTON (CA 1925). ALEXANDER TURNBULL LIBRARY)

LAND USE

Wellington City is surrounded by nature, albeit modified. The central city by contrast is characterised by hard surfaces and little vegetation. The growth of the city has resulted in extensive areas of sealed surfaces, including roofs, pavements and roads. Due to the topographical constraints, the early urban design of Wellington restricted large parklands to the surrounding town belt with limited provision of open space within the central city. Historically many stream gullies were backfilled (often as landfills) and now comprise a number of Wellingtons sporting fields.

Stormwater runoff is heavily influenced by surrounding land use and activities. Research[1] shows, fairly conclusively, that the sources of contamination are from buildings (especially unpainted galvanised iron roofs) and neighbouring land uses. Roads are contributors, recipients and conveyors of contaminants from adjacent and often extensive contributing areas.

DISTRICT PLAN ZONINGS



1 http://www.rcaforum.org.nz/stormwater-research

Land use, density and site coverage in Wellington has been influenced heavily by topography. Flat, low-lying areas have Wellington's most dense development and diverse uses including industry, commercial and residential – all served by road networks which infiltration and contribute to contaminant loads. Stand-alone housing, often on higher, steeper slopes, generally has less site coverage and lower levels of contaminant generation. The city has more than 4000 hectares of parks and reserve lands, including the inner and outer Town Belts, predominantly on higher slopes, for recreation, wildlife, and scenery. The extensive tree cover in these reserves also stabilise slopes, reducing erosion, and intercept water and recycle nutrients.

A range of past industries and activities, such as former landfill, gasworks and hazardous substances storage sites, have contaminated areas of land. The use, development (including redevelopment) and subdivision of contaminated land can mobilise contaminants to watercourses or the stormwater network.

Research has found that when impervious surfaces reach 10% of the area of a catchment, a critical threshold is reached in terms of the impacts caused by stormwater[2].

STORMWATER POLLUTANTS

Human and urban activities generate a wide range of contaminants which are often transported in stormwater. Wellington and Porirua harbours, like other coastal environments surrounded by populated areas, receive significant volumes of stormwater with the potential to pollute their ecosystems.

Apart from roadside sumps that collect some sediment and litter, there is typically no treatment of stormwater in a traditional network prior to discharge. These piped stormwater networks therefore move contaminants to the sea quickly and efficiently.

The 2011 Wellington Harbour sub-tidal sediment quality monitoring survey[1] identified marked increases in contaminants around major stormwater outfalls. In places, these contaminants are at concentrations where adverse biological effects are likely to occur and it appears to be influencing the composition of invertebrate communities at some sites.

Sewage overflows to the coast during heavy rain have a relatively short term impact – with swimming not recommended for 48 hours or beaches closed for short durations, however public health is at risk and ability to enjoy the coast is compromised.

Of more significance in the long-term is the impact of silting and sedimentation. Hydrodynamic modelling of Porirua Harbour indicates sedimentation rates average about 6mm per year in the Onepoto Arm and 9mm per year in the Pauatahanui Inlet. Work[2] has shown that the biggest sediment contribution is from bare land under construction (37%), followed by pasture (33%) and with urban runoff contributing the rest (10%). Silt is smothering the seabed, affecting seagrass and shellfish beds, and may be depleting the harbour's ability to attract and sustain fish. Localised reduction in harbour depths is affecting navigability for even small vessels.

These findings reinforce the importance of construction sediment and erosion control and the need to manage sites in accordance with consent conditions. While WSUD infrastructure is designed to capture typical urban sediment loadings it is not generally designed to manage construction activities which require specially-designed sediment basins, flocculation and site-wide management.

1 http://www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/Technical-publications/Wellington-Harbour-Subtidal-Sediment-Quality-Monitoring-Results-from-the-2011-Survey-Report-only.pdf

2 Porirua Harbour Catchment Revised Sediment Load Estimates (11 April 2013) Leigh Stevens and Barry Robertson, Wriggle Coastal Management, for Greater Wellington Regional Council

WASTEWATER NETWORK

Wellington City's stormwater discharges have historically been contaminated with sewage, particularly following heavy rainfall. Inflow and infiltration results in stormwater entering the ageing wastewater system and vice versa, as a result of interconnected sewers and storm drains because of historic design, leaky joints or old cracked pipes which subsequently exceeds capacity and then overflows to the sea. This is worsened by illegal stormwater connections into the wastewater system.

The proportion of inflow and infiltration increases significantly during or immediately after heavy rain and in some sewer catchments the ratio of peak wet-weather flows to average dry-weather flow is as high as 10:1.

While significant investment has been made in sewer management and there has been success in reducing contamination of stormwater, wet-weather pollution remains a challenge.

FLOODING

Large-scale flooding has occurred in the recent past in the Miramar, Island Bay, Newtown, Taranaki Street, Te Aro, Karori and Kaiwharawhara catchments and Tawa due to a combination of factors, including capacity of existing infrastructure, topography and permeability of the land.

Investigations triggered by flooding and flood-hazard modelling have identified many areas where the stormwater network does not have enough capacity to effectively convey water for the intended return interval storm event.

Until the 1980s, the stormwater network was designed to handle a 5-year return period storm, with excess flow being carried along streets and nominated overland flow paths. Today only about 10% of stormwater pipes meet the Council's 50-year return storm capacity standard. The remaining 90% of pipes generally have capacity for 2–5 year return storms and will result in variable magnitudes of surface flooding in events greater than this. In these instances the importance of well-defined and designated overland (secondary) flow paths is critical to reduce the incidence of damage to property and assets.

Extensive areas of impervious surfaces in the city can contribute to the flooding problem, particularly the more frequent events. Urban intensification, increased building footprints, reduced section sizes and increased impervious surfaces contribute to increased runoff from small events which would otherwise be retained within the catchments.

CLIMATE CHANGE

The effects of climate change are increasingly being felt both locally and globally. The Intergovernmental Panel on Climate Change's Fifth Assessment Report (2014) predicts more frequent and heavy rainfall, frequent storms and increasing droughts.

Many activities and assets are, or will become, at risk from the impacts of climate change. It is anticipated that more intense rainfall and storm surges (coupled with rising sea levels) will result in more frequent flooding as existing infrastructure and our conventional systems for managing water resources are overwhelmed.

The solution of replacing existing drainage pipes with even larger ones, in isolation from catchment wide WSUD interventions, is extremely disruptive, prohibitively expensive, and is considered unlikely to provide the optimal sustainable long-term solution.

Future asset design must consider the impact of climate change, particularly increases in rainfall frequency and intensity, and a rising sea level, and ensure that holistic design solutions manage and mitigate these risks.

WSUD can play a fundamental role in the future mitigation of climate change through measures such as keeping water in the landscape (attenuating runoff) and increasing green spaces within urban centres for shade.

PART THREE: LAND ZONING AND WSUD

Studies have identified stormwater contaminant sources and the extent to which they are of concern in Wellington. Land use and catchment characteristics strongly influence the selection of WSUD options, their design and long term operation.

This document gives guidance on a range of land areas including:

- Individual residential household sites
- Multiunit residential developments on individual sites
- Individual commercial or industrial
- Parks or open space
- Retrofitting current developments.

To effectively manage stormwater, site design and source control are required. Source control is the control of pollutants at the place they originate.

This section offers general guidance on potential WSUD devices suitable for different sites and land uses in Wellington to help restore a more natural hydrologic regime and help the piped networks cope during heavy rain as well as improving water quality.

The use of trees and vegetation in the urban environment not only enhances stormwater management but also has other benefits including improved air quality, lower greenhouse gas emissions, shade, aesthetics, habitat for species and noise reduction.

LOW-DENSITY RESIDENTIAL DEVELOPMENT

CHARACTERISTICS

Low-density residential development is characterised by low-rise, single houses on individual lots, typically associated with private open space in the form of rear gardens and/or street setbacks. Land ownership is likely to be under the control of a single owner with site coverage not generally exceeding 35% of the lot area.

ISSUES

- Demand/need for landscape amenity
- Reliance on mains water
- Impervious pavements increase runoff.

OPPORTUNITIES

- Integration of vegetated WSUD measures in the streetscape to provide landscape amenity
- Roof water collection and storage to supplement mains water supply
- Opt for permeable paving to reduce runoff.

AIM

Collect, detain and reuse stormwater on site to reduce discharge into stormwater network.

POTENTIAL WSUD MEASURES:

- Green roofs to reduce runoff volume and provide thermal benefits
- Rainwater tanks to reuse water and smooth peak discharge flow
- Permeable paving to reduce runoff volumes
- Distributed raingardens to improve stormwater quality and smooth peak discharge flow
- Soak pits to charge ground water
- Vegetative cover to reduce runoff volumes
- Centralised raingardens or wetlands integrated into public open space.

LOW DENSITY RESIDENTIAL, CHURTON PARK


RAINWATER TANK


PERMEABLE PAVING


RAIN GARDEN


VEGETATIVE COVER

MEDIUM OR HIGH-DENSITY DEVELOPMENT

(RESIDENTIAL, COMMERCIAL, INSTITUTIONAL)

CHARACTERISTICS

Medium to high-density development typically has a site-coverage of more than 35%. Multiple units, uses and ownership may, but not always, occur on a single parcel of land. Private open space is limited and communal or public open space associated with the development is at a premium.

ISSUES

- High site coverage (imperviousness) increases runoff
- Range of demands and uses of limited open space.

OPPORTUNITIES

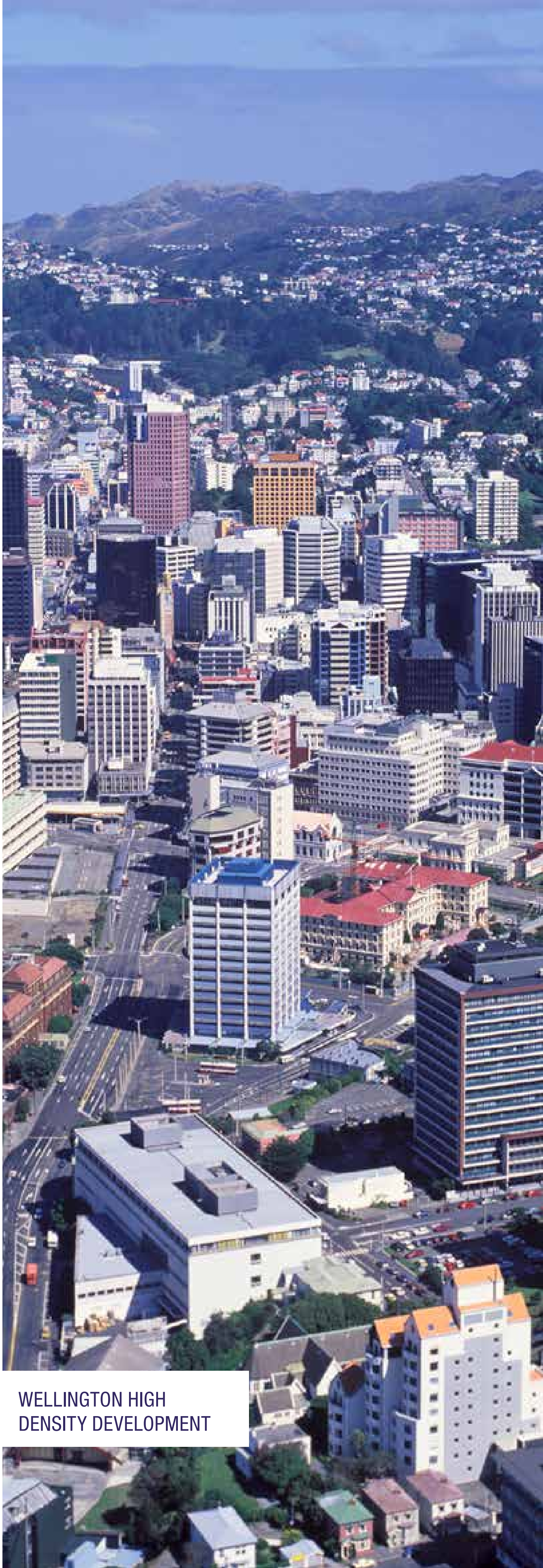
- Integrate WSUD measures into the architecture of structures to reduce runoff volume
- Integrate vegetated WSUD measures to provide landscape amenity in both private and public open space
- WSUD measures can enhance sustainable profiles of buildings and organisations.

AIM

Collect, detain and treat stormwater to improve quality and reduce discharge from site. Integrate WSUD measures to create multifunctional architecture and open space.

POTENTIAL WSUD MEASURES

- Green roofs to reduce runoff volume and provide thermal benefits
- Green walls to slow runoff and smooth peak discharge
  - » Vertical gardens (climbers) to shade north-facing facades
- Rainwater tanks for re-use and/or to smooth peak discharge
- Permeable paving in pedestrian areas to reduce runoff volumes
- Raingardens and wetlands to provide amenity, detention, stormwater treatment and biodiversity.



WELLINGTON HIGH DENSITY DEVELOPMENT


GREEN ROOF


GREEN WALL


RAINWATER TANK


RAINGARDEN

INDUSTRIAL DEVELOPMENT

CHARACTERISTICS

Industrial activities are typically associated with large areas of roof and impervious pavement with heavy traffic movements and vehicle related contaminants. They are often associated with hazardous substances that have to be carefully managed to prevent contact with stormwater runoff. Generally, this type of open space is valued for its function over amenity.

ISSUES

- High site coverage increases runoff
- Often increased contaminant loadings due to nature of vehicle movements
- Inherent risk associated with on-site hazardous substances.

OPPORTUNITIES

- WSUD can be used as tools within hazardous substances risk management strategies
- WSUD can treat runoff from impervious pavements
- WSUD vegetation measures can be used to mitigate site activity impacts on adjacent land uses.
- WSUD can enhance the image of companies/ organisations.

AIM

Collect, detain and treat stormwater to improve quality and reduce discharge from site. Use WSUD measures to mitigate effects that may be associated with commercial and industrial activities.

POTENTIAL WSUD MEASURES

- Rainwater tanks for re-use e.g. irrigation, vehicle washing and to smooth peak discharge flow
- Raingardens, lined when on contaminated sites, to improve stormwater quality
- Carbon and sand filters to treat runoff where space is limited
- Street trees to increase permeability and provide shade, wind shelter, amenity and habitat.

CENTREPORT


BIO-RETENTION SYSTEM


SUBSURFACE RAIN TANK


STREET TREES


FILTER MEDIA

STREETS, PRIVATE WAYS AND CAR PARKS

CHARACTERISTICS

Streets, private ways and car parks are the most accessible forms of open space in urban areas. They facilitate the movement of pedestrians, vehicles and services. Typically associated with impermeable surfacing such as pavements and roads, runoff from streets, private ways and car parks receive and convey contaminants from vehicles, road materials, maintenance operations and spillages.

ISSUES

- Contamination accumulation on surfaces and conveyance by stormwater runoff
- Competing demand for space (at and below grade) for amenity, movement and provision of services
- Management of infiltration to avoid oversaturation of substrates and associated risks.

OPPORTUNITIES

- Streets may be well placed to treat stormwater through properly designed raingardens
- Increased use of street trees to provide canopy and mitigate heat-island impacts
- WSUD measures can enhance environmental quality and enhance amenity in streets, private ways and car parks.

AIM

The integration of collection, detention, treatment and infiltration of stormwater within road reserves, private ways and car parks, prior to discharge into the conventional stormwater network or receiving environment.

POTENTIAL WSUD MEASURES

- Raingardens and bio-retention systems in car parks or along verges to filter, treat and detain stormwater while improving amenity and habitat
- Perforated kerbs to allow runoff to enter detention/treatment measures
- Vegetated swales to intercept and slow runoff

  Street trees to increase permeability, provide shade and shelter, improve amenity and habitat
- Permeable paving in pedestrian areas to reduce runoff volume
- In-ground tanks to store treated stormwater for reuse in irrigation and to smooth peak flows.

JERVOIS QUAY


SWALE


DETENTION POND


RAIN-GARDENS


PERMEABLE PAVING

PARKS AND GARDENS

CHARACTERISTICS

Parks and gardens are areas of City Council-managed open space used for active and passive recreation. These will often be designed and delivered as part of larger scale subdivisions, particularly in the growth areas to the north of Wellington CBD in the Porirua Harbour catchment.

ISSUES

- Recreational needs of the community may restrict where and to what extent WSUD measures occur. New parks should be planned to accommodate multiple uses.

OPPORTUNITIES

- Integrate WSUD measures to support Council Public Space Design Policy Objective 6: sustainability
- Look for strategic opportunities to design regional raingardens and wetlands to efficiently treat stormwater from a large urban catchment
- Plan and manage parks and gardens to allow for WSUD measures while balancing the recreational requirements of the community
- Provide riparian buffers
- To work with care groups to contribute to overall catchment goals.

AIM

Design parks and gardens to provide detention and retention to mitigate adverse effects of stormwater runoff on the downstream system, while balancing the recreational needs of the community.

POTENTIAL WSUD MEASURES

- Raingardens to treat stormwater from larger contributing catchments
- Wetlands to slow and treat stormwater and provide amenity, biodiversity and habitat.
- Vegetation cover to reduce runoff and enhance infiltration
- Attenuate flows from infrequent large rainfall events within parks (can be integrated with raingardens and/or wetlands) to smooth peak flows
- Vegetated swales to slow runoff and allow infiltration.

NATIVE FLORA AND FAUNA IN CLOSE PROXIMITY TO URBAN LIFE

CONSTRUCTED WETLAND

VEGETATED SWALE

BIO-RETENTION TREEPIT

RAINGARDEN

BUSH AND RESERVES

CHARACTERISTICS

Bush and reserves are areas of established or regenerating vegetation (native, exotic and mixed). Values include ecological processes, passive recreation, scenic amenity and natural heritage. Bush and reserves may be managed by the City Council, the Department of Conservation or private landowners. Areas of bush and reserve often have a natural water cycle – for example, a stream – formed by topography, soils and vegetation cover. However bush and reserves often receive urban stormwater runoff.

Riparian or stream margin management is an important part of stream and catchment biodiversity. This improves water quality and habitat by giving shelter for fish, filtering out some pollutants, preventing damage to stream banks and increasing bird and insect life.

ISSUES

- Degradation of bush areas and reserves due to the discharge of contaminated urban stormwater
- Erosion and scouring of areas of bush and reserve due to changes in the natural hydrological regime resulting in increased frequency, duration and magnitude of runoff events.

OPPORTUNITIES

- Establish or enhance riparian planting to increase the ability to remove contaminants and manage water temperature and flow
- Protect and enhance vegetation cover
- Implement WSUD measures to manage the quality and quantity of urban stormwater prior to discharge into areas of bush or reserve
- Provide 5m-minimum riparian buffers
- Work with care groups to contribute to overall catchment goals.

AIM

Protect open space and reserves from the quality and quantity impacts of stormwater discharges, through providing upstream attenuation to mitigate adverse effects of stormwater runoff on the downstream system and WSUD measures to treat water quality. Protect, retain and enhance streams in their natural state.

POTENTIAL WSUD MEASURES

- Catchment WSUD measures to treat stormwater prior to discharge into natural streams
- Plant or enhance vegetation to mitigate quality and quantity effects of urban stormwater entering areas of bush or reserve
- Dissipation measures to mitigate erosion caused by point discharges
- Retention and detention ponds to attenuate, store runoff, smooth peak flows, provide habitat and fire-fighting supply.


BUFFER PLANTING


RIPARIAN PLANTING


DETENTION POND


DISSIPATION MEASURE


OTARI-WILTON'S BUSH

PART FOUR: WSUD MEASURES

This section introduces WSUD measures and device selection procedures that can be applied on large and small-scale developments on typical Wellington soils and slopes.

Many factors influence the design, implementation, maintenance and cost of individual WSUD measures. The Council will consider certain devices on a case-by-case basis against performance criteria which include catchment conditions, topography, soakage, and total site area. A combination of devices – a treatment train – will be favoured to meet the two primary functions – attenuation or treatment.

These performance criteria and guidance material are introduced briefly below. Acceptable approaches, technical considerations and how these will be assessed are outlined in the WSUD chapter of Wellington City's Code of Practice for Land Development (COPLD).

This guide does not cover structural, proprietary devices. Neither does it give detailed assessment and engineering design of WSUD devices.

The Council is endorsing the New Zealand Water and Environmental Research Foundation's (NZWERF) On-Site Stormwater Management Guidelines (2004) as a guide for the step-by-step device-specific guidance for sizing and design procedures.

KEY SITE PARAMETERS

The main considerations that determine the stormwater characteristics and selection of WSUD measures are topography, slope, neighbouring properties, infiltration capacity and catchment imperviousness.

Aside from the many benefits, there are risks in applying WSUD principles to Wellington topography and soil conditions. To mitigate the risks, criteria have been drafted to inform the application of WSUD solutions and devices.

SLOPE

The slope of land at the likely device location may affect the types of devices that can be used or contribute to slope stability issues that might affect the disposal method. The slope of the catchment areas that contribute to proposed devices is used to calculate the time of concentration and runoff flow rates.

SOAKAGE

In Wellington, ground infiltration will only be considered when there is sufficient proven soakage capability available in the nominated area and will be subject to a satisfactory test by an engineer. Available soakage can be established from the Department of Building and Housing's Verification Method E1/VM1 (December 2000). Provision for drainage connections to the stormwater network must always be included in addition to any designed infiltration.

Where soakage to ground is not available, a piped collection system at the base of bioretention features is acceptable. Moderate lengths of oversized pipes may also be used for detention purposes with provision for overflow to the downstream pipeline. The use of lined bioretention systems with permanently saturated anoxic zones beneath the filter media are encouraged to improve the treatment performance (de-nitrification) and support plants during prolonged dry periods.

IMPERVIOUSNESS

Stormwater impacts increase dramatically when more than 10% of the land area in a given catchment is considered impervious. The impacts of impervious area are cumulative – an existing development that is not creating a problem may contribute to a future problem as adjacent land is infilled. Measures to reduce imperviousness in new and existing urban areas should be adopted.

DETENTION AND RETENTION

The restoration of more natural hydrologic regime is central to WSUD concepts. Hydrologic restoration involves both detention (peak flow attenuation) and retention (reduced volume).

The developer must provide plans and supporting information sufficient to show that the runoff flows will be less than or equal to the run off flows prior to development. This may be achieved through detention or retention. The runoff coefficient for a site can be calculated from information in the Code of Practice for Land Development section D8.4.

Detention and retention, using WSUD devices, can be used to limit the discharge from the property to mitigate adverse effects on the downstream system. This may be a requirement of the Council depending on the condition of the downstream stormwater system.

These can take the form of an above-ground i.e. rainwater tank or pond or buried tank, and may be combined with soakage.

MEASURES

During site design and planning for any development or redevelopment of property it is possible to define where stormwater is coming from, how much stormwater is expected and how to manage that stormwater.

An extensive range of resources is available to practitioners to select and design WSUD stormwater devices. The design of such devices is critical to their long-term performance with significant implications for maintenance, life cycle and sustained functionality. The design of WSUD stormwater devices must always be undertaken by an engineer with demonstrated experience with such devices.

The Council endorses the New Zealand Water and Environmental Research Foundation's (NZWERF) On-Site Stormwater Management Guidelines (2004) for sizing and design procedures.

The NZWERF Guidelines shall be used in conjunction with the technical guide contained as the WSUD chapter of Wellington City's Code of Practice for Land Development (COPLD) to undertake the detailed design.

Detailed design should also note the particular considerations applying WSUD principles to Wellington topography and soil conditions and make the correct response for Wellington.

The On-site Stormwater Management Guideline was published in 2004 by the New Zealand Water Environment Research Foundation with the financial support of the Minister for the Environment's Sustainable Management Fund. The guide provides developers, designers, planners, asset managers and stormwater design professionals with information to select and design appropriate on-site stormwater management devices for the majority of applications in New Zealand.

The NZWERF Guidelines provide the information needed to select and design suitable on-site stormwater management devices so only general outline comment is given here. The potential WSUD measures listed in the Land Use section of this guide are briefly overviewed below all of which can be used to intercept, retain and infiltrate runoff;

- Rain tank
- Raingarden
- Street trees
- Roof garden/living roof
- Green walls
- Swale
- Permeable pavement
- Detention tank/pipes
- Pond
- Depression storage
- Wetland.

Measures included in this guide are not exhaustive.

Probably the best known examples of WSUD devices are rain tanks, raingardens, wetlands and swales.

In Wellington a number of WSUD solutions have been implemented. The 80 raingardens along the quays, tree pits in lower Cuba Street, the wetlands at Waitangi Park – all provide stormwater treatment and storage for runoff from roads and other hard surfaces. Similarly the stormwater from the Westchester Drive extension in Churton Park flows into swales – shallow, sloping hollows designed to slow the flow of water, trap pollutants and replicate nature. The National War Memorial Park in Buckle Street will be the latest example. The park will incorporate rain gardens to detain stormwater to irrigate the terraced park.

The following sheets state the primary function (attenuation or treatment), a brief description, the benefits and considerations of WSUD devices.

RAINWATER STORAGE TANK

PRIMARY FUNCTION

Attenuation, little treatment potential.

A sealed tank, serving an individual property, designed to collect rainwater from roof collection through a downpipe, or from car parking or other areas, directly into above ground or underground storage tanks.

Storage tanks allow the reuse of collected rainwater as a substitute for non-potable mains water supply, either inside or outside the building (including toilet flushing, laundry use or garden watering, car washing and all other external outdoor uses).

BENEFITS

- Rainwater harvesting encourages the reuse of rainwater for everyday and emergency use
- Rainwater can be safely used, without significant treatment, for a number of end uses in both residential and commercial settings
- Reuse creates a significant offset in potable water use
- Stored rainwater has the added advantage of improving community resilience during and after disasters.

WHEN IS THIS SUITABLE?

There are many styles of rainwater tank available – ones for under the house, between the house and garage, or bladders that squeeze beneath your deck.

Rainwater that may be used inside the home should only be collected from roofs covered in painted galvanised iron, Colorbond, Zincalume and concrete, slate or ceramic tiles. Unpainted galvanised roofs, or those coated with lead – or bitumen-based paints or asbestos cement roofs must not be used.

DESIGN AND INSTALLATION CONSIDERATIONS

- Specific design standards in terms of materials, size, holding capacity and discharge from the storage tank shall be provided by manufacturer
- Storage tank size shall be calculated based upon the size of the impervious surface area from which water is collected
- Calculate extent of design storm rainfall to be stored in the tank and provide overflow capability for storm events
- Site the storage tanks near buildings when possible but not within 0.5m of a boundary due to the risk to neighbouring property and/or stability
- Site storage tank in open spaces to facilitate cleaning and maintenance
- Storage tanks can be used in conjunction with a site sprinkler system to irrigate lawns and garden beds
- Seal the storage tank at the inlet to avoid insect ingress and mosquito breeding
- Must be fitted with a ‘first flush’ device to ensure pollutants and sediments are diverted to the stormwater network, as appropriate, before reaching the tank, where usage other than outside the house is intended.

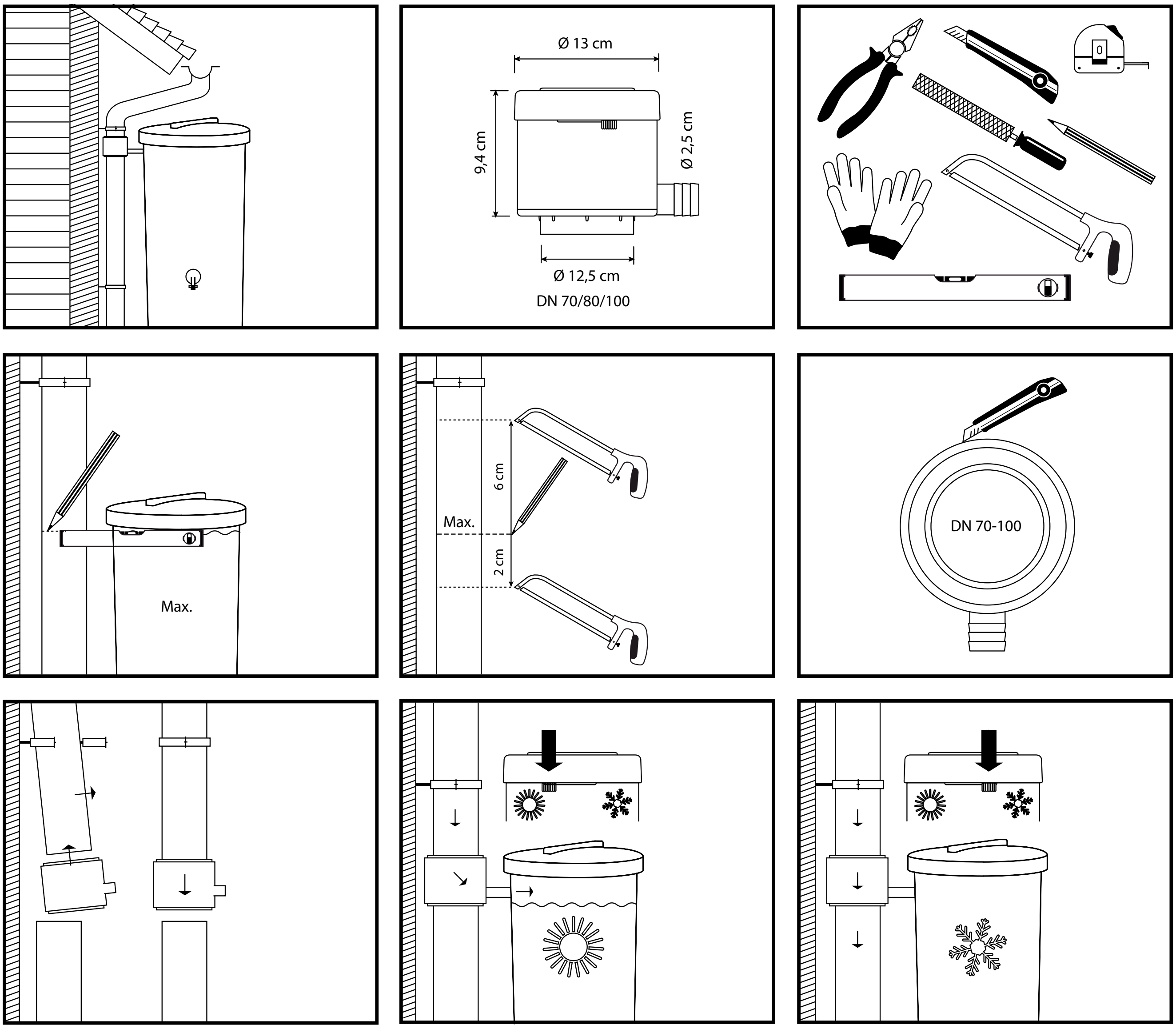
MAINTENANCE

- It is the responsibility of the property owner to regularly inspect and maintain their storage tank
- Annual flushing out of tank to remove particulate matter, salts and other debris that may collect
- Regular inspection to ensure structural integrity
- Regular maintenance of first-flush device
- Replace filters and pumps as per manufacturer’s requirements.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource and building consent requirements for individual sites, as certain areas and different sizes of tanks may require different approaches.

RAINWATER TANK



RAINGARDEN

PRIMARY FUNCTION

Significant attenuation and treatment benefits.

A raingarden is the term commonly used to describe a vegetated area which together acts to attain and filter small amounts of stormwater. The selection of plants is critical to performance to ensure that they are resilient to the prolonged dry spells with episodic inundation. Raingardens comprise a number of elements including inlets, selected vegetation, overflow pit, free draining filter media (sandy loam), drainage layer, perforated underdrains (with inspection risers) and an outlet connection to the stormwater network. Depending on site considerations and objectives the base and sides can be either lined or unlined.

Surface runoff flows into a raingarden and is first filtered through the surface vegetation removing litter, leaves and sediment. It then filters through the filter medium where fine particles are removed and soluble nutrients are taken up by roots of the plants and soil microbes. The provision of a freeboard (extended detention) allows temporary ponding at the surface.

At the base, water can either be collected by slotted pipes and directed into a drainage system or allowed to infiltrate to ground at the base of the raingarden.

BENEFITS

- Raingardens and other planted areas not only provide amenity but also enhance urban biodiversity, and can help manage stormwater in terms of water quality and quantity
- Adopting stormwater-capturing garden designs on a widescale basis can help reduce stormwater volumes entering the sewer system during storms
- Well-designed raingardens will not require any irrigation (following establishment) and can support a wide range of drought-tolerant species
- Vegetation can provide valuable urban habitat for insects and birds and help to mitigate air pollution and capture carbon dioxide from the air, improving environmental and public health
- Can incorporate community facilities such as seating or other furnishings to encourage social and recreational activities, depending on its size and asset owner.

WHEN IS THIS SUITABLE?

Raingardens are able to tolerate low levels of pollutants from vehicles and urban land uses, so are viable adjacent to roads and car parks, where slope is suitable.

Raingardens can range in size and shape from small thin gardens in road medians or along footpaths to planted kerb extensions to large-scale stormwater management systems. Typically they should be limited to around 500m^2 in filter surface area.

DESIGN AND INSTALLATION CONSIDERATIONS

- Design details should be determined on a site-specific basis in consultation with the relevant agencies
- Careful consideration must be given to overflow control, plant species, subsurface conditions infiltration rates and maintenance requirements
- Raingarden size shall be calculated based upon the size of the area from which water is collected. The size of the rain garden should generally vary between two percent of its drainage area
- Make the rain garden large enough to pond runoff from the first 25mm of rainfall in the rain garden
- Filter media should have suitable hydraulic conductivity in the range of 100 to 200mm/hr
- Infiltration to ground can occur where proven soakage capability is available. Liner and subsoil drainage to be provided if this is not possible

- Design the rain garden with adequate fall between inlet (particularly with piped inflows) and stormwater drain for outlet connection. Insufficient depth can result in reduced extended detention or shallower filter media
- Design footpaths and surrounding area to direct stormwater into raingardens wherever suitable and practicable
- Design the entry edge to protect against erosion and scour from inflow
- Where raingardens border footpaths the design shall cater for pedestrian safety
- Where vehicles can legally park beside a raingarden, provision shall be made for passengers to alight from the vehicle onto a stable surface
- Need to consider underground utilities, including the relocation of street drainage or require sump relocation.
- Plant the raingarden with a combination of native plants of various types including grasses, sedges, rushes and woody shrubs.

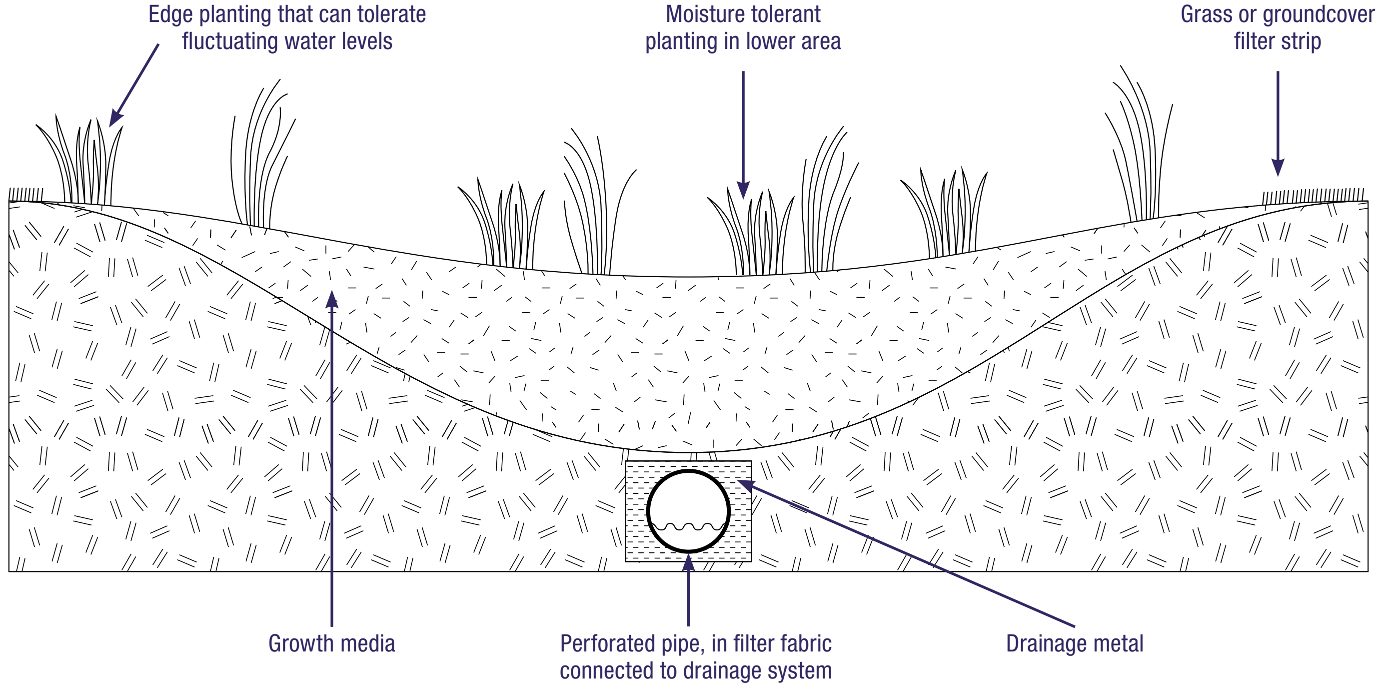
MAINTENANCE

- Monthly removal of litter and debris
- Plant maintenance, such as manual irrigation during drought, weeding, pruning and pest control
- Annual inspection and repair of raingarden profile to ensure flow conveyance
- Routinely inspect and repair inlets and overflow to clear any blockage
- Replace all filter medium and planting as required by design
- Respond to unusual events – for example remove filter medium if there is a large oil spillage or evidence of clogging.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource consent requirements for individual sites.

RAIN GARDEN/STORMWATER PLANTER



STREET TREES/TREE PITS

PRIMARY FUNCTION

Used to provide some treatment and detention capacity.

Street trees are used at regular intervals to soften the streetscape. They capture stormwater, improve air quality, quality of life and soften the built environment. They change with the seasons and provide a sense of scale within the built urban environment.

The Council currently has two types of tree pit – individual street tree pits are the only required design, and tree pits that capture stormwater from the adjacent road.

BENEFITS

- If designed well, stormwater tree pits could benefit tree health by increasing the amount of water the tree receives and reducing the need for manual watering
- Improved aesthetics
- Trees provide habitat for birds and other urban creatures.

WHEN IS THIS SUITABLE?

Street trees are used all over the city and should be used wherever pavement exists if subsurface conditions and services and utilities allow.

DESIGN AND INSTALLATION CONSIDERATIONS

- Meet minimum size and design requirements of the Code of Practice for Land Development (Section C.4)
- If work includes tree planting, consider the location of utility infrastructure, including sewers and water mains
- Maximise exposed soil to allow more water and air to get to the roots of the tree. Use Rock Pave™ or other permeable paving surface treatments over the tree pit in high pedestrian traffic areas
- Design footpaths and surrounding area to direct stormwater into tree pits wherever advisable
- Maximise size of tree pit while adequately accommodating pedestrian movement and property access needs
- Use connected tree pits instead of individual tree pits to increase root space, tree health and stormwater intake
- Paving patterns are to be modified to incorporate trees within the footpath as indicated on the standard tree detail
- The design of the pit is crucial to tree health. Stormwater should be filtered through a suitable soil mixture.

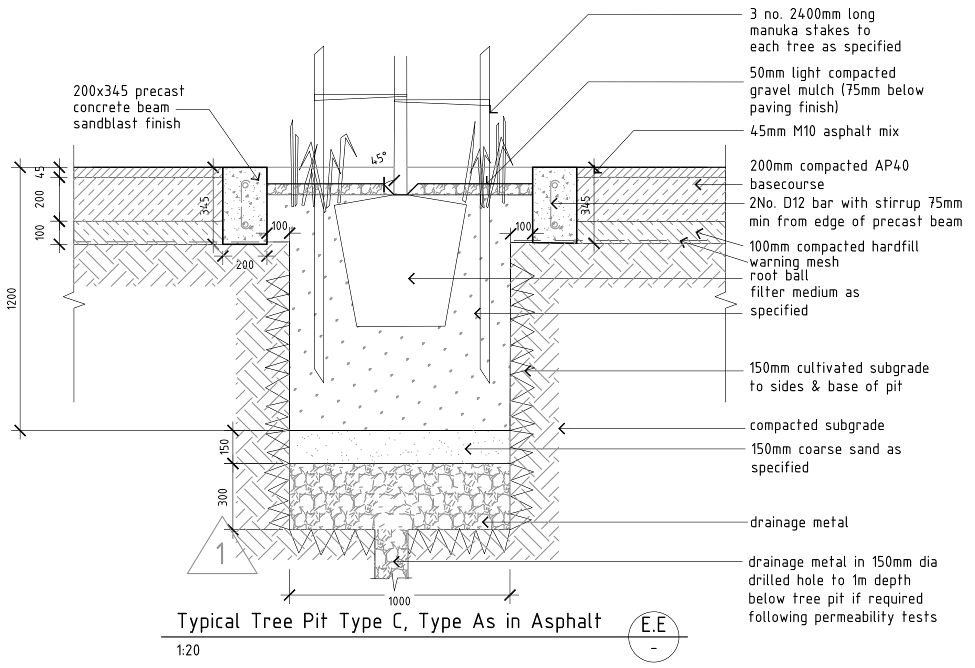
MAINTENANCE

- Annual mulching
- Check and replace stakes as required
- Weeding if necessary
- If tree fails or dies, record death, replace tree.

COUNCIL INSPECTIONS AND APPROVALS

Refer to Code of Practice for Land Development C.4.2.5.

STREET TREES



LIVING/GREEN ROOFS

PRIMARY FUNCTION

Used to provide treatment and some attenuation capacity.

The term green roof means a vegetation covered roof. Also known as eco-roof or living roof, a green roof typically consists of multiple layers, each of which plays an important role in the overall system function. Typically (from bottom to top), layers include an insulation layer (optional, depends on roof type), a waterproof membrane, root barrier, drainage layer, filter fabric, engineered growing medium or substrate and plant material. This green space could be below, at or above grade, but in all cases the plants are not planted in the 'ground'.

Flow attenuation is achieved by water stored in the substrate and then taken up by the plants from where it is returned to the atmosphere through evapotranspiration. Contaminants are removed by filtration through the soil and microbial activity.

BENEFITS

Green roofs, although a higher-cost strategy, can provide a wide range of public and private benefits:

- Reduced stormwater runoff and also delay the time at which runoff occurs, resulting in decreased stress on drainage systems at peak flow periods
- Increased green urban space amenity including urban agriculture
- Waste diversion – prolonging the life of waterproofing membranes, reducing associated waste
- Improved air quality and energy efficiency
- Noise reduction
- Increased biodiversity and act as a stepping stone habitat for migrating species
- Positive impacts on community health and psychological well-being
- Educational opportunities.

WHEN ARE THEY SUITABLE?

New developments and existing buildings with flat roofs following an engineer's confirmation that the loading and system proposed is viable.

DESIGN AND INSTALLATION CONSIDERATIONS

- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area in consultation with the relevant agencies
- A green roof professional should be involved in any green roof design team
- Careful structural loading and waterproofing detailing is needed to avoid leakage into building
- Plant selection to withstand a range of climatic conditions is vital
- Considerations shall be given to growing medium (substrate), general irrigation and plants
- Access is required for maintenance
- Active drainage is required for the water not used by the system
- The growing medium is usually a lightweight, custom mixture, composed mostly of expanded stone, volcanic rock, perlite, with only a 10% to 20% organic content.

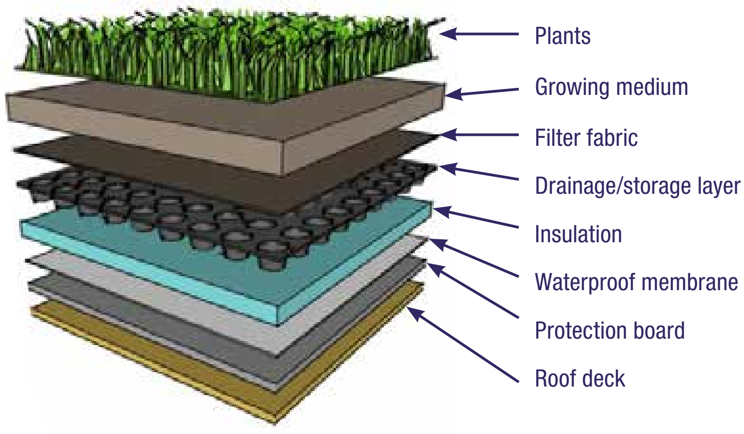
MAINTENANCE

- Green roofs requires regular maintenance; including manual irrigation during dry periods, weeding, mowing and pest control
- Annually/routinely inspect and ensure no blockage to drainage.

COUNCIL INSPECTIONS AND APPROVALS

Green roofs generally need building consent and in some situations resource consent.

LIVING ROOF LAYERS



GREEN WALLS

PRIMARY FUNCTION

Used to provide some treatment and detention capacity.

A green wall can be simply described as a vegetated vertical surface. However the term encompasses two very distinct concepts. Green facades are created by vines and climbing plants rooted in soil or containers, growing upwards or cascading down, and require a structure to maintain their position, develop growth, and survive through seasonal exposures. The term 'living wall' refers to a newly developed technology that relies on a prefabricated modular or monolithic vertical soil or hydroponic system to root plants on a vertical plane.

BENEFITS OF GREEN WALLS

- Enhance a building's appearance, disguise a car park, refresh a tired façade or add colour and texture to a complete wall or section
- Prevents graffiti
- Water-recycling – help collect and filter stormwater and/or grey water for household use or irrigation purposes
- Integration with ground-level raingardens as growing medium with vertical vegetation
- Potential for urban agriculture
- Improved air quality and energy efficiency
- Noise reduction
- Increased biodiversity and number of habitats and act as a stepping stone habitat for migrating species
- Positive impacts on community health and psychological wellbeing
- Educational opportunities.

GREEN WALL VICTORIA UNIVERSITY WELLINGTON

WHEN ARE THEY SUITABLE?

Green walls may be used for a wide variety of projects – both new-build and refurbishment for a variety of building types, from small garden projects to large industrial and commercial developments.

DESIGN AND INSTALLATION CONSIDERATIONS

- Building code and structural engineering requirements need thorough consideration
- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area in consultation with the relevant agencies
- Careful structural loading and waterproofing is needed to avoid leakage into building
- Wind exposure, sun orientation, water availability and microclimates to determine suitable plant selection.

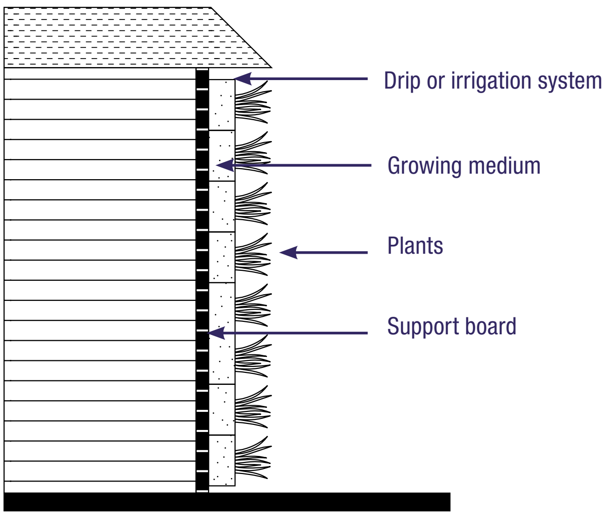
MAINTENANCE

- Ensure the irrigation system works properly – so it does not under-water or over-water the plants
- Plants must be occasionally pruned, fertilised, and weeded if necessary and sometimes will have to be replaced.

COUNCIL INSPECTIONS AND APPROVALS

Green walls may need building consent and, in some situations, resource consent.

PROFILE VIEW



SWALES

PRIMARY FUNCTION

Moderate treatment and attenuation benefits.

A vegetated channel that helps filter stormwater and enables it to infiltrate into the soil or disposal into the stormwater system. Swales generally work best on flat land or on gentle slopes that allow the plants to have more time to influence the water. Swales can either be simple vegetated systems or constructed with a specified filter media, underdrains and selected plants (bio-swale).

BENEFITS

- Add visual interest to a site or to screen unsightly views
- Help manage and improve water quality on-site
- A low cost strategy (capital cost only) relative to traditional management practices
- Habitat creation.

WHEN ARE THEY SUITABLE?

Swales are able to tolerate low levels of pollutants from vehicles and urban land uses, so are viable beside footpaths, roadways, within car parks, open spaces or sportsfields and can be adapted for most residential, commercial and industrial land uses. They should not be used on steep slopes (greater than 5%) and may be difficult to place in very urban settings due to space requirements and constraints from multiple vehicle crossings.

DESIGN AND INSTALLATION CONSIDERATIONS

- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area in consultation with relevant agencies
- Careful consideration must be given to overflow control, plant species, subsurface conditions and infiltration rates
- Fortify the entry edge to protect against erosion from inflow
- Should be at least 3m from building foundations
- Where swales border footpaths the design shall cater for pedestrian safety
- Consider the location of underground utility infrastructure including sewers and water mains
- Swales must have dense grass or vegetation coverage to reduce erosion potential and aid infiltration
- Infiltration to ground can occur where proven soakage capability is available. Liner and subsoil drainage to be provided if this is not possible.

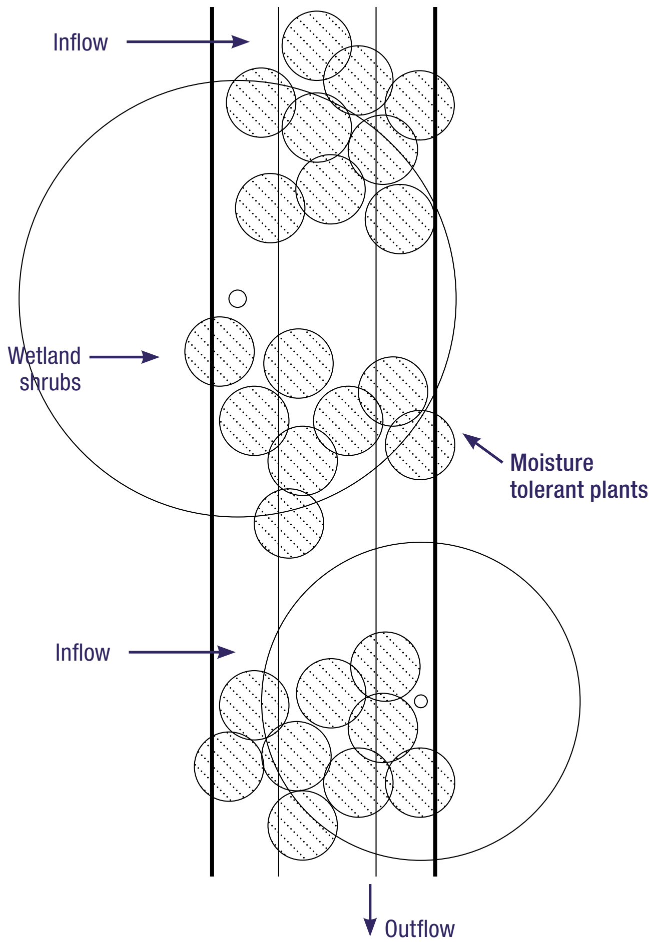
MAINTENANCE

- Periodic inspection for erosion and formation of gullies and removal of sediment build-up and debris from the bottom of channel
- Grass-lined swales should be mowed regularly
- Swales need periodical thinning out of vegetation
- Inspections after storm events to verify that they are working as intended.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource requirements for individual sites.

SWALE PLAN VIEW



PERMEABLE/POROUS PAVING

PRIMARY FUNCTION

Provides treatment.

Porous paving is designed to facilitate infiltration of surface runoff water into the underlying subsoil. This helps reduce stormwater runoff from a site and minimise the export of sediments and pollutants from the site.

Different types are available such as:

- Porous concrete
- Porous asphalt
- Plastic modular systems
- Interlocking concrete paving blocks (including modular and lattice blocks).

BENEFITS

- Reduces the amount of land needed for other integrated stormwater management measures
- Increases groundwater recharge and reduces pollutants in stormwater runoff.

WHEN ARE THEY SUITABLE?

Best used in residential situations, primarily parking areas, or low-volume roadways or driveways where vehicle use is low and there are low sediment loads that could reduce the porosity over time.

DESIGN AND INSTALLATION CONSIDERATIONS

- Should be avoided in areas subject to heavy traffic movement and turning circles (i.e. for waste collection trucks)
- Particular care is needed in the design of the pavement foundations with respect to traffic loads, the nature of the subgrade and pavement durability
- Careful consideration must be given to subsurface conditions and infiltration rates
- There are potentially significant issues with respect to blinding of the surfaces of permeable pavements with fine material. This can, in some situations, be prevented or minimised by ongoing maintenance, for example using suction devices.

MAINTENANCE

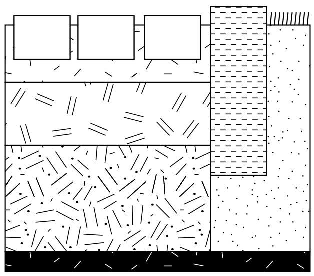
Annually inspect and repair paving as required.

COUNCIL INSPECTIONS AND APPROVALS

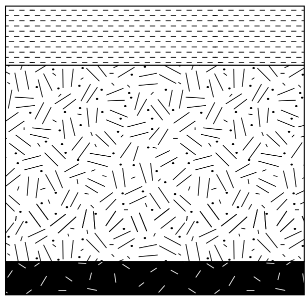
Ascertain resource consent requirements and design parameters for relevant agencies.

JOHNSONVILLE

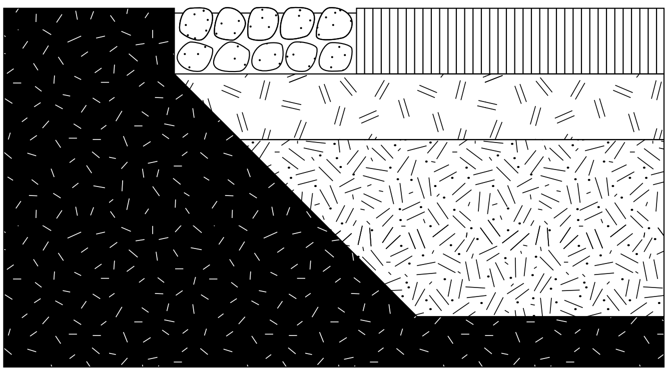
CONCRETE PAVERS



POROUS CONCRETE



POROUS ASPHALT



DETENTION TANKS/PIPES

PRIMARY FUNCTION

Attenuation.

Detention tanks, or oversized pipes, within a public or private stormwater network temporarily store rain water from any impervious surfaces. They slowly release the water through a smaller pipe into the stormwater system. This storage and slow release of the rainwater reduces peak stormwater flows and the impacts on downstream pipe networks and/or on streams.

BENEFITS

- They can be used for managing peak flows from both roof areas and paved areas
- Collected water can be filtered and stored to be used for landscape irrigation.

WHEN ARE THEY SUITABLE?

Detention tanks or pipes are useful where there is a lack of capacity in the downstream stormwater system, where flooding may be a problem, and/or to protect against stream erosion. They help manage runoff where surface space is constrained and reduce the need for ponding within vegetated WSUD elements.

DESIGN AND INSTALLATION CONSIDERATIONS

- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area in consultation with the relevant agencies. Consideration must be given to overflow control
- A 1 in 10 year rain event with a time for concentration (Tc) of 20 minutes shall be used to determine runoff and detention volumes
- The tank size will depend on the area that requires mitigation and the proportion of the impervious area to be drained. About $3m^3$ of storage for every $100m^2$ of catchment area is recommended
- The design event duration for a proposed detention structure should be based on the time for concentration of the public stormwater above the point of connection with the proposed detention structure
- A dead storage volume is required at bottom of the tank for sediment build up – the outlet is to be located at least 100mm above the base of the tank and must be located so that it can easily be accessed for inspection and maintenance. The outlet must be able to gravity drain into the intended stormwater network
- Access must be provided for maintenance
- Inlets from paved areas require standard baffled sumps to trap sediment
- Tanks must be located so as not to adversely affect building foundations.

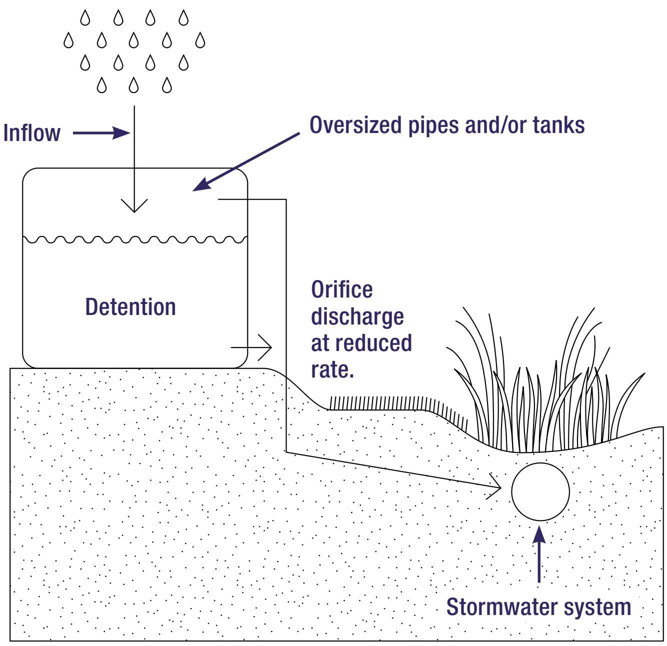
MAINTENANCE

- Inspect and clean sumps and tank for sludge/sediment build up
- Inspect tank structural integrity and pipework by qualified professionals.

COUNCIL INSPECTIONS AND APPROVALS

These assets are constructed to the Council's design compliance standards.

RAIN WATER COLLECTED FROM ROOF OR PAVED AREAS



PONDS

PRIMARY FUNCTION

Limited treatment with significant attenuation benefits.

A stormwater pond is an artificial pond designed to collect and retain stormwater. The function of the pond is to contain flood flows and release water slowly. This slow release mitigates the size and intensity of flooding on downstream receiving waters. The removal of contaminants occurs through a settling process.

BENEFITS

- Help manage stormwater volumes and improve water quality
- Provide habitat for a very diverse wildlife population and plant community
- Attractive landscaping feature
- Benches, tracks and bird blinds enhance amenities for a variety for users.

WHEN ARE THEY SUITABLE?

Usually appropriate for very large sites or multi lot developments.

DESIGN AND INSTALLATION

- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area, taking into account the characteristics of the catchment, in consultation with the relevant agencies
- Careful consideration must be given to overflow control, plant species, subsurface conditions and infiltration rates
- Calculate extent of design storm rainfall to be stored in the pond and provide overflow capability for exceptional rain events
- All ponds require a sediment forebay for maintenance access
- Design the contours of a pond to eliminate drop offs and other safety hazards
- Pond linings shall be determined based on geotechnical investigations
- Fortify the entry edge to protect against erosion from inflow
- Outlet designed to minimise downstream scour and bank erosion
- Access for maintenance and cleaning
- Provide for fish passage where necessary.

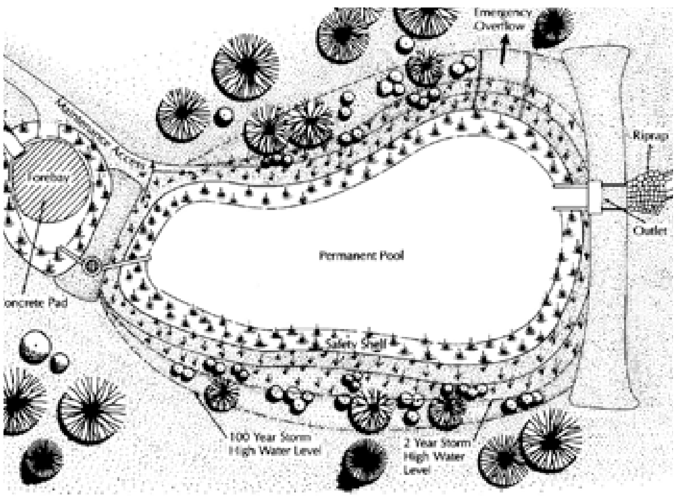
MAINTENANCE

- Sediment forebay, pond and pond outflow structures must be kept accessible for operation and maintenance purposes
- Monitor sediment accumulations and remove sediment when the pond volume has reduced significantly or the pond becomes eutrophic
- Plants must be occasionally pruned, weeded and sometimes need to be replaced
- Inspect for structural damage-repair undercut or eroded areas
- Inspect after heavy rainfall to verify that they are working as intended.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource and building consent requirements for individual sites, as certain areas and different sizes of ponds may require approaches.

PLAN VIEW



WETLANDS

PRIMARY FUNCTION

Water treatment and attenuation.

Constructed wetlands are designed to perform within a highly modified hydrologic regime and provide water treatment through a complex mix of physical, chemical and biogeochemical processes. As runoff flows through the wetland, stormwater pollutants are removed through settling, filtering, and uptake by vegetation. Biofilms which establish on the stems and roots of specific vegetation trap fine colloidal particles and 'flock' these to the wetland substrate soils. Wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. They also provide food or shelter for wildlife.

Constructed wetlands are commonly used for large development projects such as greenfield developments, golf courses, business parks and industrial sites. These wetlands may be designed as part of an integrated drainage system which may include site-wide distributed treatment, storage for re-use and integrated landscape design.

BENEFITS

- Help moderate stormwater volumes and improve water quality
- Easily integrated with regional flood mitigation when constructed in the base of ponds
- Can be designed as naturalistic or highly contemporary landscape features
- Provide habitat for a very diverse wildlife population and plant community
- Attractive landscaping feature
- Benches, tracks and bird blinds enhance amenities for a variety for users.

WHEN ARE THEY SUITABLE?

The are best on larger sites, generally over 1 hectare.

DESIGN AND INSTALLATION CONSIDERATIONS

- Design details should be determined on a site specific basis for the design storm and extent of the drainage area in consultation with the relevant agencies
- Careful consideration must be given to overflow control, plant species (and density), subsurface conditions and details for lining
- Wetlands must be constructed with variable bathymetry to support a diverse range of emergent and submerged macrophytes
- At least 80% vegetation cover must be achieved (typically <350mm permanent planting depth for planting)
- Minimum 250mm extended detention should be provided to increase treatment volume and moderate flows
- The contributing drainage area should generally be greater than 4 hectares
- Safety ledges needed adjacent to permanent pool areas deeper than 1m
- Inflow energy dispersion is required to protect against erosion
- A sediment forebay shall be used to protect macrophyte zones and facilitate settlement of coarser sediments.

MAINTENANCE

- Sediment forebay, inflow and outflow structures must be kept accessible for operation and maintenance
- Monitor sediment accumulations, and remove sediment when the forebay reaches pre-determined accumulation
- Plant maintenance, including weed control
- Inspect for structural damage – repair undercut or eroded areas.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource and building consent requirements for individual sites.

DEPRESSION STORAGE

PRIMARY FUNCTION

Attenuation capacity and some treatment.

Depression storage is a natural or artificial shallow grass-lined area capable of detaining runoff, such as a depression in a park or a low lying edge of a car park to provide temporary storage to attenuate runoff. Some pollutants can be removed from stormwater by filtration through the grass and soil. Stormwater disposal is via a controlled outlet to regulate discharges.

BENEFITS

- Simple to construct with ability to integrate with park setting
- Can be designed to only engage infrequently (>1 in 1 year event) so area is useable at other times
- Can incorporate seating or other furnishings to encourage social and recreational activities
- Adopting stormwater capturing on a wide-scale basis could reduce stormwater volumes entering the sewer system during storms.

WHEN ARE THEY SUITABLE?

Do not site where they would create a flood risk to adjacent buildings/properties or an unacceptable risk to public safety (i.e. immediately adjacent to playground).

DESIGN AND INSTALLATION

- Design details should be determined on a site-specific basis for the design storm and extent of the drainage area in consultation with the relevant agencies
- Careful consideration must be given to hydraulics (inlet, overflow and outlet), subsurface conditions, infiltration rates (to avoid permanently waterlogged soils) and maintenance
- The depression basin shall be designed to pond water, when a pre-determined threshold is exceeded, and allow the release of the water via a suitably sized outlet structure
- Fortify the entry edge to protect against erosion from inflow
- Where the depression basin borders footpaths the design shall cater for pedestrian safety
- The basin can be planted with large vegetation (such as flax and some trees) as long as allowance is made for the impact on storage volumes and maintenance access for hydraulic structures.

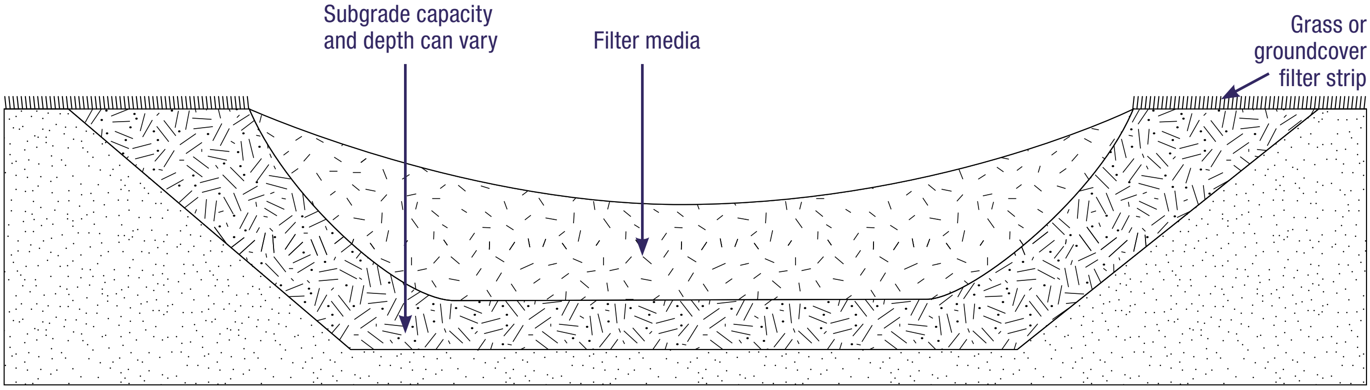
MAINTENANCE

- The maintenance requirements for grass channels and depression basins are relatively minimal
- Inspect the depressions after significant rainfall
- After vegetation is established, mow it, remove litter, and perform spot vegetation repair
- Ensure water flow into the depression is unobstructed.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource consent requirements for individual sites.

GRASSED DEPRESSION



RIPARIAN BUFFER

PRIMARY FUNCTION

Minor treatment and attenuation.

Riparian buffers along stream edges protect water quality by filtering out sediments and pollutants. They can vary in width from a minimum of 2m. The width of the riparian zone depends on the size of the stream and its flow characteristics although other factors such as property boundaries, slope, soils and amount of vegetation must be considered.

The primary function of riparian buffers is to physically protect and separate a stream or wetland from edge disturbance or encroachment. If properly protected and designed, a buffer can provide stormwater management and act as an overflow zone during floods, sustaining the integrity of stream ecosystems and associated riparian habitats. Technically, aquatic buffers are one type of conservation area that function as an integral part of the aquatic ecosystem and can also function as part of an urban habitat.

BENEFITS

- Protect water quality and allow flood flow attenuation
- Provide shading of waterways
- Provide habitat for a very diverse wildlife population and plant community
- Connect community with 'natural' waterway through restoration activity
- Attractive landscaping feature
- Benches, tracks and bird blinds enhance amenities for a variety for users
- Can be integrated with structural works to stabilise stream edges such as gabion walls
- Can be undertaken in collaboration with community groups and/or schools.

WHEN ARE THEY SUITABLE?

Existing riparian edges on all remaining waterways should be retained or enhanced where possible.

GENERAL CONSIDERATIONS

- Protective planting may be used to improve and stabilise a stream bank as well as prevent gully erosion and sedimentation
- Plantsshould represent the stream typology and location
- Consider natural geomorphology of stream and be mindful of challenges with temporarily removing existing weed species.

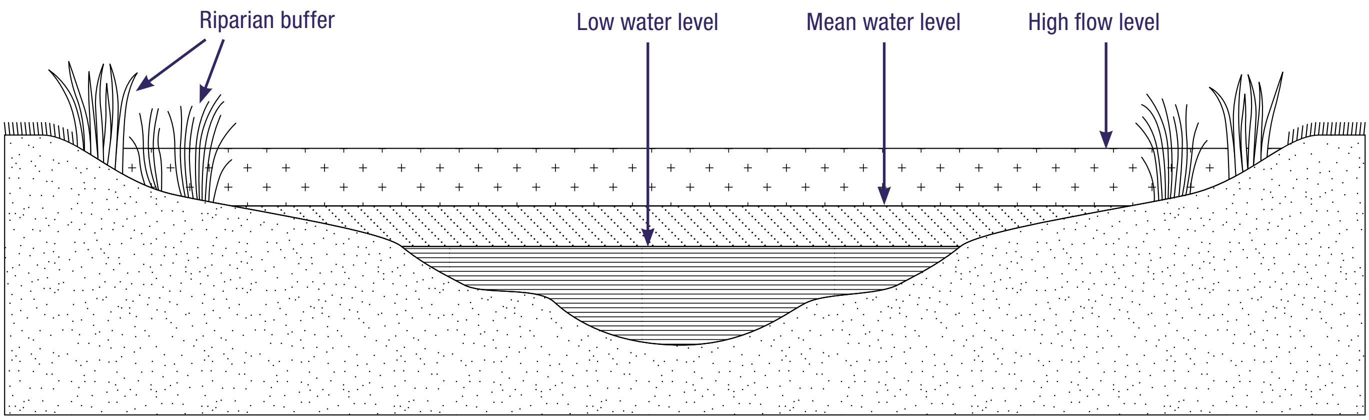
MAINTENANCE

- Plant maintenance, including weed control
- Inspect for damage – repair undercut or eroded areas.

COUNCIL INSPECTIONS AND APPROVALS

Ascertain resource consent requirements for individual sites.

PROFILE VIEW



ALL ABOARD THE TREATMENT TRAIN

Collection	Treatment	Discharge
(interception, infiltration, attenuation, conveyance)	(filter, biological uptake, separation)	(overflow)

These measures are components of a 'treatment train'. Whether natural, constructed or hybridised components, the sequence of measures rely on each other for input and discharge, collectively treating stormwater for the needs of a particular environment. The 'treatment train' and each design measure within it require site-specific design.

The Council seeks to promote WSUD concepts in stormwater management to both improve water quality and mitigate peak runoff volumes.

Sequencing of components can combine natural and urban systems of treatment and conveyance to progressively remove contaminants and reduce volume. Through site design and spatial planning of existing natural features and/or introduced stormwater control, features can be incorporated to create a WSUD 'treatment train' approach. This leads to water-quantity and water-quality benefits as well as benefits to recreation and open space and ecological value.

A 'treatment train' may be required to deal with a variety of pollutants e.g. sediments and heavy metals.

The selection of WSUD measures needs to be guided by site conditions, development type and pollutants. The design and size of the system is guided by quantity of rainfall and available site area. In designing a treatment train, with WSUD elements in series, designers must consider the interactions between the different treatment types and the subsequent impact on sizing. For example rain gardens are not suited downstream of a constructed wetland but can be used for pre-treatment upstream of the wetland.

TREATMENT TRAIN EXAMPLES:

Waitangi Park includes a good example of a treatment train. This includes:

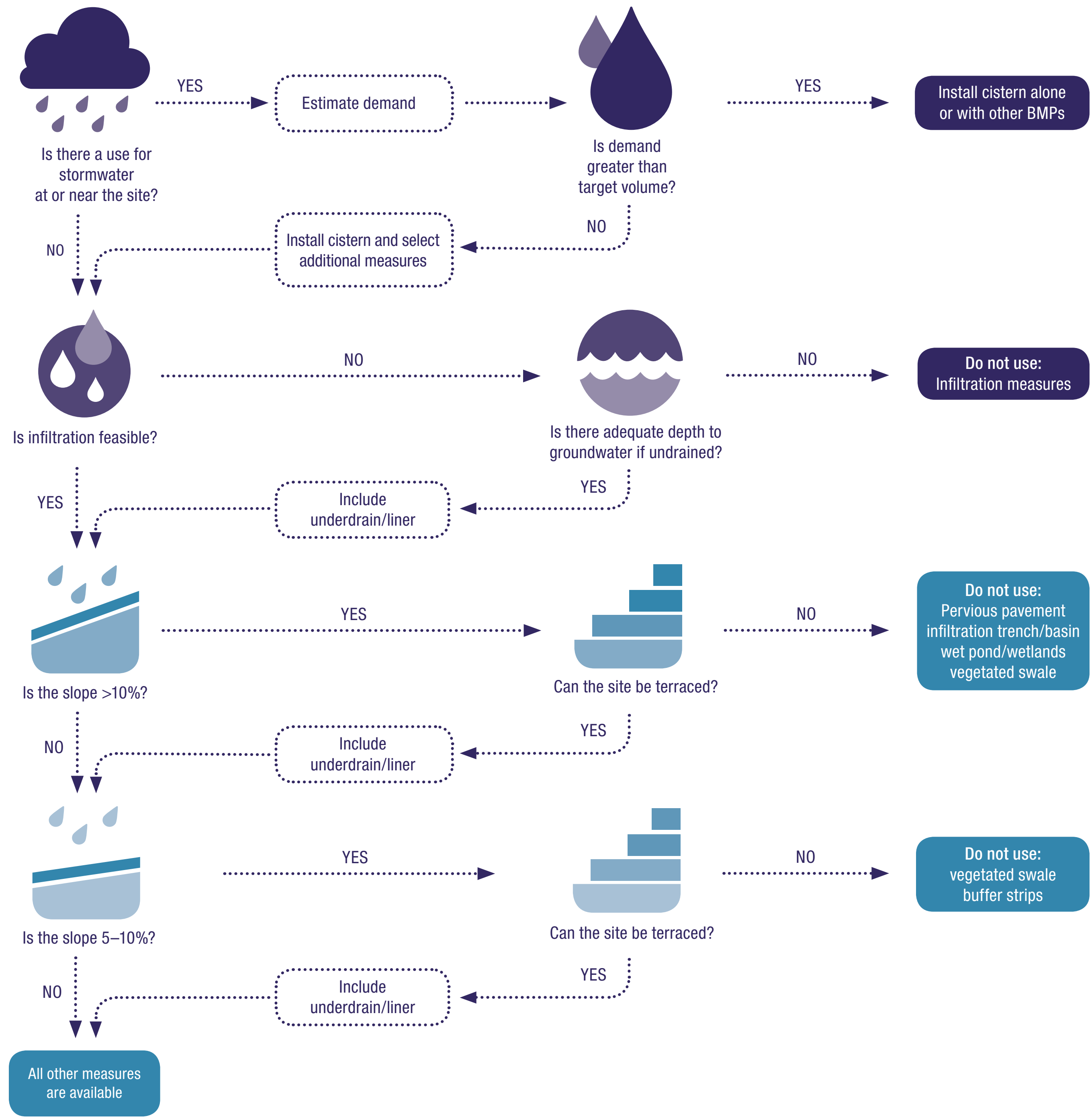
- Culvert
- Subsurface wetland
- Flow-through planter
- Constructed wetland
- Pond
- Irrigation
- Discharge.

PART FIVE: WSUD SELECTION

A generic process for selection and design of WSUD stormwater treatment devices is shown below.
The matrix is from the San Francisco Stormwater Design Guidelines and is helpful in establishing the selection of WSUD measures based on site characteristics.

The process follows logical progression based on parameters applicable to Wellington i.e. slope and soakage. It identifies early on whether or not on site soakage is a viable option.

DECISION TREE



BENEFITS

WSUD should, where practicable, be used within the context of integrated catchment and asset management plans to:

- Protect or enhance water quality and preserve natural habitat and ecosystems
- Mimic natural drainage regimes
- Adopt more sustainable forms of development
- Reduce the amount and form of hard infrastructure and impervious surfaces
- Improve visual and physical amenity values.

This guide can demonstrate the benefits of WSUD. It can also point to case studies for making the case for WSUD. However it cannot provide a formula that calculates the values relating to a particular project. It may be possible to make a value transfer, in which values are inferred from similar cases. Values can be environmental, social or economic.

Most traditional grey infrastructure has a single function. Green infrastructure, by contrast, is multi-functional. As well as reducing pressure on the sewer network (reducing sewer overflows to the sea) and filtering out pollutants from stormwater, WSUD can also provide ecosystem services such as bringing more of our native flora and fauna into the heart of the city, reducing impervious areas, creating shade, improving the streetscape and storage of carbon in the trees and soil.

The City of Philadelphia is pursuing a WSUD approach to minimise sewer overflows – this includes retrofits on existing roofs and converting roads to make them more permeable. Such an approach is expected to reduce annual sewer overflows by nearly 8 billion gallons per year – at a cost of billions less than the more traditional approach of building underground storage tunnels. Philadelphia has estimated that the cost of a WSUD approach is $US3 billion compared to $US100 billion for a piped solution.

In Seattle, replacing traditional asphalt streets with permeable pavement and green infrastructure has cut paving budgets nearly in half.

Multi-value benefits from investments are now expected and becoming de rigeur. We need to make decisions at the macro scale to provide WSUD on the back of other major investment. Utilisation of WSUD and nature's ecosystem services will yield far greater benefits than single-focused projects. For example, roading projects can incorporate WSUD elements and bring benefits to other interests – urban design, flood management and biodiversity to name but a few.

In New York a WSUD approach that integrates swales and green roofs is being used as an alternative approach in managing rain-related pollution. The city is directing investments in WSUD to optimise the existing piped system and reduce flow volumes into its combined sewer system. This project is expected to save about $1.5 billion in treatment and infrastructure costs over 20 years. For billions of dollars less than the cost of the traditional tanks and pipes that are useful only when it rains, New York is benefiting from improved water and air quality, reduced greenhouse gas emissions, increased property values, and beautified communities.

Compared with the performance of grey infrastructure approaches, green infrastructure has reduced:

- Built capital (equipment, installation) costs
- Operation costs
- Land acquisition costs
- Repair and maintenance costs
- External costs (off-site costs imposed on others)
- Infrastructure replacement costs (potential for longer life of investment).

HOW THIS GUIDE RELATES TO OTHER DOCUMENTS

There is national evidence that environmental standards are increasing. Stormwater quality is an aspect that is attracting increasing regulatory attention in New Zealand in terms of compliance with legislation and increasing community expectations.

The WSUD guide pre-empts increasing regulatory attention around water resources.

The following national and regional policy documents all make reference to water quality and the way urban runoff is managed;

- National Policy Statement on Freshwater Management (2011)
- Land and Water Forum third report (2012)
- Freshwater Reform (2013) policy document,
- Review of NZS4404 Land development and subdivision infrastructure (2010)
- Regional Policy Statement for the Wellington Region (2013)
- Current Regional Plan review.

The Regional Policy Statement (2013) (RPS) must be given effect to by regional and district plans and must be given particular regard to when resource consents are processed. It includes objectives, policies and methods which relate to water quality. The Council's District Plan will have to be revised to give effect to the RPS.

The RPS direction is to use low impact design-WSUD concepts in order to minimise the effects of stormwater.

Specifically this guide supports national, regional and district objectives, policies and standards including:

- New Zealand Coastal Policy Statement (2010)
- National Policy Statement for Freshwater Management (2011)
- Regional Policy Statement (2013).

Coastal Environment:

- Policy 6: Recognising the regional significance of the Porirua Harbour – district and regional plans
- Policy 37: Safeguarding the life-supporting capacity of coastal ecosystems – consideration.

Fresh Water:

- Policy 40: Safeguarding aquatic ecosystem health in water bodies – consideration
- Policy 42: Minimising contamination in stormwater from development – consideration[1]
- Policy 43: Protecting aquatic ecological function of water bodies – consideration.

Indigenous Ecosystems:

- Policy 24: Protecting indigenous ecosystems and habitats with significant indigenous biodiversity values – district and regional plans
- Policy 47: Managing effects on indigenous ecosystems and habitats with significant indigenous biodiversity values – consideration.

REGIONAL STANDARD FOR WATER SERVICES (NOVEMBER 2012):

4.2.10 Environmental:

"Downstream impacts to be managed and mitigated against shall include, but not be limited to, changes in peak flow and flooding, erosion, sedimentation and contamination. Works will be required to address any adverse effect."

4.2.11 Low Impact Design:

"Using low impact design concepts and practices enables multiple social, environmental, cultural and transport outcomes to coexist through improving the overall design quality, providing amenity, and enhancing environmental quality and attractiveness of the area. Alternative approaches to stormwater management, including attenuation and/or some disposal on site, may be encouraged where practical."

1 This is a crucial policy for WSUDs and stormwater management – it is a test that should be used for all plan changes and resource consents.

CODE OF PRACTICE FOR LAND DEVELOPMENT (WELLINGTON CITY COUNCIL, DECEMBER 2012):

F.4 Stormwater Control:

"The Council seeks to promote low impact design concepts to stormwater management to both improve water quality and curb peak runoff volumes."

WCC PUBLIC SPACE DESIGN POLICY (WELLINGTON CITY COUNCIL, DECEMBER 2010)

Objective 6: Sustainability/Policy 3:

"Innovative planting projects and water-sensitive urban design practices will be incorporated in public spaces, contributing to an ecological sustainable city."

Studies have identified stormwater contamination sources and the extent to which they are of concern in Wellington. It is understood that land use and catchment characteristics influence stormwater runoff.

The biggest issues of concern for stormwater management are sediment, runoff volumes and velocity and the inundation of drainage systems causing sewage overflows.

The objective of the stormwater system is to protect people, property, public health and the environment from the adverse effects of stormwater by the safe disposal of rainwater and associated runoff.

A WSUD system must support these vital functions while achieving its design objectives, using a selection of measures depending on catchment conditions and land use.

Many factors influence the design, implementation, maintenance and cost of individual WSUD measures. Knowledge regarding the long term operation, maintenance and success of some designs may also be limited. The Council must ensure that the solutions are robust.