Water Sensitive Urban Design (WSUD) Guide

A guide for WSUD stormwater management in Wellington

APPENDIX 1

This 'Water-sensitive Urban Design Guide' was prepared by Wraight & Associates Ltd
for Wellington City Council with input from industry experts. July 2013

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Introduction

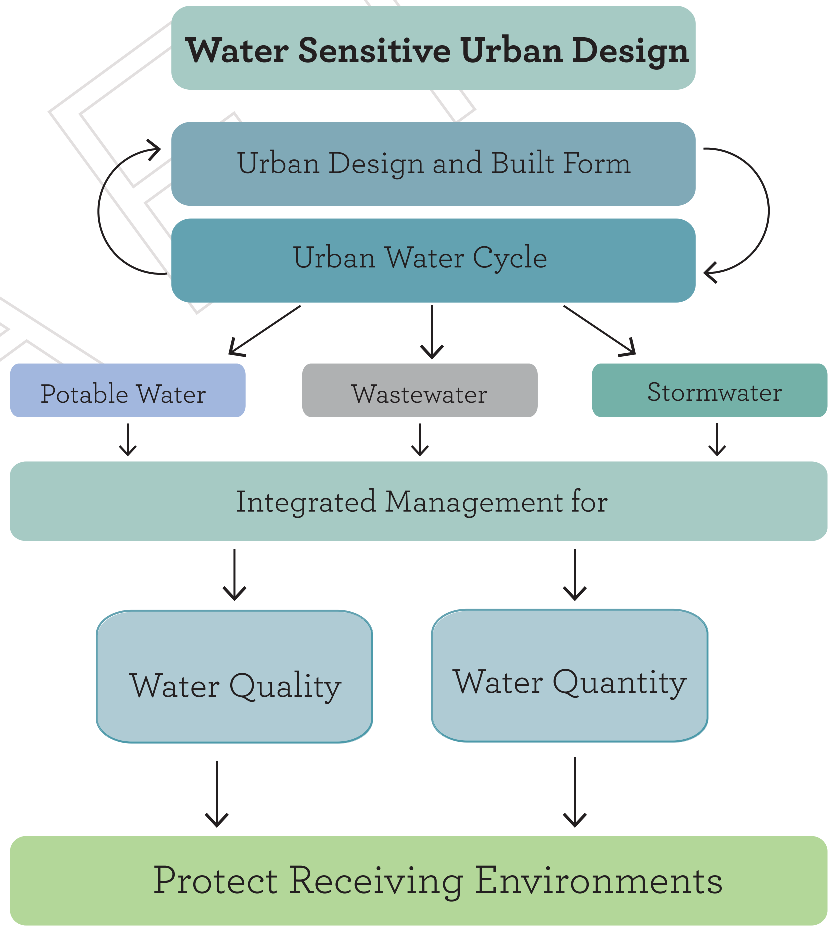
What is water-sensitive urban design (WSUD)?

Water-sensitive urban design 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. WSUD integrates the water systems with the 'built environment' - buildings and infrastructure and landscapes. In doing so it is important to design systems for urban activity.

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.

A number of processes occur between rain falling and the return of most stormwater to the sea. These processes of stormwater management occur in a number of ways at different points along water's flow path. The processes can be divided up into the three basic stages: collection and transport; its retention; and distribution by way of re-use, infiltration and evapotranspiration. Polluted stormwater can be purified in each of these stages. To maximise opportunities a number of these processes can be included sequentially throughout the catchment to contribute to the treatment of stormwater. This is called a 'treatment train'

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.



What are the objectives of WSUD?

- Protect or enhance the environmental, social and economic values of downstream environments: *Clean waters*
- Reduce infrastructure overload + flood hazard: *Integrated catchment management*
- Reduce demand on potable water supply: *Water conservation and reuse*
- Improve amenity in the urban environment: *Enhance the 'livability' of Wellington*

Who should read this document?

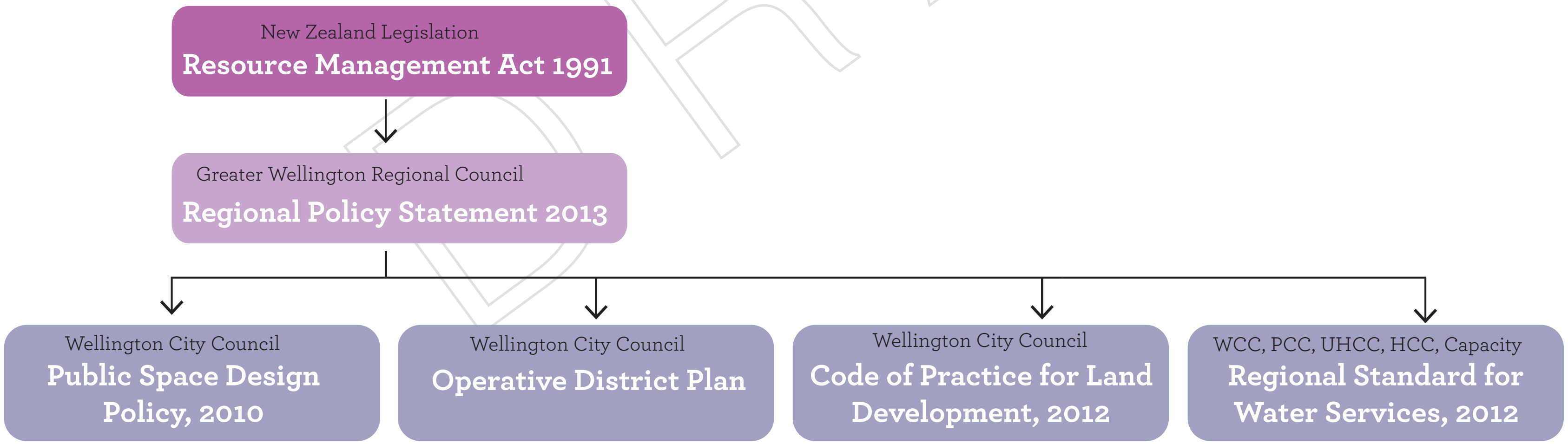
It is for, but not limited to:

- Developers
- Consultants
- Land owners
- Wellington City Council, Greater Wellington Regional Council, and Capacity staff.

Proposed Wellington City approach

Integrated at source stormwater management - understanding Wellington's unique characteristics.

This guide supports national, regional and district policies and standards including:



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APPENDIX 1

Part One:

Stormwater systems

Stormwater systems manage the movement of water from rain interception through to discharge into streams, lakes and the sea. Natural and urban stormwater systems each have their own attributes and issues. WSUD systems hybridise the two to take advantage of their respective attributes while minimising problems.

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1.1 Natural systems

Precipitation | Interception | Attenuation & Conveyance | Uptake | Evapo-transpiration | Infiltration | Retention | Evaporation | Discharge to receiving environment

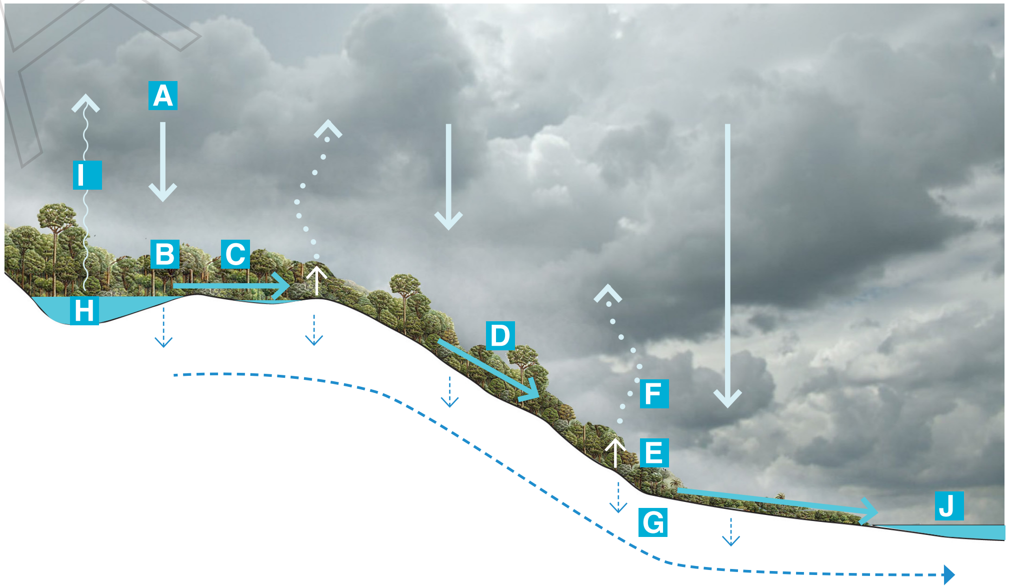
Collection | Treatment | Storage

The natural stormwater system allows the continuous circulation of water at, on and below ground level. It involves the following processes:

- Landform and vegetation retains and releases water, collecting and attenuating flows from raindrop to sea.
- The movement of water in the natural stormwater system influences nutrient distribution and landform transformation.
- Infiltration retains ground water & soil moisture levels at reasonably stable levels.

Attributes
- Flood attenuation
- High ecosystem services
- Natural beauty
- Nutrient distribution
- Infiltration charges ground water storage
- Clean available water

Issues (to human settlement)
- Flooding can occur in big events
- Land area intensive
- Integrating dynamic (natural) and rigid (man-made) structure
- Super saturation of soils can occur



1.2 Conventional systems

Precipitation | Interception | Uptake & Evapotranspiration | Conveyance | Evaporation | Infiltration | Sediment & Litter collection | Conveyance | Discharge

Collection | Storage

Conventional stormwater systems collect rainwater and discharge to streams and the sea. Apart from sumps, which collect some sediment and litter, there is usually no treatment of stormwater before it is discharged.

Typically, conventional stormwater systems are designed to manage quantity not quality - however rapid drainage of urban catchments can cause high peak flows. With fixed infrastructure capacity, this can cause flooding.

Sediments and pollutants from urban activity accumulate on roofs, roads and pavements. Pollutants include:

- Heavy metals
- Organics and faecal matter
- Nutrients
- Litter.

When it rains, runoff can be contaminated with pollutants and be transported to streams or the sea.

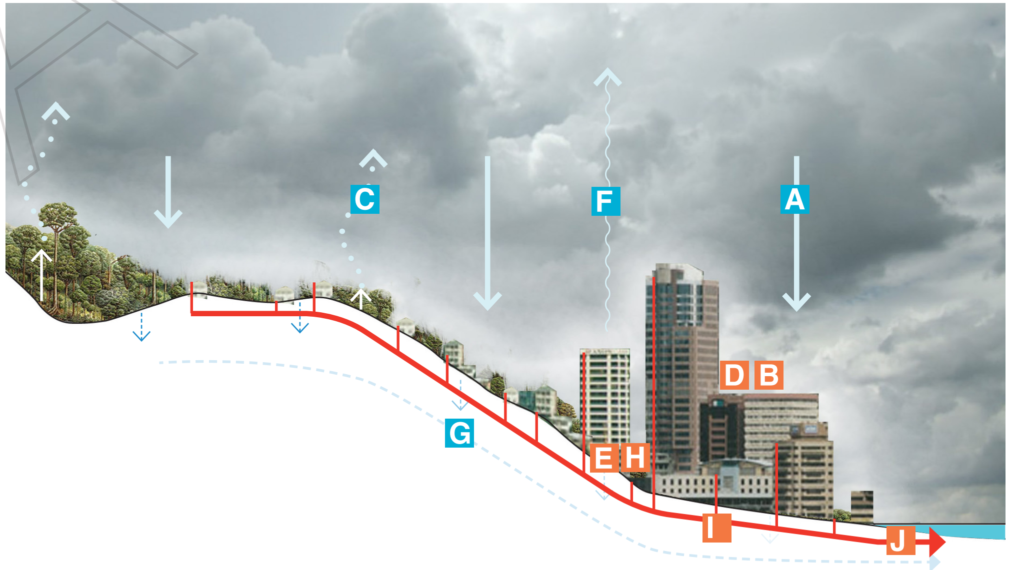
Hard surfaces reduce infiltration which reduces ground water and soil moisture content. This can cause soils to shrink, destabilising older built structures and infrastructure. Conversely, over saturation of subsoils can affect constructed pavements.

Attributes

- Minimal land requirement
- Flood mitigation
- Prevents over-saturation of soil

Issues

- Pollution of receiving ecosystems
- Health Impacts from polluted waterways
- Flooding
- Reduces ground water
- Risk of element failure



1.3 An integrated WSUD system

Water-sensitive urban design requires an integrated approach to stormwater management. WSUD combines the positive attributes of the natural and urban systems to design networks that reduce the volume of stormwater runoff, reduces peak flows and reduces the amount of contaminants entering natural water bodies.

The principles of WSUD set out to:

1. Protect natural water systems within urban developments.
2. Integrate stormwater treatment into the landscape and built environment
3. Protect the quality of water draining into streams and the sea
4. Reduce volumes of runoff and peak flows
5. Add amenity value to a development while reducing development costs.

WSUD requires creative design: the design measures shown in this document are examples of how this can be achieved. There may be more.

Attributes

- At source stormwater management
- Combined multiple functions - integrated stormwater treatment with landscape elements
- Improves the visual and ecological amenity of sites and streets
- Provides passive irrigation to 'green' site and street elements
- Reduces potable water use
- Protects or enhances water quality in downstream environments

Issues

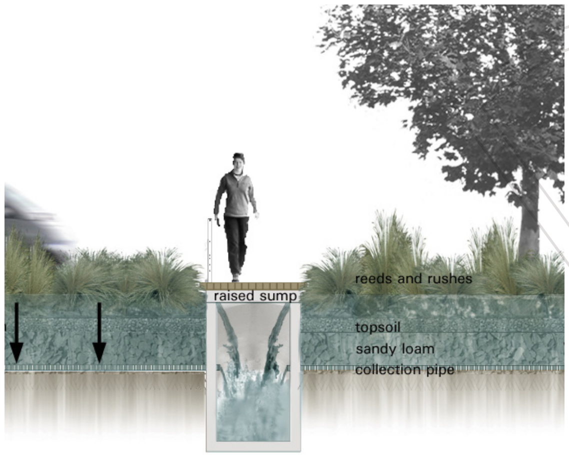
- Components, such as soils, can be sensitive to damage during construction
- Public perception of increased pest habitats
- Adjustment to standard maintenance requirements of drainage assets
- Risk of element failure

Harbour Quays, Centreport - A Wellington example

Private & 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.

CentrePorts' Harbour Quays development master plan embraces environmentally responsible and responsive design. The development implements an integrated storm water management strategy that deals with water quality and quantities at source.

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



Bio-retention swales, (image: Wraight + Associates)

WSUD measures include:

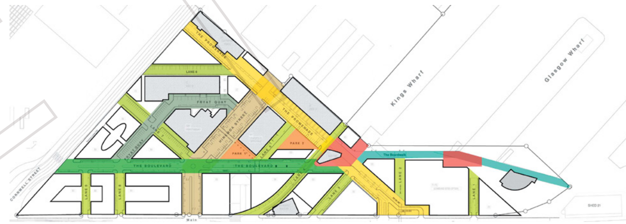
Bio-retention swales:
'First-flush' stormwater run-off, the earliest and subsequently the most polluted component of rainfall, is directed towards a densely planted swale located either in the median or at the road edge. The swales have capacity to detain and filter run-off. Clean filtered water flows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

Rain-gardens:
Rain gardens occur within urban plazas and laneways to both improve stormwater runoff quality and visually augment these spaces.

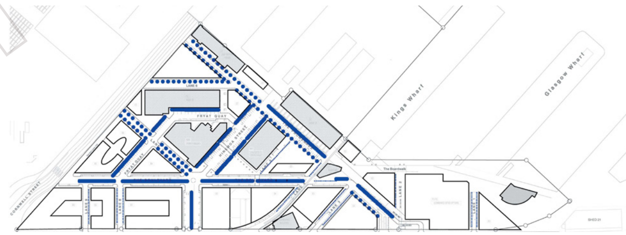
Bio-retention tree pits:
The majority of tree pits site wide filter stormwater run-off from roads and foot path pavements.

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

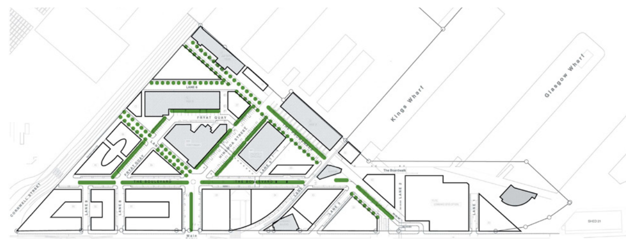
Harbour Quays WSUD strategy showing stormwater system integrated with urban design



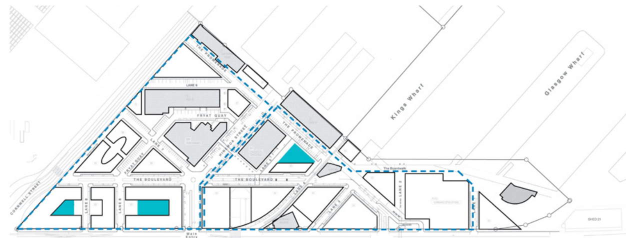
Street network, squares & parks



Stormwater collection



Stormwater infiltration



Stormwater storage and reuse

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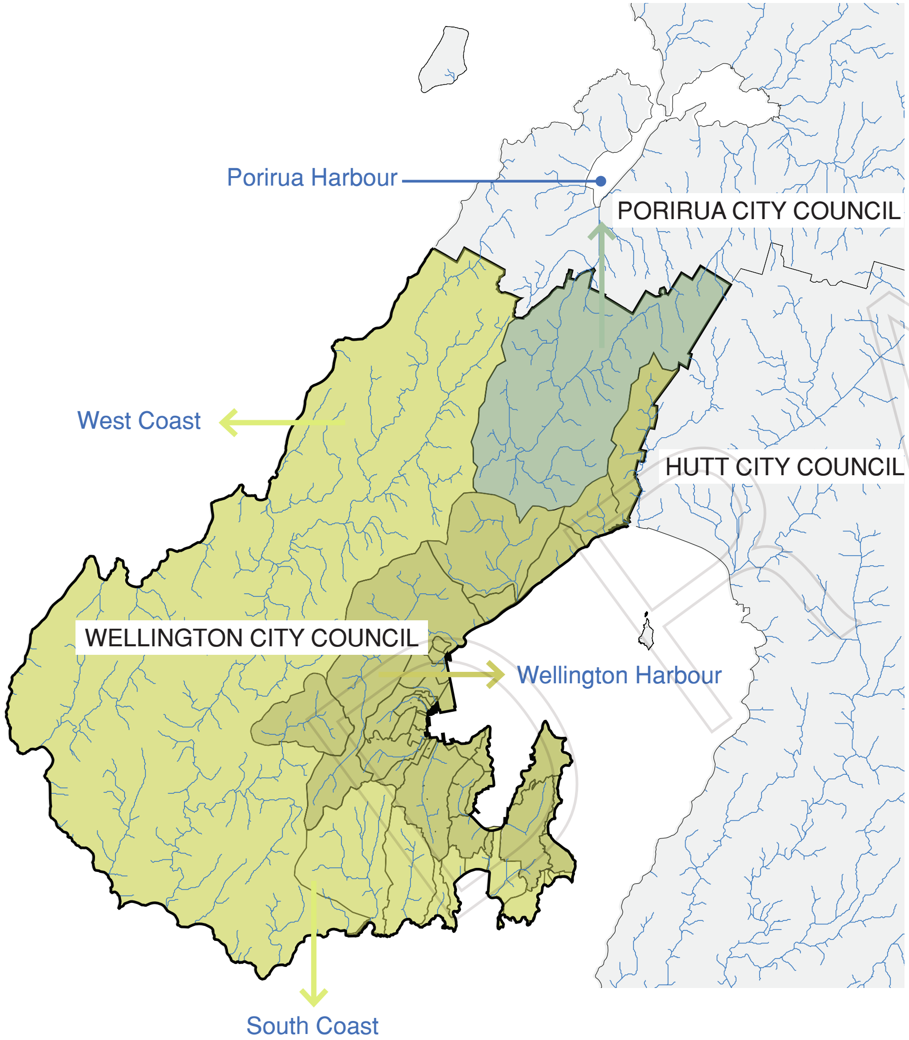
Part Two:

Wellington Context

Wellington is unique. Its catchments, steep topography, variable soils and land uses influence the quality and quantity of stormwater as it moves through the city's natural and urban stormwater systems.

2.1 Catchments & water-quality



Map illustrating where Wellington's stormwater is directed

Stormwater drains into streams and pipe systems that ultimately end up in the harbour or ocean.

Wellington's harbour and coastline are our places to swim and fish. Pollution negatively impacts water quality, affecting recreational activities, freshwater and marine ecosystems, fish and shellfish health, and puts our health at risk.

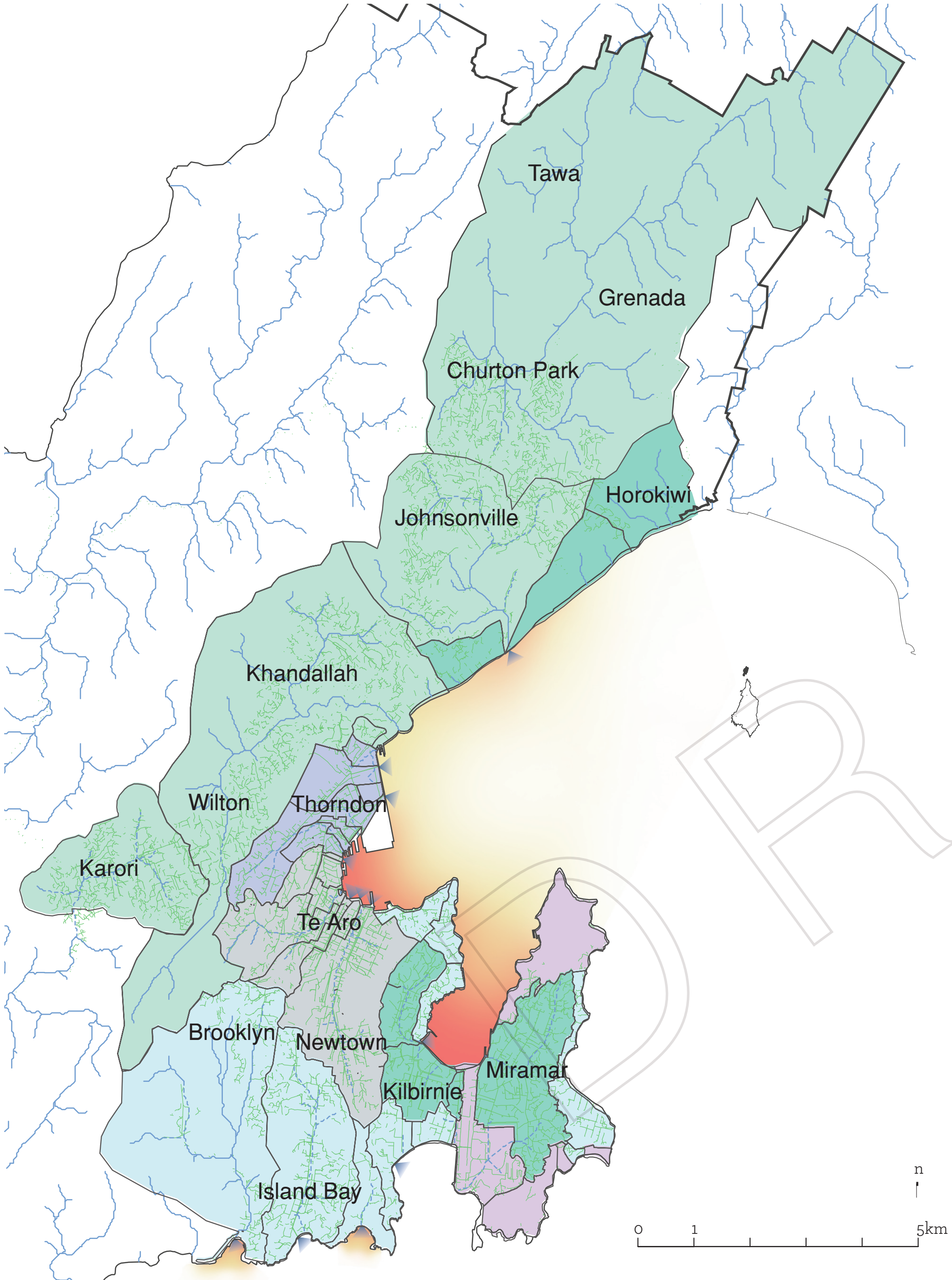
Western areas of Wellington drain towards the west and south coasts.

Urban areas south of Grenada & Churton Park drain toward either Wellington Harbour or the South Coast. Sheltered bays within Wellington Harbour such as Port Nicholson and Evans Bay are low flow water environments where sediment accumulates.

Stormwater runoff generated within the district boundaries of Wellington City Council is not always managed and discharged within the district boundaries.

Wellington's northern suburbs (Churton Park, Grenada & Tawa) drain to Porirua Harbour. Porirua Harbour is a shallow water body that facilitates the accumulation of sediment.

Contaminated sediment accumulation impacts ecological health and the values and/or uses that may be associated with these areas.



The city has a number of catchments, ranging in size and scale, and different receiving environments - including streams, Wellington and Porirua Harbours and coastal waters. These receiving environments are valued for a range of uses such as shellfish gathering, boating and swimming.

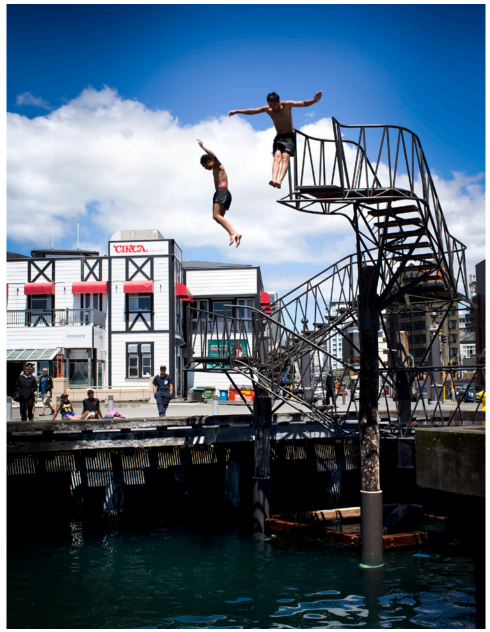
Legend

Catchments based on predominant use of receiving environments.

- Commercial Port
- Shellfish
- Casual Boating/ Fishing
- Streams
- Bathing
- Inner Harbour

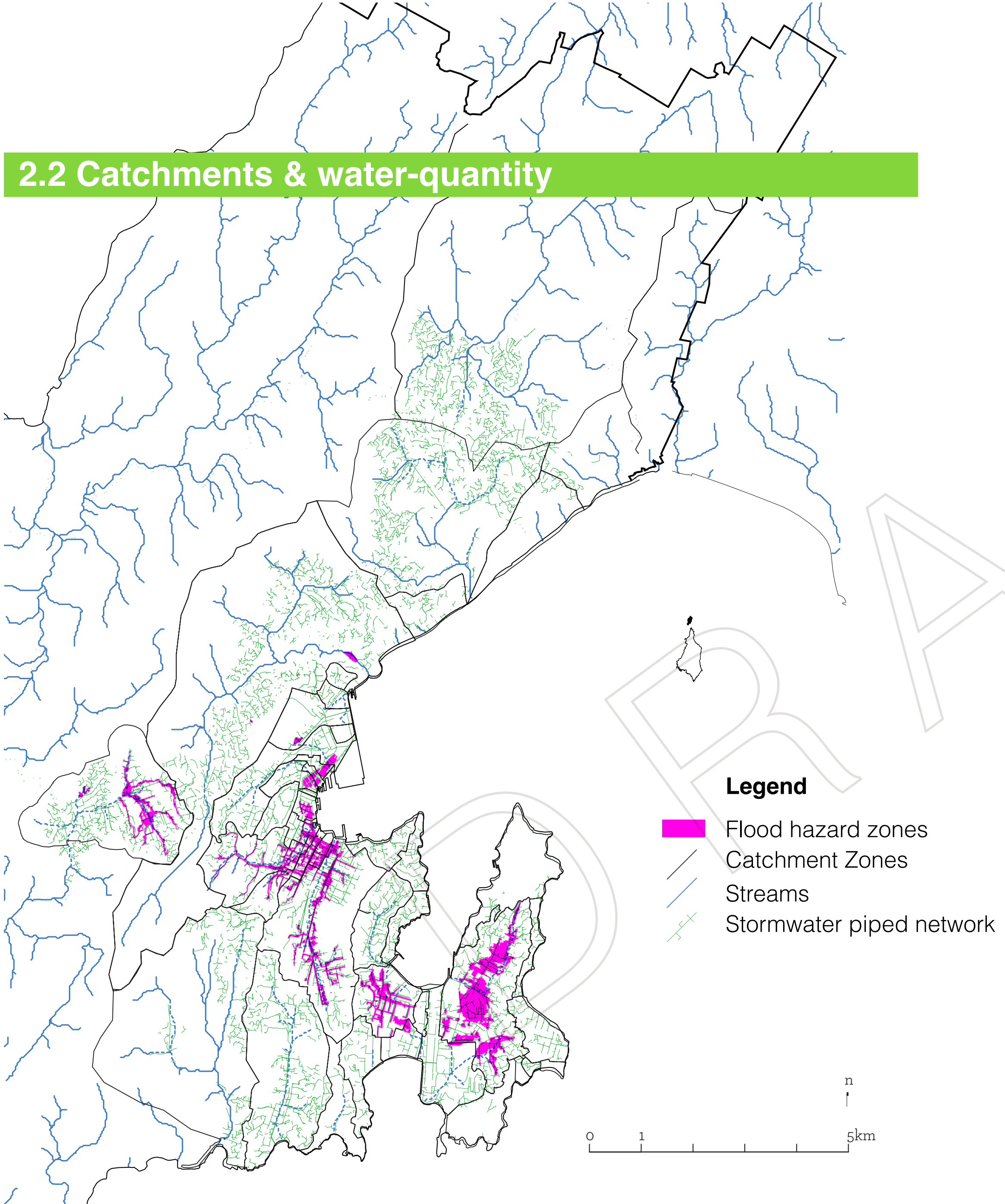
- Piped Outfalls
- Catchment Zones
- Streams
- Stormwater piped network

- Contaminanted sediment accumulation (Derived from Greater Wellington document 'Coastal water quality and ecology in the Wellington region' June 2012)



Pollution negatively impacts on recreational activities.

2.2 Catchments & water-quantity



The urbanisation of the city has resulted in extensive areas of sealed surfaces, including roofs, pavements and roads. Rain that falls on lawns and gardens (pervious areas) soaks into the soils. Rain that falls on hard impervious sealed surfaces cannot soak to the ground and is directed to the piped network and eventually the sea.

During heavy rain the piped network can be overwhelmed. When this happens, localised flooding can occur, damaging property and blocking streets. In some catchments the stormwater drains and sewers are interconnected because of historical design and current day cross connections, leaky joints and old cracked pipes, so sewage can find its way into watercourses and beaches.

Zealandia Reservoir (WCC)

There are extensive areas of impervious surfaces in our city, which contribute to the problem. This is exacerbated by subdivision of sections and increase in paved areas to provide car parking spaces. New high density developments also reduce the extent of gardens. Gardens are a valuable resource for urban drainage as they can absorb up to ten litres of rainwater a minute.

The loss of green space for soakage results in increased pressure on the stormwater network; intensifies run off volumes and velocities, and has implications for the transfer of pollutants to streams and the sea.
As a result more buildings, gardens and roads are being flooded more frequently than Council's agreed levels of service and those implied in the Building Act 1991. These flood problems are exacerbated by developments in natural ponding areas and secondary flow paths. Large-scale stormwater flooding has occurred in the recent past in the Miramar, Island Bay/ Berhampore, Newtown, Taranaki, Te Aro, Karori, Kaiwharawhara catchments and the Tawa Basin due to a combination of factors, including capacity of existing infrastructure, topography and permeability of the land.

Daylighting, or opening up these lost channels, can provide valuable habitat, offer educational and recreational opportunities, enhance urban landscapes, reduce costs through WSUD techniques, and help to give identity to a place.

Wakefield Street flooding (2013) Phil Reid/Fairfax NZ

Upgrading the pipe network

Waitangi Stream has been daylighted in the park, contributing to cleaning the stormwater and creating a strong identity.

Willis Street flooding (Jan 2002)

Wakefield Street flooding (Jan 2002)

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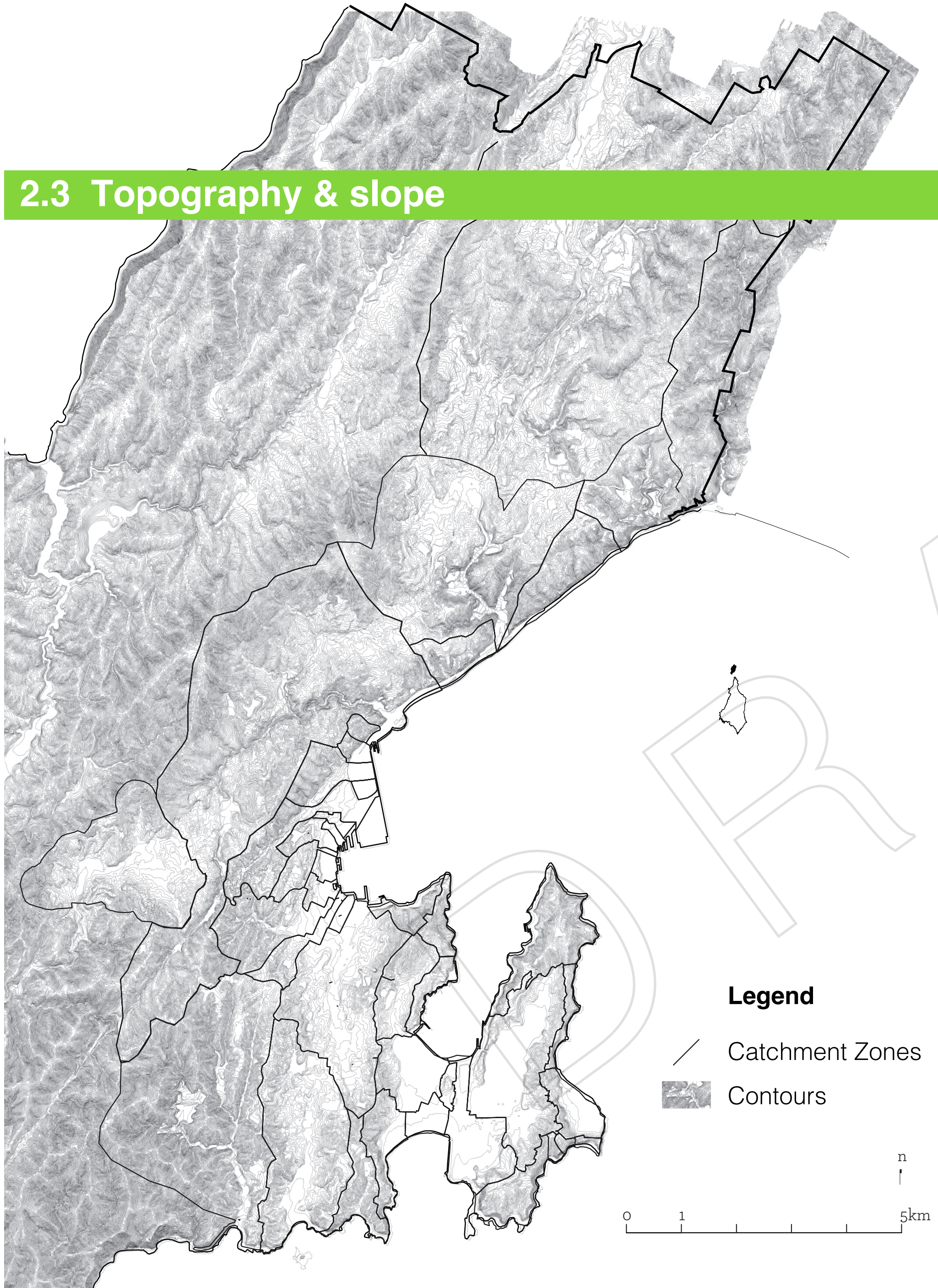
2.3 Topography & slope



Wellington's topography is highly diverse, ranging from steep hills to lowland flats. Slopes affect the velocity and amount of surface water flows, and the rate and amount of infiltration. These factors affect urban settlement.

When water flows quickly there are potential erosion hazards. High velocities also carry sediments and pollutants which, in concentration, affect the quality of water downstream. High velocities also allow high volumes to arrive downstream quickly, creating flood problems.

Infiltration reduces surface water problems. If infiltration is maximised flooding issues can be reduced, and water quality is improved because pollutants are filtered out through vegetation and soils.

Upper

Characteristics

- Typically Steep terrain and vegetated
- Low site coverage

Issues

- High water velocities
- Slip Hazard

Foothills

Characteristics

- Mediumsitecoverage
- Some areas of fill

Issues

- High water velocities
- Convergence of tributaries - flooding

Lowlands

Characteristics

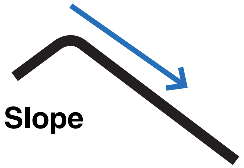
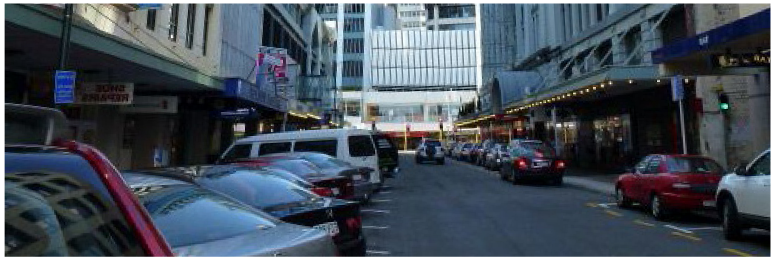
- Typically flat
- Low water velocities
- Extensive areas of fill
- High site coverage

Issues

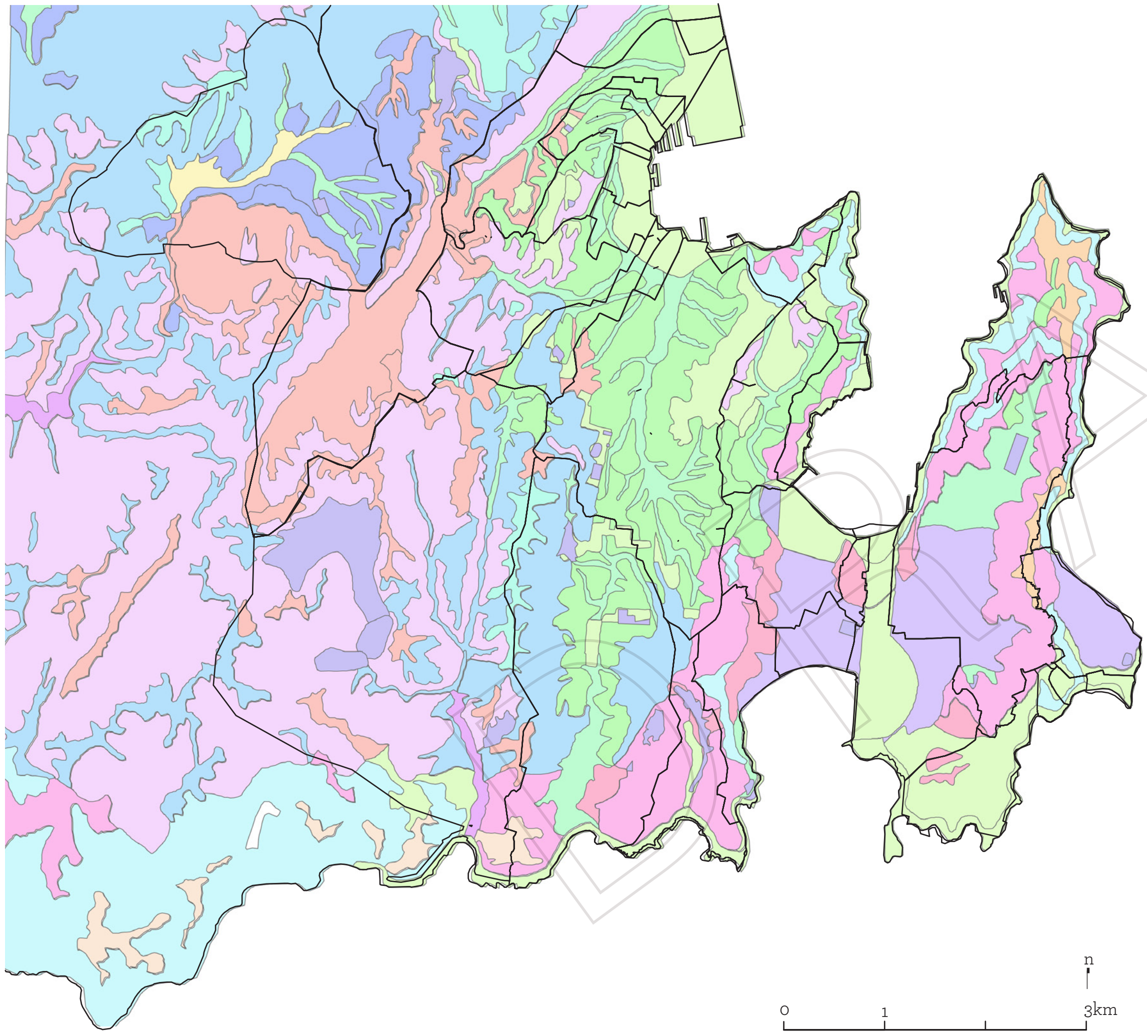
- Flooding
- Tidal influences
- Limited open space

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	

2.4 Soil & permeability



Most soils in Wellington are derived from greywacke rock, which results in heavy clays. The clays and silts are fine-grained and have low levels of permeability.

Medium-grained soils (Loess and Colluvium) occur in the natural stream valleys, such as in Newtown and Te Aro.

Coarser-grained sands occur in the coastal environments of Lyall Bay, Strathmore and Seatoun.

Legend

Heretaunga silt loam	Alluvium
Korokoro hill soils	Silty colluvium
Makara hill soils	Greywacke
Makara steepland soils	Greywacke or colluvium
Ngaio hill soils	Silty loess
Ngaio silt loam	Silty loess or colluvium
Paremata hill soils	Thin silty or clayey loess or colluvium
Paremata silt loam	Thin silty or clayey loess or colluvium
Porirua fine sandy loam	Sandy loess & colluvium
Porirua hill soils	Sandy loess & colluvium
Terawhiti hill soils	Greywacke
Terawhitisteeplandsoils	Greywacke or colluvium
Waikanae silt loam	Alluvium
Waitarere sand	Dune sand
Waiwhetu silt loam	Alluvium

The predominantly clayey soils have an impact on permeability. Because they are fine-grained they get saturated quickly. Wellington's clayey soils are prone to slip hazards especially on steep slopes.

In built-up areas, buildings and roads decrease the potential for permeability. Lack of permeability also restricts water infiltration, resulting in increased surface runoff.

Traditional piped networks very quickly and efficiently transport water and contaminants to aquatic receiving environments like the harbour. Stormwater contaminants accumulate near stormwater outfalls and degrade ecosystems, ultimately smothering and killing plant and shellfish.

The potential for a high level of infiltration on sandy and colluvial soils is adversely affected by the quantity of impermeable surfaces on the flat land.

Wellington Harbour reclamations contain variable fill material (Land reclamation, Thorndon, Wellington (ca 1925). Alexander Turnbull Library)

Fill Sites

Characteristics

Imported material
Low infiltration capacity

Issues

Ponding
Potential ongoing consolidation
Liquefaction

Contaminated Sites

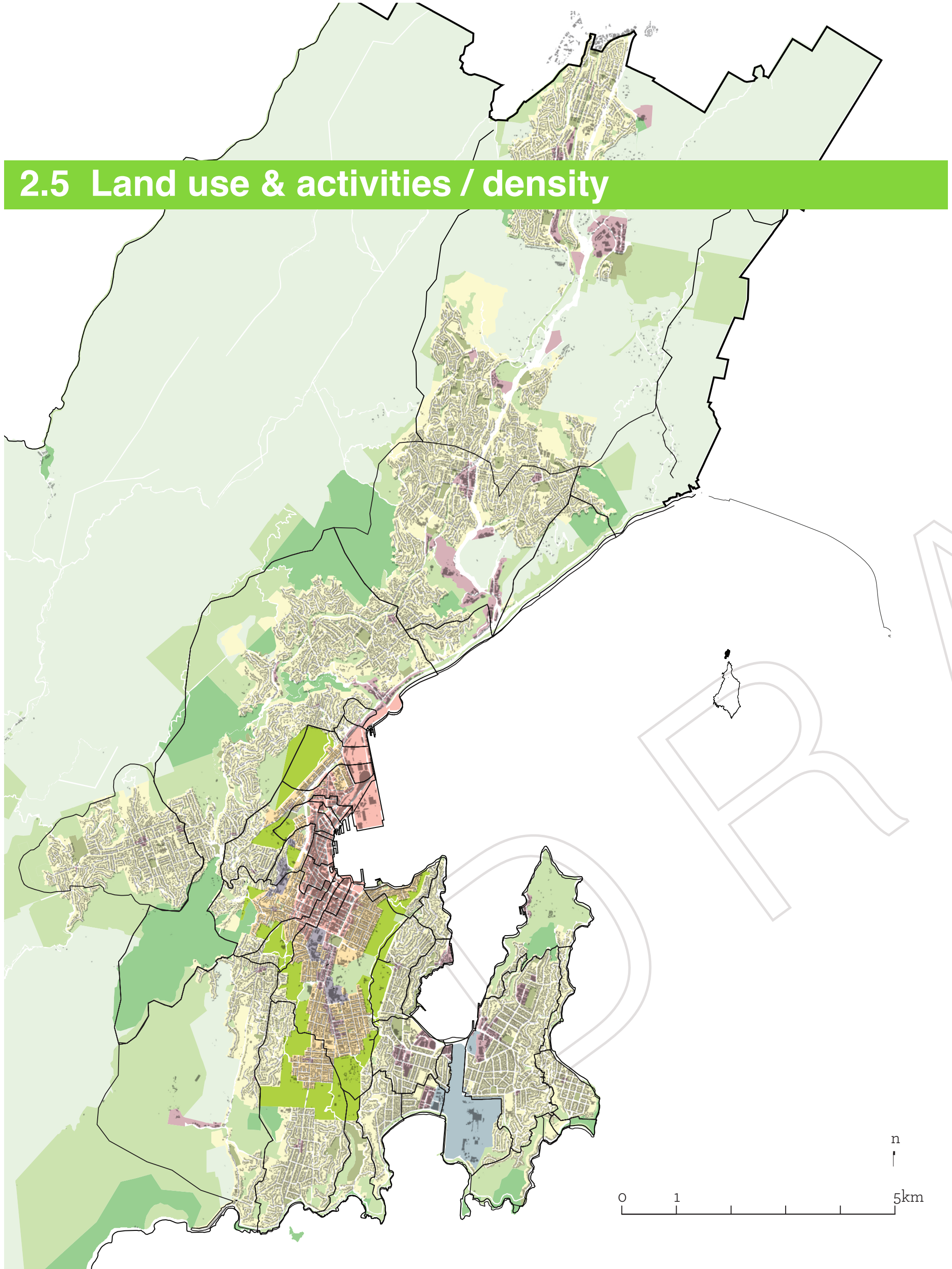
Characteristics

Land involved (historically or currently) in the use, storage or disposal of hazardous substances and as a consequence may contain residues of these substances

Issues

Health risks
Environmental impacts
Leaching of contaminants into adjacent environments

2.5 Land use & activities / density



Land use & water quality

Land use and building density are key factors influencing:

- Decreased infiltration (the greater the surface cover, the less infiltration occurs)
- Increased concentration of the following typical storm water contaminants, including:
    - Litter
    - Organic and faecal matter
    - Sediments
    - Oil and grease
    - Heavy metals
    - Nutrients
    - Pathogens including bacteria.

Legend

(As defined by WCC District Plan)

- Outer Residential
- Inner Residential
- Suburban Centre
- Central Area
- InstitutionalPrecinct
- Airport Precinct
- Rural
- Conservation
- Open Space A
- Open Space B
- Open Space C
- Catchment Zones
- Built density

Land use, density and site coverage in Wellington has been influenced heavily by topography and proximity to infrastructure.

Flat, low-lying areas have the most dense development and attract diverse uses including industry, commercial and residential uses, all serviced by paved road networks which altogether create a high site coverage. These land uses generate contaminants, and the high site coverage reduces infiltration.

Less-dense housing, often occurs on higher slopes, generally has less site coverage and lower levels of contaminant generation.

It is important that any increase in density or site coverage maintains the current levels of infiltration and contamination dispersal.

Large parklands like the Town Belts, on higher slopes, assist in water infiltration and where vegetated slow the velocity of runoff, retaining sediments on site.

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Part Three:

Land use

Land use and density generate variable impacts on stormwater quality and quantity.

Integration of WSUD Systems into site design improves water quality and helps reduce peak flows. Its integration into infrastructure, architecture and landscape enables improvements in amenity and biodiversity.

APPENDIX 1

3.1 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 to provide landscape amenity
- Roof water collection and storage to supplement mains water supply
- Opt for permeable paving to reduce runoff
- Increasing home owner interest in sustainable design.

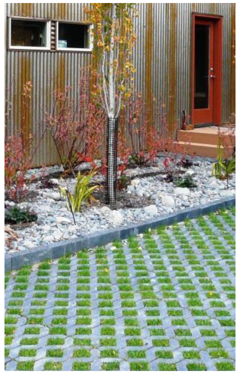
Low density residential, Churton Park

Aim:
Collect, detain and reuse stormwater to reduce discharge into street stormwater network.

Potential WSUD measures:

- Greenroofs to reduce runoff volume
- Rainwater tanks for reuse and to smooth peak discharge flow
- Permeable paving to reduce runoff volumes
- Rain garden to improve stormwater quality
- Soak pit to charge ground water
- Vegetative cover to reduce runoff volumes
- Bio-retention planters in streets to improve stormwater quality and detain run off.

Rainwater tank



Permeable paving

Rain garden

Vegetative cover

3.2 Higher density / mixed use development
(residential, commercial, institutional)

Characteristics

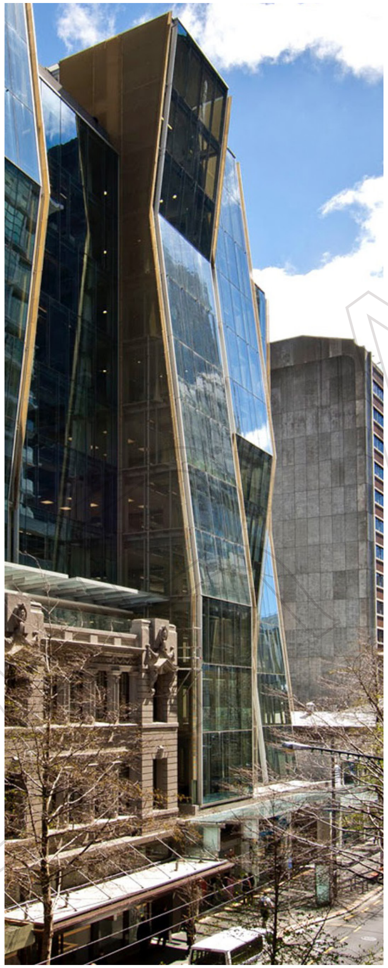
Medium to high density development typically has a site coverage of more than 35%. Multiple units, uses and ownership may, but not always, occur on a single parcel of land. Private open space is limited and communal or public open space associated with the development is of a premium.

Issues

- High site coverage 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.


Willis Street high density development

Aim:

Collect, detain and treat stormwater to improve quality and smooth discharge flows. Integrate WSUD meaures to create multifunctional architecture and open space.

Potential WSUD measures:

- Green roofs to reduce runoff volume
- Green walls to slow runoff and smooth peak discharge
- Rainwater tanks for reuse and/or to smooth peak discharge
- Stormwater planters to reduce and smooth stormwater discharge
- Permeable paving in pedestrian areas to reduce runoff volumes
- Rain gardens and bio-retention to provide amenity, detention and stormwater treatment.


Green roof


Green wall


Rainwater tank


Raingarden

3.3 Industrial development

Characteristics

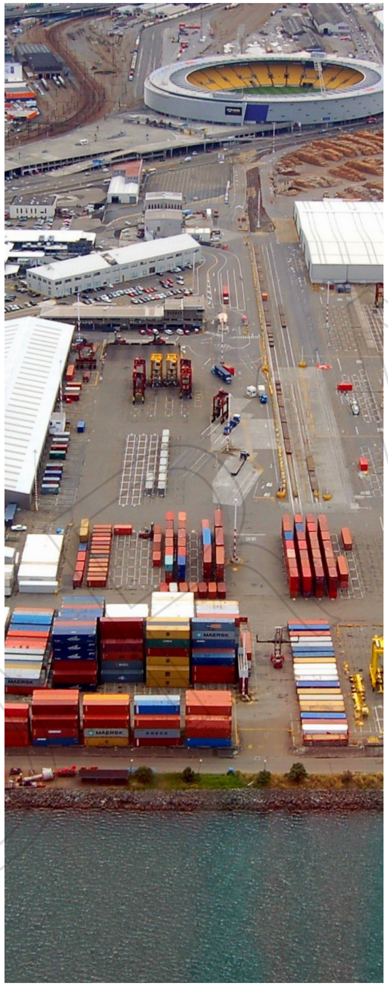
Industrial activities are typically associated with large areas of roof and impervious pavement. They are often associated with hazardous substances that have to be carefully managed to prevent contact with stormwater runoff. Generally, this type of open space is valued for its function over amenity.

Issues

- High site coverage increases runoff
- Inherent risk associated with onsite hazardous substances.

Opportunities

- WSUD measures can treat runoff from impervious pavements
- WSUD vegetation measures can be used to mitigate site activity impacts on adjacent land uses
- WSUD measures can enhance the image of companies/organisations.

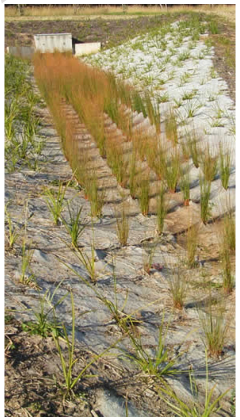


Centreport

Aim:
Collect, detain and treat stormwater to improve stormwater quality and smooth discharge flow. Use WSUD measures to mitigate negative effects that may be associated with particular industrial activities.

Potential WSUD measures:

- Rainwater tanks for reuse e.g. irrigation, vehicle washing and to smooth peak discharge flow
- Bio-retention system and 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.



Bio-retention system

Subsurface rain tank

Street trees

Filter media

APPENDIX 1

3.4 Streets, private ways and carparks

Characteristics
Streets, privateways and car parks are the most accessible form 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, privateways and car parks receive and convey contaminants from vehicles, road materials, maintenance operations and spillages that may occur. Runoff is also heavily influenced by surrounding landuse e.g. unpainted galvanised roofs.

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.
- Poorly managed infiltration can oversaturate subsoils

Opportunities
- Streets, while not the sole source of contaminants, may be the best places to treat stormwater.
- WSUD measures support compliance with the Council's Transport Strategy by minimising adverse environmental effects associated with transport activity.
- WSUD measures can enhance environmental quality and enhance amenity in streets, private ways and car parks.

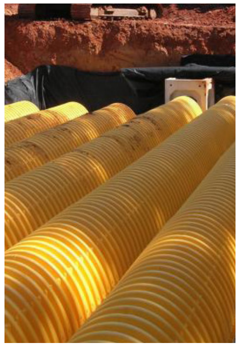
Jervois quay

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

Potential WSUD measures:

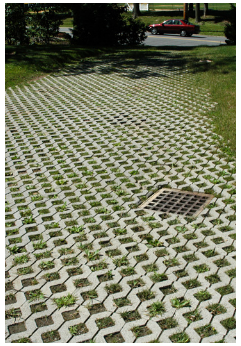
- Vegetated swales to intercept and slow runoff.
- Rain gardens and bio-retention systems in car parks or along verges to filter, treat and detain stormwater while improving amenity and habitat
- Perforated kerbs to allow runoff to enter detention/treatment measures
- Street trees to increase permeability,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

Vegetated swale



Subsurface detention

Rain-gardens



Permeable paving

This report is officer advice only. Refer to minutes of the meeting for decision.

3.5 Parks and gardens

Characteristics

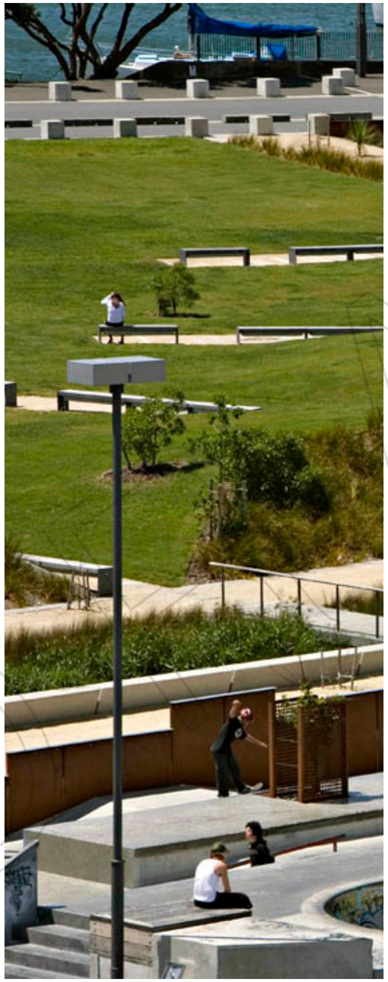
Parks and gardens are areas of City Council managed open space that are used for active and passive recreation.

Issues

- Recreational needs of the community may restrict where and to what extent WSUD measures occur.

Opportunities

- Integrate WSUD measures to support WCC Public Space Design Policy Objective 6: sustainability(Policy 3 WSUD practises will be incorporated in public spaces)
- Parks and gardens may have space to detain and treat stormwater from the upper catchment to mitigate stormwater quality and quantity effects on downstream
- Plan and manage parks and gardens to allow for WSUD measures while balancing the recreational requirements of the community.



Waitangi Park

Aim:
Design parks and gardens to mitigate the adverse effects of upper-catchment stormwater, while balancing the recreational needs of the community.

Potential WSUD measures:

- Vegetated swales to slow runoff and allow infiltration
- Rain gardens and bio-retention systems to treat stormwater
- Vegetation cover to reduce runoff and enhance infiltration
- Retention ponds to store runoff and smooth peak flows
- Detention ponds to slow runoff and smooth peak flows
- Wetlands to slow and treat stormwater and provide amenity and habitat.

Waitangi Park: collection & filtration 'treatment train'

Constructed wetland

Vegetated swale

Bio-retention treepit

Detention pond

3.6 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 are often receiving environments for urban stormwater runoff.

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 the discharge of large volumes of water over short time periods.

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 quality of urban stormwater prior to discharge into areas of bush or reserve.

Otari-Wilton's Bush

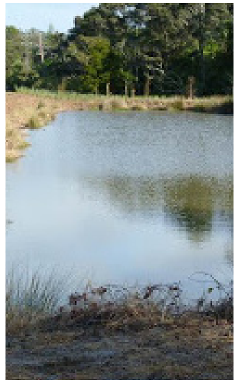
Aim:
Protect bush and reserves from impacts associated with the quality and quantity of stormwater discharge. Protect, retain and enhance streams in their natural state.

Potential WSUD measures:

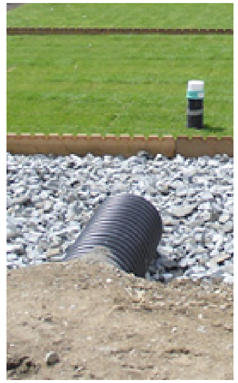
- Vegetated swales to intercept and slow runoff upstream from bush or reserve
- Plant or enhance vegetation to mitigate quality and quantity effects of urban stormwater entering areas of bush or reserve
- Dissipation measures to mitigate erosion caused by point discharges
- Retention and detention ponds to attenuate, store runoff, smooth peak flows, provide habitat and fire-fighting supply.

Riparian planting

Buffer planting



Detention pond



Dissipation measure

APPENDIX 1

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Part Four:

WSUD measures

These WSUD measures are components of a 'treatment train'. Whether natural, constructed or hybridised, measures rely on each other for input and discharge, collectively managing stormwater effectively. The 'treatment train' and each design measure within it require site-specific design. Measures included in this guide are not exhaustive.

4.1 All aboard the treatment train

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

Through site design and spatial planning existing natural features and/or introduced stormwater control features can be incorporated providing a WSUD treatment train. An integrated approach providing both water quantity and water quality benefits, as well as recreation and open space and ecological value.

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

Sequencing of components can combine natural and urban systems of treatment and conveyance to progressively remove contaminants and reduce volume.

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.

Collection

(interception, infiltration, attenuation, conveyance).

- rainwater harvesting
- infiltration trench
- permeable paving

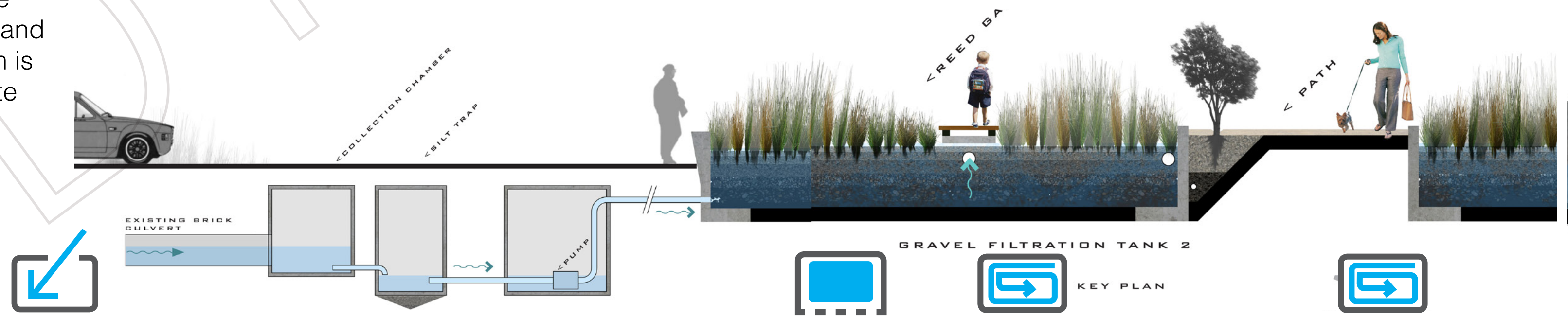
Retention

(temporary storage)

- rainwater tanks

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

Culvert → Subsurface wetland → Flow planter → Polishing wetland → Storage pond → Reuse / Discharge



Treatment
(filter, biological uptake, separation)

- bio-retention swales
- rain garden
- flow-through planter
- vegetated buffer strip
- vegetated swale
- media filter
- sand filter
- vegetated rock filter
- swirl separator
- water quality inlet
- drain insert
- baffle sump

Detention
(storage, infiltration)

- constructed wetland
- detention pond
- irrigation
- washdown

Discharge or reuse
(overflow)

Rain gardens I bio-retention swales

Function

Collection Retention Treatment Discharge

General description

Rain gardens are planted gardens with the added function of bio-retention systems. The use of plants at the surface, along with a below-ground filter medium, acts to detain and filter stormwater. The provision of a freeboard creates temporary ponding at the surface, which facilitates infiltration of the rain garden. The surface run off collected in rain gardens is cleansed as it percolates downwards. The filtered water is then collected in the subsoil drains and conveyed to sumps. Sumps provide overflow collection in larger storm events.

When is this suitable?

Rain gardens and bio-retention swales are able to tolerate low levels of pollutants from vehicles and urban land uses, so are viable adjacent to footpaths, carriageways and within car parks.

Case study: CentrePort, Wellington

Requirements

Collection:
- Surface run off - ensure falls towards the rain garden.
- Stormwater connection - protect against erosion from fast flowing discharge.

Size
- 5% - 7% of the drainage area that it is intended to accommodate. So a 1 hectare site (1,000m2)will require 50-70m2 of rain garden.
- Depth of 1m is preferable and relatively level ground.

Treatment
- Surface runoff is first filtered through the surface vegetation removing coarse to medium sediments. It then percolates through the filter medium where fine particles are removed and soluble nutrients are uptaken by the roots of the plants and soil microbes.

Discharge
- Ground infiltration can occur where ground is permeable (liner and subsoil drainage to be provided if this is not possible, for example in areas of contamination).
- Discharge to the stormwater mains via subsoil drains to sumps then mains.
- Grated sumps provide overflow system for times of extreme surface flows.

Maintenance

Monthly

Remove litter and debris (to be part of general soft landscape maintenance).
Plant maintenance, such as manual irrigation during drought, weeding, pruning and pest control are necessary (to be part of general soft landscape maintenance).

Annually

Routinely inspect and repair rain garden profile (to ensure flow conveyance).
Replant any gaps in planting
Routinely inspect and repair inlets and overflow to clear any blockage.
Routinely clean overflow sumps to remove litter and sediment.

Every 20 years

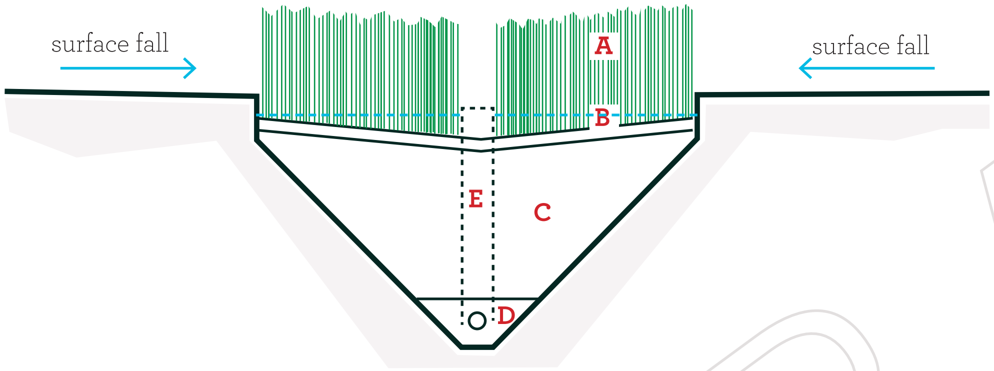
Replace all filter medium and planting. Dispose as contaminated.

Unusual events

Remove filter medium if large oil spillage or evidence of clogging.

Rain gardens I bio-retention swales

Typical cross section
Scale 1:50@A4



A Planting of appropriate species (with fibrous root systems to help keep the filter media porous)
B Shallow water ponding area (do not exceed 300mm)
C Filter media, 600 - 1000mm advisable
D Drainage layer
Sand over drainage metal with slotted subsoil drain connected to overflow system
E Overflow system
Grated sump connected to stormwater mains

Possible variations:
lining to prevent water infiltration into subsoils or adjacent paving sub-bases (if required)

Pros:

Environmental
- Reduction of stormwater quantity into the public system
- Visual enhancement, particularly in urban environments
- Habitat creation and promotion of biodiversity

Social
- Improves visual and environmental quality which in turn encourages positive use of urban spaces

Economic
- High visual and environmental quality spaces improve land values.

Cons:

Environmental
- Flat area requirement (but can provide weirs or terracing in slopes)
- Possible amendment of surface falls

Social
- Requires ongoing maintenance to retain quality

Economic
- Installation cost
- Maintenance cost.

Considerations:

- Planting, soil media and drainage require design to suit catchment and site conditions
- Width, length, depth and profiles require design to suit catchment area and site conditions
- Ensure freeboard is no greater than 300mm to reduce risk of drowning.
- Thorough investigation of in ground services is required.

Reference

- ‘On site stormwater management Guideline’ October 2004 - NZ Water Environment Research Foundation (NZWERF)
- ‘Active beautiful clean waters: Design Guidelines’ July 2011 - Public Utilities Board, Singapore
- Faculty for advancing water bio-filtration (FAWB) guide, June 2009 - Monash University.

Permeable paving

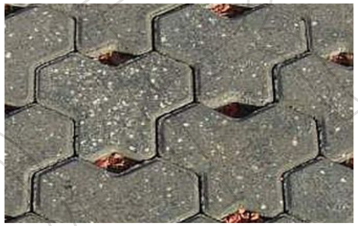
Function

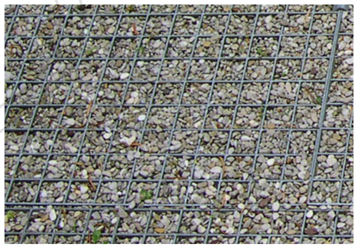
Collection | No Treatment | No Storage | Discharge

General description

Paving systems to facilitate and maximise infiltration of surface run-off water. Different types are available such as:

- porous concrete
- porous asphalt
- plastic modular systems
- interlocking concrete paving blocks (including modular and lattice blocks)





above: example of interlocking concrete block system
below example of plastic modular system

case study: Konst, Netherlands. infiltration into tree pits provides irrigation to trees and aeration for tree roots

When is this suitable?

Within urban developments to help reduce surface water rushing into the stormwater system.

Requirements:

Collection: - Surface run off - ensure falls towards the rain garden. Grade to be no greater than 7° (1:8)

Size - No size restriction. Amount of infiltration is limited so active drainage system required in conjunction with permeable paving

Treatment - None provided

Storage - None provided

Discharge - Ground infiltration combined with surface run-off collection.

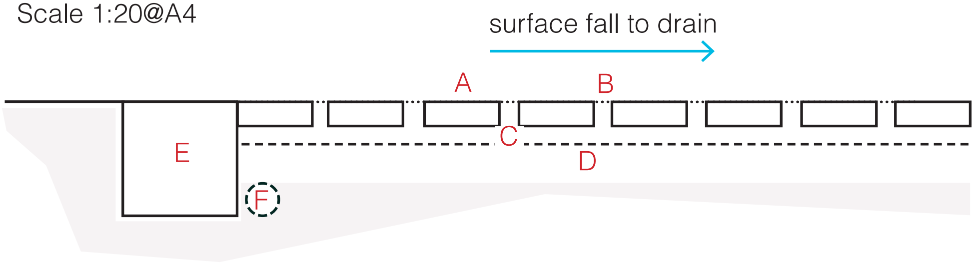
Maintenance:

Annually

Routinely inspect and repair paving.

Permeable paving

Typical cross section
Scale 1:20@A4



A Paving - concrete pavers shown
B Sand Joints
C Bedding sand
D Free-draining basecourse
E Edge constraint
F Subsoil drain

Considerations:
Pavement design for traffic and soil subsoil drainage to protect adjacent pavements

Reference:
- 'On site stormwater management Guideline', October 2004 - NZ Water Environment Research Foundation (NZWERF)
- 'Active beautiful clean waters: Design Guidelines' July 2011 - Public Utilities Board, Singapore
- Code of Practice for Land Development, December 2012 - Wellington City Council.

Pros:
Environmental
- Reduction of stormwater quantity into the public system with surface water infiltration in a situation where generally none is provided

Social
- Contributes to visual quality in areas of paving

Economic
- Permeable pacing can contribute to improved visual quality in urban areas.

Cons:
Environmental
- Infiltration rate is minimal in contrast to alternative methods
- No treatment unless combined with another WSUD measure

Social
- May not be the best hard surfacing option for practicability

Economic
- Higher cost than asphalt and maintenance is required

Green roofs

Function

General description

Extensive green roofs are vegetated and usually accessible for maintenance only. Planting is low-level and low-maintenance.
Intensive green roofs are often accessible and used for recreational purposes by public or building tenants. These intensive roofs can incorporate rain garden systems to provide potable water for irrigation or other purposes.

When are they suitable?

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

case study: Sedum roof, Littleborough, UK

Requirements

Collection: - rainwater onto roofs

Size - size limited to structural loading capacity
- access is required for maintenance

Treatment - rainwater infiltrates through the planting and limited volumes are stored in the lightweight soil. As the water percolates through the lightweight soil fine particles are removed and soluble nutrients are uptaken by the roots of the plants and soil microbes

Storage - limited storage within the lightweight soil. Can be connected to storage.

Discharge - plant evapotranspiration
- active drainage is required for the water not used by the system.

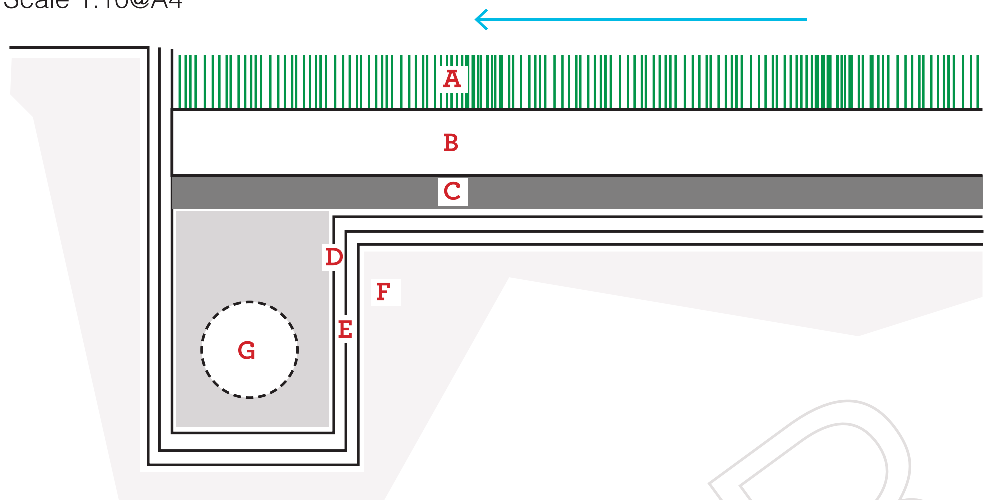
Maintenance:

Usually every three months (excluding winter)
Remove litter, debris from planted area and sediments from sumps
Plant maintenance, such as manual irrigation during drought, weeding, mowing and pest control are necessary

Annually
Routinely inspect and ensure no blockage to drainage.
Replant any gaps in planting.

Green roof

Typical cross section
Scale 1:10@A4



A Planting of appropriate species (shallow rooted and drought tolerant due to minimal soil depth)
B Lightweight soil
C Drainage system
D Root barrier
E Waterproof roof membrane
F Roof structure
G Perforated drain with drainage metal surround connected to stormwater mains.

Possible variations:
Deeper rooted plants where structural loading suitable for increased soil depths.

Considerations:
Careful structural and waterproofing detailing is need to avoid leakage.

Pros:
Environmental
- Reduction in stormwater quantity into the public system
- Visual and environmental enhancement, particularly in urban environments
- Habitat creation and promotion of biodiversity.
- Improvements to air quality and reduction in ‘heat island’ effect

Social
- Aesthetically attractive
- Can work in highly urban setting
- Acts as sound and temperature insulation

Economic
- Insulation of buildings regulate heating and cooling reducing mechanical temperature control infrastructure and electricity costs.

Cons:
Social
- Careful detailing and construction required.

Economic
- Initial installation cost.

Reference

- ‘On site stormwater management Guideline’ October 2004 - NZ Water Environment Research Foundation (NZWERF)
- ‘Active beautiful clean waters: Design Guidelines’ July 2011 - Public Utilities Board, Singapore.

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APPENDIX 1

Appendix A

Future document development

Recommendations on possible further studies.

APPENDIX 1

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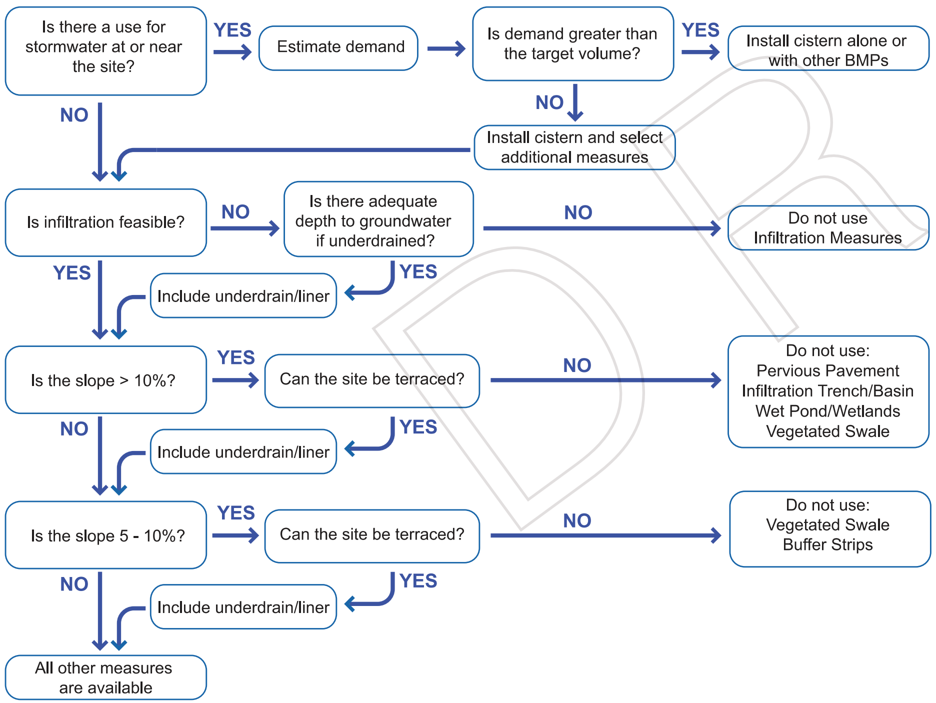
APPENDIX 1

WSUD measures selection matrix

A WSUD measures selection matrix will be useful in summarising what measures may or may not be suitable on specific sites. The Matrix below is included in the 'San Francisco Stormwater Design guidelines' and provides a useful example of a diagram that guides the reader through the selection of WSUD measures based on site characteristics.

It is recommended that a matrix be developed specific to Wellington.



Additional WSUD measure data sheets

A suite of data sheets is recommended to be developed prior to public consultation. Additional data sheets could include (but not limited to):

- Infiltration trench
- Flow-through planter
- Media filter
- Sand filter
- Vegetated rock filter
- Swirl separator
- Water quality inlet
- Drain insert
- Baffle sump
- Constructed wetland
- Detention pond
- Rainwater tanks.

Glossary

A glossary will be useful and is recommended to be developed and included prior to public consultation.

APPENDIX 1