Climate Adaptation Options Catalogue for Wellington

Urupare Huringa Āhuarangi
Climate Change Response

Absolutely Positively
Wellington City Council
Me Heke Ki Pōneke

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Introduction

The coastal location of Te Whanganui-a-Tara (Wellington, also known as Pōneke), with its steep hills and cliffs, combined with strong winds and rainfall make it very susceptible to natural hazards. Parts of the city are exposed to climate-related hazards, including flooding, coastal inundation and landslides.

Climate science shows that impacts of climate change are already affecting Wellington, and the projections show impacts will likely worsen over the coming decades and centuries.

Effective adaptation requires flexible long-term planning and implementation of adaptation actions to ensure co-benefits to many sectors and systems.[1] That means in practice, a range of adaptation options are likely to be considered and applied as environmental conditions change that reflect the local circumstances.

This catalogue provides a compendium of about 50 adaptation options to support Wellington City Council and its communities to have conversations on climate change and possible adaptation options to address risks arising from flooding, coastal inundation and landslides. There is a wide array of adaptation options and this catalogue is not an exhaustive list. The intent is to provide an introductory guide to a range of adaptation options for the Wellington context

Other hazards such as earthquakes, tsunamis, liquefaction, wildfire, drought and high winds are not directly included, but interrelationships of options with these hazards are mentioned to ensure a holistic perspective.

1. IPCC AR6 SYR SPM B4

The need for adaptation

The existence of these climate related natural hazards requires us to take actions to adjust to changing conditions. This need for adaptation has been identified in Wellington's Te Atakura - First to Zero Climate Action Plan. In its Action Area: Adaptation, the plan lays out how we can adapt to climate change, including by coming together as a community to develop adaptation plans.

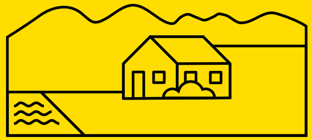
Adaptation are the actions that help manage, moderate, and cope with the effects of climate change. For example, avoiding building in areas likely to be affected by rising sea levels (Te Atakura First to Zero 2023 Update, p4).

Adaptation options are the array of strategies and measures that are available and appropriate for addressing adaptation (IPCC, p. 2898).

Actions taken to adapt to a climate related hazard can lead to increased risk of adverse climate related outcomes as an unintended consequence, such as increased greenhouse gas emissions or increased or shifted vulnerability to climate change. This is referred to as **maladaptation** (IPCC, p. 2915).

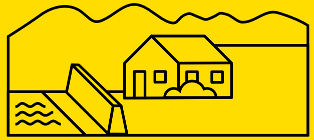
For more information on how climate change may affect Wellington, please visit Wellington City Council's climate change website.

Several types of adaptation options are available for adapting to climate related hazards. Often, they are classified according to whether they protect against, accommodate, retreat from or avoid climate related hazards (called **PARA framework**). Examples for each of these categories are shown opposite.



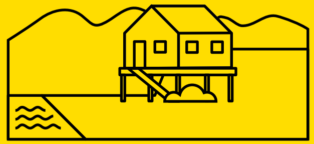
Examples for each of the PARA framework categories

Protect



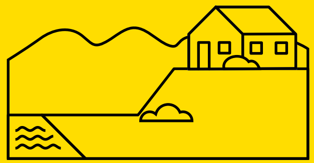
We keep the hazard away.
Protect assets from the hazard through structure (eg stop banks, sea walls) or natural-based (reg restored wetlands).

Accommodate



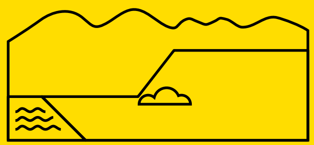
We live with the hazard.
Staying in place by adapting buildings and other structures to make them more resilient to the hazards. Options include things like raising land levels, managing ground and stormwater.

Relocation (also called Retreat)



We move away from the hazard.
Moving away from areas where the risk is too high, this can involve proactive relation or reactive relocation (eg property sales or buyouts).

Avoid



Prevent exposure to the hazard.
Minimise exposure by staying away from areas where the risk is too high. Examples of options include things like land zoning (eg high risk coastal hazard areas).

Source: PARA framework, adapted from MfE 'Coastal hazards and climate change guidance' (2024)

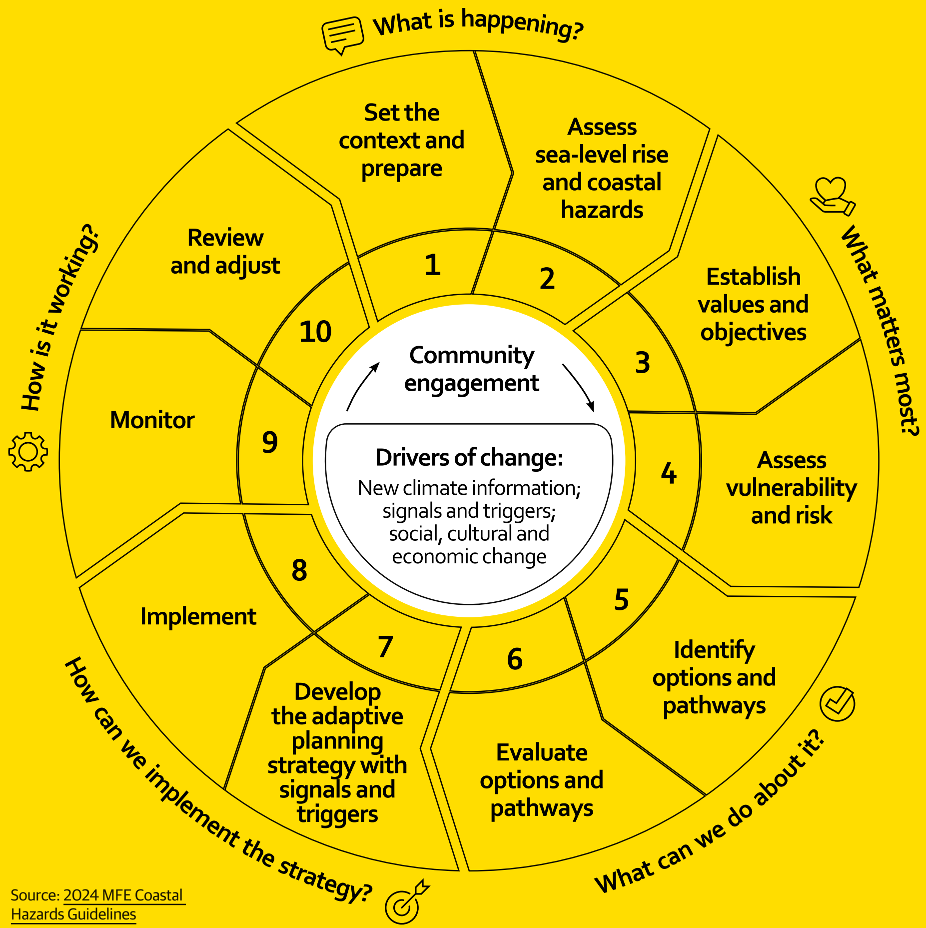
The Ministry for the Environment in its 'Coastal hazards and climate change guidance' (2024) recommends using a **10-step decision cycle for adaptation** to coastal and other climate-related hazards (see figure opposite). This includes the identification and evaluation of adaptation options (steps 5 and 6) and the use of the dynamic adaptation pathways planning (DAPP) approach.

In practice, a suite of options should be considered that reflect the local circumstances. The recommended dynamic adaptation pathways planning (DAPP) approach does not prescribe one single solution, but leaves future solutions for future decisions. It does so by identifying adaptation pathways made up from different options that might be suitable to adopt in the future once conditions change.

Once options and pathways have been identified, it is important to evaluate what is a good adaptation option or pathway. Evaluation criteria might include ability to meet objectives, flexibility to change in the future and avoid maladaptation, feasibility of implementation, costs, ability to meet community values and provide further co-benefits and adverse effects among others.

Partnership with mana whenua and involvement of the local community is integral to the identification and assessment of options.

More information on DAPP as well as evaluation techniques for adaptation options are provided in the Ministry for the Environment's Coastal Hazard and Climate Change Guidance.



Source: 2024 MFE Coastal Hazards Guidelines

Identification and assessment of options integral to adaptation planning

Effective adaptation requires holistic and flexible long-term planning together with mana whenua and local communities, the integration of western theory as well as mātauranga Māori and implementation of adaptation actions to ensure co-benefits to many sectors and systems.

What this catalogue covers

Adaptation options to address flooding, coastal inundation and landslides

This report outlines adaptation options to address potential risks arising from these three natural hazards that can be exacerbated with climate change. These have been identified as the key climate related natural hazards for Wellington based on the best available data. Other hazards such as earthquakes, tsunamis, liquefaction, wildfire, drought and high winds are not directly included, but interrelationships of options with these hazards are mentioned to ensure a holistic perspective.

Flooding both from excess overland water flows as a result of extreme rainfall that overwhelm drainage systems and natural waterways (pluvial flooding) and from overtopping/flooding of awa (rivers and streams, also known as fluvial flooding);

Coastal inundation (including from sea level rise, combined with storm surges and wave action); and

Landslides.

Mātauranga Māori

All options have the potential to be informed by mātauranga Māori (eg in relation to design, suitability, location and/or operation). A detailed assessment of specific options that includes mana i te whenua values and mātauranga is contextual, place-based, and highly variable, and at the discretion of mana i te whenua.

Early and meaningful involvement of mana i te whenua in the identification, assessment and selection of adaptation options is essential.

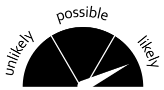
This report includes only high-level potential advantages and disadvantages of options from a te ao Māori perspective. For example regarding the potential for impacts on taonga species and wāhi tapu, water flows/mauri enhancement, or the ability of Māori to stay in their kāinga/ancestral lands.

The report mentions examples led and/or informed by mātauranga-a-whānau/hapū/iwi (ie Māori knowledge) which have also been sourced from iwi and hapū beyond Wellington City Council. In practice, mana whenua would be called upon to inform mātauranga-led options for the Wellington region, which may not be listed in this guide at this time but expect to expand over time.

Description of adaptation options

Detailed information is given for each adaptation option. This includes both identification of key characteristics in form of icons as well as a more detailed descriptions.

Key characteristics displayed as symbols include:

• **PARA classification**:	**Protect, Accommodate, Relocate/Retreat, Avoid**
• **Hazard/s addressed**: flooding, coastal inundation and/or landslides;	Hazards addressed: 
• **Cost range** (over the anticipated design life of the option): $,$$,$$$;	Cost: $ $$ $$$
• **Timeframe (likely)** (ie the anticipated design life of the option): short (0-20 years), medium (20-50 years), or long term (50-100 years);	Timeframe: S M L (0, 20, 50, 100)
• **Consenting requirements** (whether it the option is likely to be subject to resource and/or building consent): unlikely, possible, likely, n/a; and	Building and/or resource consent: 
• **Sponge city** (whether a solution supports the sponge city concept)	**YES**

Each option is then described and images and examples (local where possible) are provided. Advantages and disadvantages include environmental, economic, technical, socio-cultural, carbon and implementation aspects. The flexibility to respond to future uncertainties and interdependencies with other hazards such as erosion, earthquakes, liquefaction, tsunami, wildfire, and drought is also indicated. In order to avoid maladaptation, this report highlights any potential unintended consequences of an option on other hazards as well as the option's impact on greenhouse gas emissions.

Categorisation of adaptation options

This report categorises adaptation options into the following six categories:

- **Buildings** includes actions that can be taken at individual property level to adapt to climate related hazards.
- **Infrastructure general** includes actions to increase the resilience of infrastructure (eg energy, telecommunications, transport, waste, social).
- **Stormwater infrastructure** (also referred to as 'grey infrastructure') refer to human-engineered infrastructure for water resources, such as water and wastewater treatment plants, pipelines, and pumping stations.
- **Nature-based solutions** (also referred to as 'green infrastructure' or 'soft adaptation') are actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges such as climate change effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.
- **Structural or hard protection** approaches aim to stabilise shorelines, riverbanks or unstable slopes by constructing seawalls, dykes or retaining walls; and
- **Strategic planning approaches** that aim at avoiding or minimising risk through long term strategic planning of land use, including retreat, through land use and spatial plans.

What is a sponge city?

A concept that has become increasingly popular over the last decade is that of **sponge cities**.

A sponge city essentially soaks in rainwater and retains excess stormwater, then filters and releases the water slowly, much like a sponge, to avoid flooding or runoff in undesirable areas. Sponge city techniques utilise a combination of nature-based solutions (such as rainwater gardens, permeable surfaces) and grey stormwater infrastructure (such as retention ponds). They are intended not only to help with flood mitigation, but also help restore biodiversity and mauri of the environment within an urban context, and increase amenity and wellbeing. The concept of a sponge city is supported by the Water Sensitive Urban Design (WSUD) approach being taken by Wellington City Council.

Key considerations for all options

Common characteristics

Most of the potential adaptation options described in this report share some common characteristics, including:

- **Prevention of loss and damages**: options aim to reduce risk to life and/or damage from the hazard to buildings, infrastructure and wāhi tapu, and hence reduce future repair costs from damage.
- **Transformational vs adaptive change**: options seek to maintain current use of land, such as for housing, including living in papakāinga, infrastructure or recreational purposes (though this does not apply to retreat options).
- **Changes over time have thresholds and triggers**: options are generally designed to withstand a hazard of a certain size (eg 1 in a 100 year flood, sea level rise up to a certain level) and are prone to failure if this design capacity is exceeded or they are not appropriately maintained.
- **Systems approach**: options are likely to be designed as part of a system of other options, either directly in the location (eg pumps in floodable basements) or over time (eg dune restoration as a measure to buy time before retreating).
- **Multi-hazard management**: option design incorporates considerations in relation to a wider range of known hazards (eg earthquakes, liquefaction).

These characteristics are not mentioned again in the individual option descriptions, unless they do not apply to a specific option or there is a specific element that is worth highlighting.

Adaptation Options

Buildings

Adaptable buildings

PARA category:

Accommodate

Hazards addressed:

Cost:

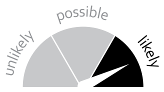
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Adaptable buildings are built and used in ways that accommodate future changes in environmental conditions. This includes floatable buildings that are anchored to a fixed point but able to move vertically so they can rise and fall with flood water levels as well as relocatable houses that can be moved elsewhere when conditions change. Mainly used for newbuilds.

Advantages:

- Can increase design life, value, saleability and insurability of the building.
- Potential for increased amenity (eg living right by the water), and recreational opportunities (eg boat access).
- Provides flexibility to adapt to future changes.
- Potential for low embodied and/or operational carbon emissions (eg through reuse/ recycling of materials), or longer lifespan.

A modern floating house

Disadvantages:

- Potentially increased building costs, depending on design, borne by owner, which might increase inequalities.
- Potentially increased building costs, depending on design, borne by owner, which might increase inequalities.
- Likely to require resource and/ or building consent.
- Potentially reduced access to building during flood (assuming road is not raised).
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake.
- Takes time for the housing stock to be renewed.
- Can incentivise further development in exposed areas and hence increase future vulnerability.

Examples:

- Relocatable house in Mapua.
- Floating village in Amsterdam, Netherlands.
- Pātaka store houses, though mainly used to keep food safe from rats, also had the co-benefit of preventing goods from being flooded.

Dry floodproofing buildings

PARA category:

Protect

Hazards addressed:

Cost:

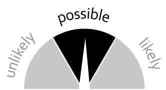
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



A building is sealed to prevent floodwaters from entering. This can be done through the installation of temporary or permanent devices such as door barriers, watertight window shields, flood gates and wall or non-return valves to keep the water out, as well as the use of sealants and membranes to reduce seepage of floodwaters through walls. Might need to be paired with other options (eg pumps to prevent ponding from rainwater or rising groundwater).

Removable flood barrier for door. Image courtesy of Lakeside Flood Solutions

Advantages:

- Relatively easy to install and maintain.
- Can increase design life, value, saleability and insurability of the building.
- Potentially low embodied carbon emissions (depending on materials used).

Disadvantages:

- Costs borne by owner, which might increase inequality.
- Requires early warning systems and awareness and appropriate and timely actions by owner.
- Might temporarily impede access to building during flood.
- Potential to increase flood risk to neighbouring properties (eg from flood water being diverted onto their land).
- Flood shields and sealants may not be aesthetically pleasing.
- Might require further incentives (eg rates rebates) or regulations (eg building standards update) for widespread uptake.

Examples:

- Queensland Flood resilient building guidance.

Flood pumps

PARA category:

Accommodate

Hazards addressed:

Cost:

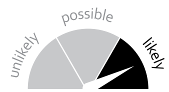
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Pumps that remove flood waters out from individual properties or neighbourhood areas, with water pumped to designated pits, stormwater drains, streams, rivers or the coast. Often paired with other options (eg wetproofing of buildings or flood gates). Some communities own mobile pumps that can be transported to flooded areas to help mitigate impacts during flood events.

Advantages:

- Relatively easy to implement and operate, with increasing options for automation (eg pump turns itself on if certain water levels are detected).
- Provides flexibility to adapt to future changes.

Disadvantages:

- Requires pipe system and land for installation of detention pit or tank where water can be pumped to.
- Costs for installation borne by owner, which might increase inequalities.
- Requires ongoing maintenance and/or upgrades.
- Potential negative impacts on neighbouring properties (eg from flood water being diverted onto their land).
- Potential operational carbon emissions (eg depending on how electricity required for pump operation is generated).

Examples:

- Use of flood pumps during Auckland Anniversary weekend flooding.

Flood pump after flooding

Living/green roofs and walls

PARA category:

Accommodate

Hazards addressed:

Cost:

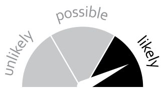
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Planting of vegetation or garden beds on the roofs or along the walls of private, commercial or industrial buildings of any size to prevent runoff generation from an otherwise impervious area at source and temporarily store and slow down water flows. Bigger living roofs and living walls are usually connected to the stormwater systems, so water release into the stormwater system after heavy rainfall can be controlled. These can be installed on new buildings or retrospectively fitted if structural design allows.

Advantages:

- Can increase design life, value and saleability of property.
- Creation of habitats for flora and fauna, including taonga species, in otherwise unused urban spaces.
- Opportunity to include mātauranga and Māori values for design and plants species.
- Provides wider ecosystem services (eg water filtering, water storage, nutrient accumulation, decrease of surface temperatures, improved air quality).
- Increased amenity (including noise reduction), recreational opportunities, and opportunity for cultivation of māra kai/ mahinga kai.
- Can act as carbon sink (eg if recycled plastics or zero-plastic aggregates used).

Disadvantages:

- Costs for installation and maintenance are higher than for a normal roof and borne by owner, which might increase inequalities.
- Careful structural loading and waterproofing is needed to avoid leakage into building.
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake by private entities.
- Requires ongoing maintenance and pest management.

Examples:

- Living Wall at Victoria University Wellington.
- Green walls at Westfield Newmarket.
- Hundertwasser Wairau Māori Arts Centre in Whāngārei.
- The Wellington Water Sensitive Urban Design Guide provides more information on green walls.

Bus shelter at Te Herenga Waka, Victoria University of Wellington

Roof garden

Permeable fencing

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

unlikely possible likely

Sponge city:

YES

Fences that are permeable and built of a water resilient material to allow the natural flow of flood waters and avoid localised pooling of water on individual and neighbouring properties. Permeable fences can be made of wires, steel, timber or mesh.

Advantages:

- Relatively easy to install.
- Provides flexibility to adapt to future changes.
- Emissions are likely to be low, depending on materials used.

Disadvantages:

- Potential impact on amenity, especially visual intrusions, including on neighbouring properties.
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake.
- Requires ongoing maintenance and potentially repair after events.

Examples:

- Fences deemed appropriate to use in flood-prone areas by the North Central Catchment Management Authority (Victoria, NSW) can be found in these Fencing Guidelines for Flood-Prone Areas.

Picket fence with pickets or palings spaced a minimum of 50mm apart and with a 150 mm clearance off the ground

Raised ground levels

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

unlikely possible likely

Land for buildings and infrastructure is raised to be above expected future flood levels and/or potential landslide runout areas. Materials commonly used to raise land include soil, rock or concrete. Land can be raised for individual building or infrastructure when newly built or upgraded, or for whole subdivisions.

Advantages:

- Can increase design life, value, saleability and insurability of the building.
- Requires no extra land.
- Potential amenity benefits (eg improved views due to higher elevation).

Elevated home

Disadvantages:

- Risk of erosion and potential to increase flood risk to neighbouring properties (eg from flood water being diverted onto their land).
- Costs borne by owner, which might increase inequalities.
- Impacts on amenity values and the 'streetscape', including shading of daylight.
- Potentially reduced access to building during flood (if road is not raised).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Potentially high embodied carbon emissions (eg depending on materials and methods used to fill in land).

Examples:

- Weka St Nelson.

Rainwater tanks

PARA category:

Accommodate

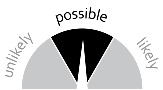
Hazards addressed:

Cost: $ (selected) | $$ | $$$

Timeframe: S (selected) | M | L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

A sealed tank serving an individual property designed to collect rainwater runoff from roofs, carparks through gutters, pipes and sometimes pumps. Can be above or below ground. This helps control stormwater runoff and reduce peak flows, reduces flooding and pressure on stormwater systems. Can also prevent stormwater from entering soil and reduce potential for landslides.

Advantages:

- Easy to install.
- Stored grey water can be used for gardens, laundry, and reduce costs for water bills.
- Improved emergency preparedness (eg drought, fire) through alternative water supply.
- Can design to minimise visual intrusion (eg tank colours/ buried in ground).
- Provides flexibility to adapt to future changes.

A 1000L rainwater tank fixed to a fence
Image courtesy of Watersmart

Disadvantages:

- Requires land space.
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake.
- Requires ongoing maintenance.
- Potentially high embodied carbon emissions depending on tank materials.

Examples:

- Rainwater tanks are one of the approved solutions for managing stormwater runoff for developments in Wellington.
- Puna Wai Ora, also known as Te Hiku Drought Relief Programme, is an iwi-led drought relief programme in the Far North, with the aim to install rain water tanks for Te Hiku whānau (funded with $8m million grant from the National Emergency Management Agency in the wake of the 2020 drought).

Wet floodproofing buildings

PARA category:

Accommodate

Hazards addressed:

Cost: $ | $$ (selected) | $$$

Timeframe: S (selected) | M (selected) | L

0 20 50 100

Building and/or resource consent:

Sponge city:

YES

Buildings that can accommodate flood waters, ie water is allowed to enter and exit the building, encouraging a more natural flow of water and sand, mud or silt. This can be done by lifting the structure above flood levels (eg on poles or stilts) and/or creating floodable basements (also called sacrificial ground floors) using flood damage resistant building materials, installing vents and ensuring service infrastructure is located above flood levels. Mainly implementable for new builds, but some options are available for wet flood proofing of existing buildings (eg lifting existing timber building by putting it on poles).

House being retrospectively raised

Advantages:

- Can increase design life, value, saleability and insurability of the building.
- Requires no extra land.
- Potentially low embodied carbon emissions (eg through reuse/recycling of materials).

Disadvantages:

- Costs borne by owner, which might increase inequalities.
- Potentially reduced access to building during flood.
- Takes time for the building stock to be renewed, ie widespread implementation takes time.
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake.
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.

Examples:

- Papakāinga Ngātiawatanga concept design for the Kōkōhīnau Papakāinga Trust.
- Flood resilient Brisbane – how to improve flood resilience for homeowners.

Yard and garden drainage

PARA category:

Accommodate

Hazards addressed:

Cost:

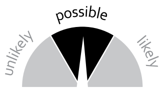
$ | $$ | $$$

Timeframe:

S | M | L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Installation of small scale drainage solutions in yards and gardens to divert and/or temporarily store water, such as swales, surface drains, trenches, infiltration boxes and small detention ponds. This reduces the quantity and speed of stormwater flow, relieving pressure on the stormwater system, as well as local ponding.

Advantages:

- Relatively easy to install.
- Provides wider ecosystem services (eg water filtering, water storage, nutrient accumulation).
- Emissions are likely to be low, depending on materials used.
- Provides flexibility to adapt to future changes.

Disadvantages:

- Requires space on property.
- Requires ongoing maintenance.
- Costs borne by owner, which might increase inequalities.
- Nuisance from bugs/mosquitos, and safety issues if not fenced.
- Might require further incentives (eg rates rebates) or regulations (eg district plan rules) for widespread uptake by private entities.

Backyard drainage system

Adaptation Options

General infrastructure

Increase capacity and durability of built infrastructure

PARA category:

Accommodate

Hazards addressed:

Cost:

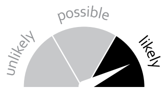
$ | $$ | **$$$**

Timeframe:

S | **M** | L

0 20 50 100

Building and/or resource consent:



Designing and building, upgrading, repairing or replacing infrastructure (energy, telecommunications, transport, waste, social) with increased ability to withstand, accommodate and recover rapidly from disruptions over its design life. This can include using floodable structures, raising infrastructure or vulnerable components (eg plugs) above flood levels, adaptable designs, or use of water resistant materials (eg stainless steel to reduce corrosion).

Advantages:

- Might increase design life, value and insurability of infrastructure.
- Increases reliability of provision of services, especially during and after events.
- Can attract further development and economic growth in surrounding areas.

Disadvantages:

Wairau Road substation Auckland
Image courtesy of Transpower

- Significant installation, upgrading and maintenance works.
- Potential impacts on neighbouring properties (eg through diverting of flood waters, visual impacts, noise).
- Can incentivise further development of buildings and infrastructure in exposed areas, potentially increasing future risk.
- Might require additional land and/or change in land use, leading to a loss of current land uses and potentially habitats and species, including taonga species, ecological connectivity and species migration.
- Potentially high embodied emissions through use of heavy machinery and materials such as concrete.

Examples:

- Wairau Road substation in Auckland, built in 2013 to withstand a 1 in a 450 year flood, remained fully operational during the Auckland Anniversary floods in 2023 despite 1.5m of water flowing through it.
- RiverLink, Lower Hutt.

Infrastructure operation and management

PARA category:

Accommodate

Hazards addressed:

Cost:

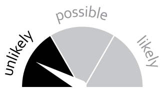
$ **$$** $$$

Timeframe:

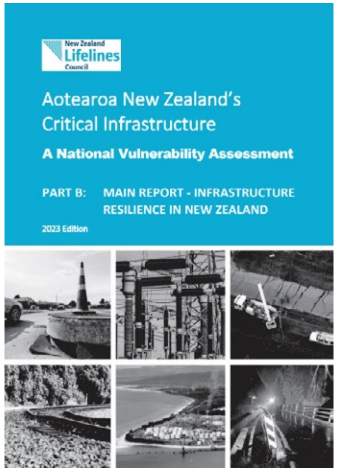
S M L

0 20 50 100

Building and/or resource consent:



Management of infrastructure and building works that account for weather and climate impacts (eg improved monitoring, revised works and maintenance schedules, operating rules of plants, timing of earthworks, creation of disaster mitigation plans, or strategic planning for climate impacts).



Aotearoa New Zealand's Critical Infrastructure Part B, Main Report

Advantages:

- Potentially increases asset/ design life and reliability of provision of services.
- Does not require physical changes to the asset or the environment.
- Provides flexibility to adapt to future change.

Disadvantages:

- Might require change in how infrastructure is currently being managed and installation of monitoring and early warning systems.
- Potential reduction of access during and after events.

Examples:

- Transpower's resilience plan includes work to understand the network vulnerabilities, service impacts, and acceptable risk levels for a range of credible resilience threats, including natural hazards exacerbated by climate change.

Adaptation Options

Stormwater infrastructure

Beach drainage

PARA category:

Accommodate

Hazards addressed:

Cost:

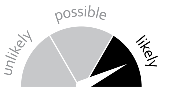
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Perforated pipes are buried in the upper beach of sandy surf beaches (ie beaches exposed to swell waves) to lower the beach ground water table. This increases the ability of water coming up in waves on the "uprush" to drain into the beach sand and reduces wave energy that moves back out on the wave "backwash", which can encourage sand to stay on the beach. This can reduce coastal erosion and in turn could reduce the potential of wave overtopping on the beach that could flood the hinterland.

Advantages:

- Pipes are largely buried, so limited visual impact.
- Relatively simple to install.
- Could help maintain natural habitats for coastal flora and fauna.

Disadvantages:

- Needs to be paired with pumping.
- Only suitable in specific locations (eg sandy beaches with swell waves that are not eroding long-term).
- Functionality can be reduced during high water levels (eg storm surges/king tides).
- Mixed performance in applications elsewhere, maintenance required and uncertain life expectancy.
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.

Examples:

- Beach drainage at Lyall Bay.
- Beach drainage on the Quend-Plage beach, France.

Lyall Bay, Wellington

Detention and retention tanks

PARA category:

Accommodate

Hazards addressed:

Cost:

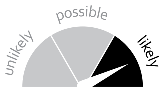
$ | **$$** | $$$

Timeframe:

S | **M** | L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Detention and retention tanks temporarily store stormwater from impervious surfaces during heavy rainfall/flood events. Tanks can be above or below ground and are usually made of concrete or plastic. Water can be slowly released into stormwater systems post event or stored and used for other purposes (eg irrigation) which will reduce the effect of the stormwater quantity/ flooding on the downstream catchment. Potential pairing with other options required (eg pumps).

Advantages:

- Can be used for irrigation and reduce costs for water usage.
- Can function as alternative water source in case of emergencies (eg drought, fire).
- Might increase value and insurability of neighbouring properties and can attract further investment and economic growth in surrounding area.
- Provides flexibility to adapt to future change.
- Low maintenance.

Disadvantages:

- Significant installation costs.
- Requires space and potentially the repurposing and/or purchase of additional land.
- Likely to require resource and/ or building consent.
- Potential increase in embodied emissions (eg through use of concrete).

Examples:

- The Wellington City Council Proposed District Plan requires hydraulic neutrality for more intense developments, including through on-site retention or detention tanks.
- The Wellington Water Sensitive Urban Design Guide provides more information on detention tanks.

Underground stormwater tank installed as part of land development

Diversion channels

PARA category:

Accommodate

Hazards addressed:

Cost:

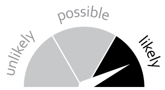
$ | **$$** | $$$

Timeframe:

S | **M** | L

0 20 50 100

Building and/or resource consent:



Engineered channels built to offer an alternative route for excess water flow to prevent flooding and reduce landslide risk if water is diverted away from landslide prone slopes. Can be large or small scale and permanently or temporarily (eg to divert water flow during construction) installed on private or public properties. Can be paired with vegetation along the margins.

Advantages:

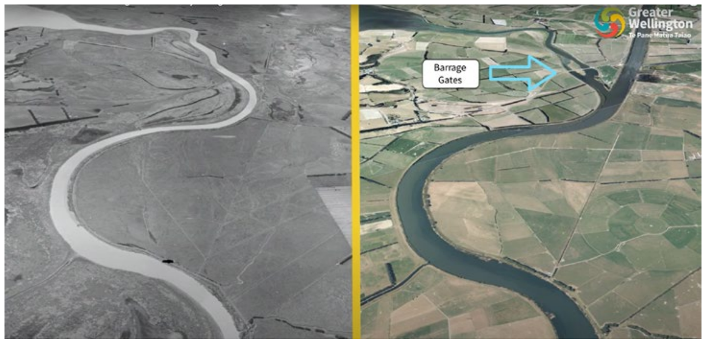
- Might increase value, saleability, and insurability of neighbouring properties.
- Can increase amenity (especially if planted), recreational opportunities (eg walkways along the bank).
- Can attract further investment and economic growth in surrounding area.

Disadvantages:

- Requires space and potentially the repurposing and/or purchase of additional land.
- Potential loss of habitats for flora and fauna, at installation site as well as at downstream wetlands and flood plains.
- Potential health and safety hazard (eg due to poor water quality of stormwater overflows or lack of fencing).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Potential increase in embodied emissions (eg through use of concrete).

Examples:

- Lower Wairarapa Valley Development Scheme (LWVDS).



Ruamahanga River diversion channel (to the right of the barrage gates) as part of the LWVDS, diverting water from its direct course into Lake Wairarapa to prevent flooding

Existing stormwater infrastructure management and upgrade

PARA category:

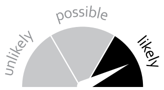
Accommodate

Hazards addressed:

Cost: $ $$ **$$$**

Timeframe: **S** **M** L (0, 20, 50, 100)

Building and/or resource consent:



Upgrade and maintain existing stormwater infrastructure to be able to accommodate future water levels, for example through changed design standards (eg such as larger pipes for water, wider streams) and the use of nature-based stormwater management techniques (eg vegetated filter strips or gravel trenches adjacent to roads). This decreases the likelihood of overtopping and flooding, and increases the resilience and reliability of the stormwater system.

Advantages:

- Can attract further investment and economic growth in surrounding area.
- May increase amenity values and recreational opportunities, especially if paired with nature-based solutions (eg tree pits).

Disadvantages:

- Significant installation, upgrading and maintenance costs borne by local government. May lead to increase in rates.
- Construction may put temporary strain on stormwater system and lead to overflows, flooding and erosion, and also impact on other infrastructure (eg roads) and private properties as well as access.
- Might require additional land and/or change in land use, leading to a loss of current land uses and potentially habitats and species, including taonga species, ecological connectivity and species migration.
- Can incentivise further development in exposed areas, which might increase future risk.
- Potential increase in embodied and/or operational emissions (eg through use of concrete, plastic or steel for construction).

Examples:

- Bridge to Better Nelson.
- Pinehaven Stream Improvements (Upper Hutt) to provide capacity in the stream for a 1 in 25 year return period flood event, including by building of retaining walls in built up areas and widening of stream where there is space.
- Up to date information on Wellington Water projects underway.

Retaining wall and stream divider as part of the Pinehaven Stream Improvement

Overland flowpaths management

PARA category:

Accommodate

Hazards addressed:

Cost: $ **$$** $$$

Timeframe: **S** **M** L (0, 20, 50, 100)

Building and/or resource consent:

The routes taken by water where there is no engineered drainage network or the network. Overland flow path management involves the identification and creation of flow paths (eg within road corridors, the clearing of blockages such as buildings, fences or other structures or leaves or fallen trees), as well as finding space for and widening floodplains to ensure water can flow freely without causing harm until it reaches a drain, river or the sea. Flow paths need to be kept clear to be effective but some flow paths are combined with planting programmes in the surrounding areas.

Advantages:

- Can reduce erosion and landslide risk through reduced stormwater flow speeds.
- If planted, flow paths can create habitats for flora and fauna, including taonga species, provide ecological corridors and enhance amenity and recreational opportunities.
- Provide flexibility to adapt to future changes.
- Can act as carbon sink if planted.

Overland Flowpath Overlay of the Proposed Wellington District Plan

Disadvantages:

- Might require access to and utilisation of private and public properties, and hence coordination of multiple stakeholders (eg councils, NZTA, hapū/iwi, residents, community groups).
- Potential health hazard if stormwater quality is poor.
- Requires ongoing monitoring and maintenance to keep flow paths clear.
- Potential embodied emissions if concrete and heavy machinery used.

Examples:

- Overland Flowpath mapping and regulations in the Proposed Wellington District Plan – if a house is located in an Overland Flowpath, it will need to be demonstrated that the floor level of the house is above the flood level and that the Overland Flowpath can still function.

Pervious surfaces

PARA category:

Accommodate

Hazards addressed:

Cost:

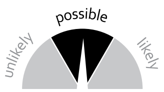
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Pervious or permeable surfaces and porous paving allow water to pass through to the underlying soil layers to assist in the reduction of runoff and flooding. Two distinct types include porous paving that stormwater travels through (eg porous concrete or asphalt) and permeable paving where stormwater travels through the gaps between the impervious blocks. Mainly used for low-impact transport infrastructure (eg driveways, parking lots, footpaths, walkways).

Advantages:

- Can improve water quality by filtering contaminants out of stormwater and increases groundwater recharge.
- Low maintenance.
- Potentially low embodied emissions if appropriate materials are reused (eg recycled tyres to make porous paving).

Disadvantages:

- Do not withstand heavy traffic very well and often have a shorter design life than nonpermeable pavings.
- Potential high embodied and/or operational emissions (eg through use of concrete, plastic or steel).

Examples:

- The Wellington Proposed District Plan requires at least 30% of residential sites to have permeable surface (able to absorb water).
- The Wellington Water Sensitive Urban Design Guide provides more information on permeable/porous paving.

Pervious pavement around trees along Wellington's waterfront

Pump stations

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

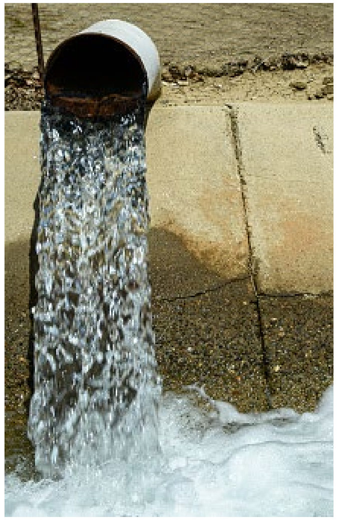
0 20 50 100

Building and/or resource consent:

Pump stations remove waters from flooded areas and pump it to designated water bodies, tanks or drainage areas. They are permanently installed and can function automatically if coupled with an automatic float switch. They tend to be part of a wider municipal flood defence systems (eg when combined with natural floodplains).

Advantages:

- Can increase value, saleability and insurability of neighbouring properties.
- Easy operation through automated systems.



Flood water being pumped into river

Disadvantages:

- Requires ongoing maintenance.
- Needs to be built resiliently to provide reliant services (eg above flood levels).
- Requires a designated area where water can be pumped to and energy to operate.
- May impact on amenity (eg noise during operation).
- Can incentivise further development in exposed areas which might increase future risk.
- Potential increase in embodied (eg through use of concrete) and operational emissions (eg through use of non-renewable energy).

Examples:

- Stormwater Pump Station in Waimakariri District.
- Karehana Park flood relief pump station in Plimmerton.

Underground drainage of slopes

PARA category:

Accommodate

Hazards addressed:

Cost:

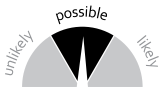
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Underground drainage installed into slopes to lower the groundwater table and stabilise slopes. Drains can be drilled or cut into soil or rock slopes. In many circumstances it is best used in conjunction with other measures such as earthworks to recontour the slope, soil/rock nails and anchors, and mesh protection.

Advantages:

- Might increase value, saleability, and insurability of neighbouring properties.
- Low maintenance.

Disadvantages:

- Lowering of groundwater can be harmful to flora and fauna, including taonga species.
- Potentially challenging installation and maintenance and significant costs, depending on site characteristics and scale.
- Potential increase in embodied emissions (eg through use of concrete).

Examples:

- Underground slope drainage as part of Nelson's Rocks Road cliff stabilisation.

Underground slope drainage on Transmission Gully

Adaptation Options

Nature-based solutions

Beach modification

PARA category:

Protect

Hazards addressed:

Cost:

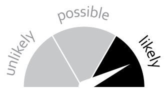
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



An option that mainly addresses coastal erosion but can also protect from wave overtopping. It involves the redistribution and regrading of on-site beach sand/material to provide natural protection or change conditions to reduce hazard risk. Does not involve addition from any off-site beach sand or other material.

Advantages:

- Can maintain natural habitats for flora and fauna such as on dunes, including taonga species, both on the beach and in near coastal environments.
- Can improve connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Can increase amenity and recreational opportunities (eg wider beach) which can raise value and saleability of nearby property and boost local economy (eg through attraction of tourism).
- Lower cost than beach nourishment.
- Provides flexibility to adapt to future change.

Disadvantages:

- Requires availability of onsite materials and ongoing beach maintenance (regularly, after storm events).
- Can damage natural habitats for flora and fauna, especially benthic communities that live within the sand.
- Temporary reduction of public access and nuisance from noise during grading.
- Operational emissions due to use of heavy machinery during grading works.

Examples:

- Owhiro Bay beach grading trial 2021/2022.

Owhiro Bay

Beach nourishment

PARA category:

Protect

Hazards addressed:

Cost:

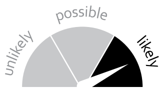
$ **$$** $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



This option mainly addresses coastal erosion but can also protect hinterland from wave overtopping. Beach nourishment involves deposition of off-site sediment (normally sand) on the beach, building a buffer between the sea and the coastal hinterland. The sand required can be excavated from nearby accumulating areas, through offshore dredging, or other suitable sources. Beach nourishment can reduce coastal erosion and in turn could reduce the potential of wave overtopping on the beach that could flood the hinterland.

Advantages:

- Can maintain habitats for coastal flora and fauna, including taonga species.
- Can improve connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Can increase amenity and recreational opportunities (eg wider beach) which can raise value and saleability of nearby property and boost local economy through attraction of tourism.
- Provides flexibility to adapt to future change.

Disadvantages:

- Requires ongoing monitoring, additional renourishments, maintenance and reliable material source.
- Costs can be significant if material imported.
- Potential loss of habitats and species, including taonga species, at both source and deposition sites (eg through burying of marine life and disruption of seafloor areas).
- Imported material could impact the mauri of the beach.
- Temporary reduction of public access and nuisance from noise during renourishment.
- Operational emissions due to use of heavy machinery and transport of materials.

Examples:

- Proposed beach renourishment at Makara Beach.
- Beach nourishment at Oriental Bay.

Beach nourishment at Oriental Bay

Beach nourishment at Oriental Bay

Contour drains

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

unlikely possible likely

Temporary excavated channels or ridges, or a combination of both, that are constructed across the contour of a land area to prevent scouring and erosion that can cause landslides, or to divert water away from landslide prone slopes to minimise rainwater from triggering a landslide. Often used during earthworks and construction but also on a small scale on private land and/or next to non-stabilised driveways.

Advantages:

- Relatively easy to implement.
- Reduced downstream sedimentation maintains natural habitats for flora and fauna, including taonga species.
- Provides flexibility to adapt to future change.

Disadvantages:

- Concentrated flows can cause increased erosion and landslides at downstream areas.
- Can damage natural habitats for flora and fauna, including taonga species, on site and change the natural landscape of an area.
- Requires continuous maintenance, especially after rain events.
- Potential operational emissions due to use of heavy machinery during drain creation.

Examples:

- Environment Canterbury Regional Council information on contour drains.

Contour drain. Source: ResearchGate

Creeks and streams restoration

PARA category:

Accommodate

Hazards addressed:

Cost:

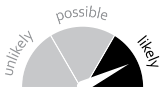
$ **$$** $$$

Timeframe:

S **M** **L**

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Also known as 'daylighting' or 'rewilding' creeks and streams, this option brings previously buried waterways back to the surface and into restored environments, or restores natural stream environments if already at the surface. This increases the area available for water to pass through, increasing storage capacity which reduces peak flows and increases flow duration. This helps to reduce downstream and localised flooding. Typically combined with riparian planting and floodplain restoration.

Advantages:

- Creation of natural habitats for flora and fauna, including taonga species, enhanced ecological connectivity, improved water quality, cooling effects.
- Can enhance natural character, mauri (eg maintain water flows for important puna (springs) and awa (streams and rivers)) and the connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Increased amenity, recreational opportunities and mental wellbeing by providing green spaces.
- Mātauranga could be used to guide the restoration process (eg the identification of original stream locations and native flora and fauna, design of restoration process).
- Initial costs can be mitigated with community support (eg planting days), low costs in the long term (easy maintenance once plantings are established, reduced water treatment costs). Can increase property values in surrounding areas.
- Provides flexibility to adapt to future change.
- Can act as carbon sink.

Disadvantages:

- Slopes cut for streams may experience instability and streams may cause instability of existing slopes.
- Requires space and potentially repurposing of land in urban areas.
- Potentially significant costs to create space (eg purchase land) and physically daylight streams as well as to coordinate multiple stakeholders (eg councils and council-controlled organisations such as Wellington Water, hapū/iwi, Department of Conservation, community groups).
- Potential health hazard if stormwater quality is poor.
- Requires ongoing maintenance and pest management.
- Initially potential increase in embodied emissions due to removal of piped infrastructure and use of heavy machinery.

Examples:

- Houghton Valley – Lifting the Creek.
- Mountains to Sea Wellington.
- Project Twin Streams (Auckland).
- Kia Mouriora te Kaiwharawhara Sanctuary to Sea.

An artist's impression of a daylighted Waitangi Stream on Kent/Cambridge Terrace

Buckley Reserve Kids Play Area, Houghton Valley

Dry detention basin

PARA category:

Accommodate

Hazards addressed:

Cost:

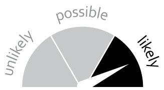
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

A constructed basin also known as dry ponds that detain stormwater before slowly releasing it into the storm water system to reduce peak flood flow rates. Allows for sand, mud, silt and pollutants to settle so they can be removed. Does not usually contain permanent pool of water. Suitable for areas with low groundwater levels and often has vegetated buffer around it.

Advantages:

- Easy to install with almost all soil types, though subsurface drainage may be required for non-porous soils.
- Provides flexibility to adapt to future change.
- Vegetated buffer can act as carbon sink.

Disadvantages:

- Limited water quality treatment ability.
- Decreased amenity values and recreational opportunities. Potential decrease in surrounding land values due to unnatural characteristics of basin.
- Nuisance from bugs/mosquitos and potential health and safety issues around water (especially for children) and if water quality is poor.
- Requires space, which might be difficult and costly to obtain in urban environment.
- Costs for building and maintenance.
- Regular maintenance required to prevent blockages and remove mud, silt and sand.
- Potentially high embodied emissions (eg if concrete is used).

Examples:

- Watersquare Benthemplein in Rotterdam, The Netherlands – a basketball court when it's dry, used for stormwater detention when it's wet.
- The Wellington Water Sensitive Urban Design Guide provides more information on depression storage.

Vegetated dry detention basin

Dune restoration

PARA category:

Protect

Hazards addressed:

Cost:

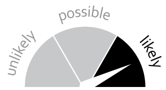
$** **$$ $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Restoration of dunes such as through earthworks and dune reshaping and of indigenous plants such as spinifex and pīngao. These plants catch windblown sands during storm events and trap it to build and maintain the dunes. Dunes can help absorb wind and wave energy, reduce coastal erosion and create a natural buffer between the sea and land, protecting the coastal hinterland from flooding.

Advantages:

- Can maintain and restore natural habitats for flora and fauna, including taonga species.
- Can enhance natural character, mauri, and access to the natural environment, including wāhi tapu (eg mahinga kai).
- Mātauranga could be used to guide the restoration process (eg the type of plant, practices for dune preservation such as selective harvesting of plants).
- Provides flexibility to adapt to future change.
- Can act as a carbon sink.

Disadvantages:

- Can require additional space and might impede on current uses of coastal areas.
- Can be a barrier to beach access and coastal views, and hence decrease amenity, recreational opportunities and property values.
- Requires ongoing maintenance including of access ways to maintain dune health.

Examples:

- Dune restoration in Lyall Bay and Island Bay.

Lyall Bay dunes

Living shorelines

PARA category:

Protect

Hazards addressed:

Cost:

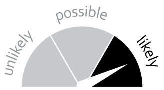
$ | $$ | $$$

Timeframe:

S | M | L

0 20 50 100

Building and/or resource consent:



Active planting of shorelines (including rocky coastal sections, turf fields) to create a barrier between land and sea, potentially combined with other natural materials such as rocks to support plant growth. They can act as natural "glue" for these environments and increase their ability to absorb and dissipate wave energy.

Advantages:

- Costs can be further mitigated with community support (eg planting days).
- Can maintain and restore natural coastal habitats for flora and fauna, including taonga species (eg banded dotterel, little penguin).
- Can help reduce drought and temperature fluctuations in coastal areas.
- Can enhance natural character and mauri.
- Mātauranga could be used to guide the restoration process (eg the type of plants and other materials to use and choice of locations).
- Can increase amenity and recreational opportunities.
- Provides flexibility to adapt to future change.
- Can act as a carbon sink.

Disadvantages:

- Takes time for plants to establish.
- Requires ongoing monitoring, maintenance and pest management.
- Can be a barrier to beach access and coastal views, and hence decrease amenity values, recreational opportunities.

Examples:

- Planting of rocky shore plants and restoration of coastal turf fields on Taputeranga Island, Houghton Bay and around the South Coast.

Newly planted area at Oruaiti Reserve

Rain gardens

PARA category:

Accommodate

Hazards addressed:

Cost:

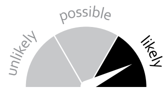
$ | $$ | $$$

Timeframe:

S | M | L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

A shallow landscaped depression planted with water tolerant native plants designed to soak up stormwater flowing from hard impervious surfaces, such as roads and driveways. Usually connected to below ground stormwater drains. Raingardens allow water to slowly seep into the ground rather than ponding or flooding at the surface before it enters the stormwater system.

Advantages:

- Relatively low cost to install.
- Creates natural habitats for flora and fauna, including taonga species.
- Provides wider ecosystem services such as increased water quality, groundwater recharge, air quality filtering and temperature regulation.
- Mātauranga could also be used to guide the construction process (eg the type of plants).
- Can enhance the connection and access to natural environment, including wai.
- Increased amenity, visual impacts, recreational opportunities and mental wellbeing through green spaces in the city.
- Provides flexibility to adapt to future changes.
- Can act as a carbon sink.

Disadvantages:

- Installation and maintenance costs to property owners and/or community.
- Requires space in communal zones or on private property.
- Requires maintenance and pest/weed management.
- Might require further incentives (eg rates rebates, public education) or regulations (eg district plan rules) for widespread uptake.
- Potential embodied emissions (eg through use of concrete for curbs).

Examples:

- Rain gardens in Swan Lane and Garrett Street.
- National War Memorial Park in Buckle Street will incorporate rain gardens to detain stormwater to irrigate the terraced park.
- The Wellington Water Sensitive Urban Design Guide provides more information on rain gardens.

Swan Lane rain garden
Image courtesy of JFC Ltd

Riparian planting

PARA category:

Accommodate

Hazards addressed:

Cost:

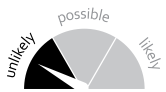
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Planting and maintenance of native species along the banks of rivers, streams, drains, wetlands, lakes or ponds to stabilise banks, slow down water flows and decrease risk of erosion. Can also help to stabilise toes of slopes and reduce landslide risk where water flows close to steep hills. Can be combined with other riparian stabilisation techniques such as brush mattresses that help stabilise the slope while vegetation grows.

Advantages:

- Low costs, can be mitigated with community support (eg planting days).
- Increased amenity and recreational values.
- Creates natural habitats for flora and fauna, including taonga species, on land and in the water. Provides further ecosystem services such as improved water quality.
- Can enhance natural character and mauri.
- Mātauranga can be used to guide the planting process (eg the successional planting of different species at different stages of the year, woven brush mattresses to help stabilise riparian margins).
- Relatively easy and low cost to install and maintain.
- Provides flexibility to adapt to future change.
- Can act as carbon sink.

Restored Kaiharawhara Stream with a healthy riparian plant coverage. Image courtesy of Steve Attwood - Auldwood Birds

Disadvantages:

- Costs associated with initial site preparation, planting, maintenance, restoration (eg if plants washed away during floods) and weed/ pest management, but costs can be partly mitigated with community support (eg planting days, maintenance and pest management).
- Requires consent of landowner, potential access issues on private land (could be mitigated by placing covenants on land)
- Takes time for plants to grow and maximise stabilisation effects.

Examples:

- Wellington City Council Stream Restoration Planting Guide
- The Wellington Water Sensitive Urban Design Guide provides more information on riparian buffers.

Seaweed restoration

PARA category:

Protect

Hazards addressed:

Cost:

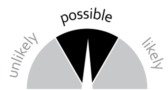
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Restoration of seaweeds on the seafloor can act as a natural form of coastal protection. It can reduce wave action and energy, in particular in shallow waters, reducing the strength and size of waves before they reach the coast.

Advantages:

- Can maintain and restore natural marine habitats for flora and fauna, including taonga species.
- Provides wider ecosystem services such as water filtering, more stable marine temperatures and control of ocean acidification.
- Can enhance natural character and mauri.
- Mātauranga could be used to guide the restoration process (eg the types of seaweeds and choice of location).
- Can increase amenity and recreational opportunities (eg diving, fishing).
- Can increase productivity of local fisheries and seaweed production.
- Provides flexibility to adapt to future change.
- Can act as carbon sink.

Disadvantages:

- Can be very difficult to implement properly, requires a lot of knowledge around specific species and where to best locate seaweed beds.
- Takes time for plants to establish.
- Costs for initial planting and ongoing maintenance.
- Requires monitoring, maintenance and pest management
- Can impede current use of the sea.

Examples:

- Love Rimu-rimu – Regenerating Wellington's Underwater Forests.
- Operation Crayweed – Restoring Sydney's Underwater Forests.

Seaweed along the Wellington coastline
Image courtesy of Mountains To Sea Wellington

Swales

PARA category:

Accommodate

Hazards addressed:

Cost:

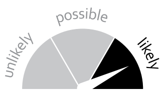
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

A landscaped 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 materials, underground drains and selected plants (bio-swale).

Advantages:

- Creation of natural habitats for flora and fauna, and provision of wider ecosystem benefits, such as improved water quality.
- Mātauranga can be used to guide the planting (eg type of plants).
- Can act as carbon sink.

Disadvantages:

- Costs for installation and maintenance (eg to prevent the accumulation of sand, silt and mud and debris such as leaves that could block drains).
- Requires space, which may be difficult and costly to obtain in highly urbanised areas.
- Changes in rainfall patterns may cause the system to become less effective.

Examples:

- The Wellington Water Sensitive Urban Design Guide provides more information on swale.

Swales at Harbour Quays, Centreport

Terracing

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

Sponge city:

YES

Conversion of steep slopes into a series of terraces, usually along the natural contours of the hill. This increases the slope's capacity to store water and slows down and guides surface runoff into a suitable outlet, reducing soil erosion. Can include vegetation and other features to further increase soil stability and/or control the movement and speed of water.

Advantages:

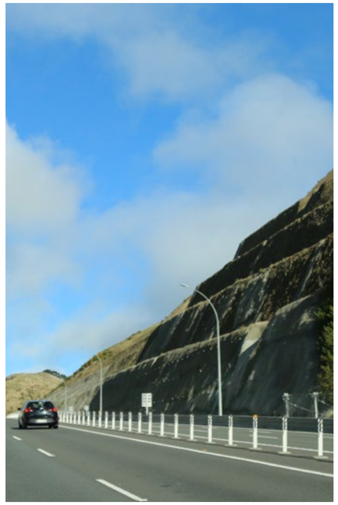
- Can create and maintain natural habitats for flora and fauna, including taonga species, both on the terraces and downstream (through reduced sedimentation).
- Terraces can be used for other purposes (eg gardens, buildings and infrastructure).
- Provides flexibility to adapt to future change.
- Can act as carbon sink if planted.

Disadvantages:

- Does not reduce deep seated landslides.
- Requires space and usually needs significant amount of earthworks and access for machinery.
- Potentially high costs for creation, depending on size.
- Can damage natural habitats for flora and fauna, including taonga species, on site and change the natural landscape and mauri of an area.
- Requires ongoing maintenance, especially after rain events, and pest management.
- Some embodied emissions due to use of heavy machinery and materials used during terrace creation.

Examples:

- Terracing was part of the slope stabilisation package at Transmission Gully.



Terracing on Transmission Gully

Tree pits

PARA category:

Accommodate

Hazards addressed:

Cost:

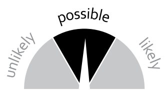
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Pits along sidewalks that trees are planted in with underground stormwater drains that capture water filtered through the pit. Tree pits capture and slow down stormwater runoff from the street and surrounding impermeable areas and temporarily store water before it enters the stormwater system.

Advantages:

- Requires very little space and can be incorporated widely across the city.
- Relatively easy and low cost to install and maintain.
- Creation of natural habitats for birds and other fauna in urban spaces, with an opportunity for incorporation of indigenous trees to urban spaces.
- Mātauranga could be used to guide vegetation (eg the types of native trees).
- Provides wider ecosystem services such as increased water quality, groundwater recharge, air quality filtering and temperature regulation.
- Can enhance te mauri o te taiao.
- Increases amenity values, visual impacts, and mental wellbeing through greening the city scape.
- Can act as carbon sink.

Disadvantages:

- Flooding can still occur if above design parameters or if not properly maintained (eg mulch can get clogged).
- Requires ongoing maintenance and pest management.
- Might increase fire risk during drought and health hazard during strong winds.

Examples:

- Tree pits at Pukeahu National War Memorial Park, Waitangi Park.
- Giess den Kiez ('Pour the neighbourhood') – online platform in Berlin, Germany, that allows citizens to coordinate the watering of Berlin's trees using an interactive map.

Tree pit at Pukeahu National War Memorial Park

Image courtesy of Steve Attwood - Auldwood Birds

Vegetating hills and slopes

PARA category:

Accommodate

Hazards addressed:

Cost:

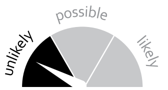
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Sponge city:

YES

Hills and slopes that are vegetated with grass, bush or trees to reduce, slow down and filter stormwater runoff, minimise erosion potential and stabilise slopes. Can be used on natural or engineered slopes (eg where cuts have been made to create roads).

Advantages:

- Creates natural habitats for flora and fauna, including taonga species, on site and in downslope environments, as well as further environmental co-benefits (eg filtered water, clean air, temperature regulation).
- Can enhance natural character and mauri, especially if native species used.
- Mātauranga could be used to guide vegetation (eg the types of plants and successional planting of different species at different stages of the year).
- Increased amenity, visual impacts, recreational opportunities and mental wellbeing.
- Can increase value of surrounding land and properties.
- Relatively easy to implement and maintain at a low cost.
- Can act as carbon sinks.

Disadvantages:

- May not be enough to prevent landslides under all conditions.
- Costs for initial planting and ongoing weed/pest management, but costs can be mitigated with community support (eg planting days).
- Requires space in communal zones or on private property.
- Requires maintenance and pest/weed management.
- Might increase wildfire risk during drought.

Examples:

- Forest in the Heart of Wellington project.
- Auckland's Urban Ngahere (Forest) Strategy.

Forest in the Heart of Wellington project planting in Tawatawa Reserve

Wet pond

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

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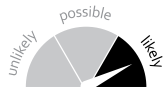
0 20 50 100

Building and/or resource consent:



Sponge city:

YES

A constructed basin or pond that has a permanent pool of water and is used to temporarily collect and store storm water. Water is held in the pond for a time, allowing sand, mud, silt and pollutants to settle so they can be removed. Water is then slowly released into stormwater systems post event to mitigate the size and intensity of flooding downstream or stored and used for other purposes (eg irrigation). Most ponds have some vegetation surrounding them.

Advantages:

- Can create natural habitats for flora and fauna, including taonga species, if planted, and can provide wider ecosystem services (eg improved water quality).
- Mātauranga Māori can help populate these new spaces with appropriate vegetation and help determine where to place the ponds.
- Can serve as alternative water supply (eg irrigation), especially in times of drought.
- Can be built on steeper slopes with terraces.
- Provides flexibility to adapt to future change.
- Can act as carbon sink if vegetated.

Disadvantages:

- Requires space, which might be difficult and costly to obtain in urban environment.
- Can lead to loss of natural habitats for flora and fauna on site and/or in downstream locations (eg through release of warmer water).
- Medium costs for installation and maintenance, depending on size, scale and complexity, and whether additional land needs to be purchased.
- Nuisance from bugs/mosquitos and potential safety issues around water (especially for children).

Examples:

- Aotea Stormwater Pond Porirua.
- The Wellington Water Sensitive Urban Design Guide provides more information on ponds.

Aotea Stormwater Pond Porirua

Wetlands: constructed

PARA category:

Accommodate

Hazards addressed:

Cost:

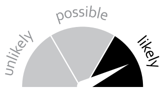
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

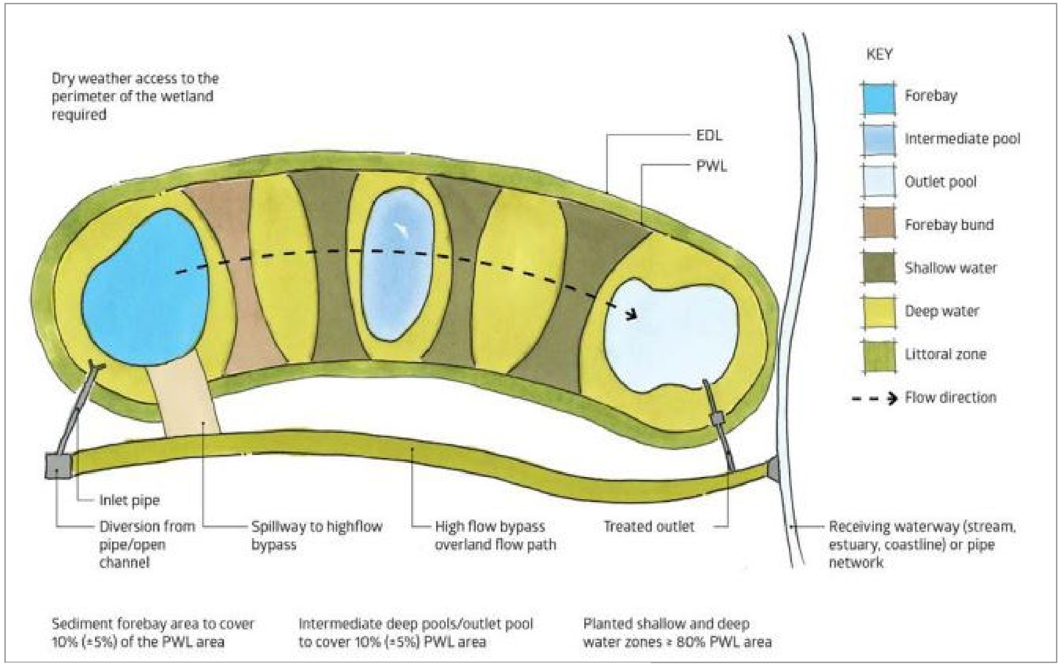


Sponge city:

YES

An engineered shallow-water environment that provides treatment and storage of stormwater and/or tidal flows in a series of shallow pools that are planted with riparian or emergent vegetation. Depending on design and storage capacity, can provide protection through buffering of flows during frequent small or more infrequent medium/large rainfall events or coastal inundation that are retained in the wetland and released slowly.

Constructed wetland at Waitangi Park, Wellington



Schematic main of constructed wetland components

Advantages:

- Creates habitats for flora and fauna, including taonga species
- Provides wider ecosystem services such as improved water quality on site and in downstream environments by filtering out nutrients, sand, mud, silts and microbes such as E.coli.
- Costs can be mitigated through community involvement (eg for planting, regular maintenance and pest control).
- Low maintenance once established.
- Can enhance natural character and mauri.
- Mātauranga could be used to guide the restoration process (eg the type of plants, the location of wetland).
- Can increase amenity, recreational opportunities and value of surrounding land and properties.
- Can reduce the risk of wildfires.
- Provides flexibility to adapt to future change.
- Can act as a carbon sink.

Disadvantages:

- Significant installation and maintenance costs, but costs can be partly mitigated with community support (eg planting days, maintenance and pest management).
- Requires a lot of space and time to fully restore to a self-sustaining wetland.
- Might need a sustainable water source during dry spells to maintain the health of the wetland.
- Nuisance from bugs/mosquitos and potential safety issues around water (especially for children).
- Can impede beach and river access and coastal views.
- Potential embodied emissions if concrete features used and due to machinery use during construction.

Examples:

- Constructed wetland at Waitangi Park.
- Porirua constructed wetland Te Kukuwai ō Toa.
- Manmade kūkūwai at Zealandia Te Māra a Tāne.
- The Wellington Water Sensitive Urban Design Guide provides more information on constructed wetlands.

Wetlands: restored or preserved

PARA category:

Accommodate

Hazards addressed:

Cost:

$ **$$** $$$

Timeframe:

S M **L**

0 20 50 100

Building and/or resource consent:

Sponge city:

YES

Wetlands are permanently or intermittently wet areas that support natural ecosystems that can reduce the impacts of flooding. Preserving existing or restoring former natural wetlands along coasts and rivers with indigenous species reinstates natural water table levels and flows as well as floodplains, allowing them to absorb heavy rain and release water gradually. Wetlands also help stabilise shorelines and riverbanks.

Restored wetland within Kāpiti's Queen Elizabeth Park

Advantages:

- Can restore natural habitats for flora and fauna, including taonga species.
- Provide wider ecosystem services such as improved water quality on site and in downstream environments by filtering out nutrients, sand, mud, silt, and microbes such as E.coli.
- Can enhance natural character, mauri and the connection to natural environment, including wāhi tapu (eg mahinga kai).
- Mātauranga could be used to guide the restoration process (eg where wetlands originally existed, soil health or the appropriate plants to use).
- Can increase amenity, recreational opportunities and mental wellbeing through providing natural open spaces.
- Can increase value of surrounding land and properties.
- Can reduce the risk of wildfires.
- Low maintenance once established, and a very long life span (>100 years).
- Provides flexibility to adapt to future change.
- Can act as carbon sink.

Disadvantages:

- Requires a lot of space and time to fully restore to a self-sustaining wetland but costs can be partly mitigated with community support (eg planting days, maintenance and pest management).
- Nuisance from bugs/mosquitos and potential safety issues around water (especially for children).
- Can impede beach and river access and coastal views.

Examples:

- Waikoko Wetland on Mana Island, Keith Taylor Wetland.
- Pikiraurahi, Te Pā Mahika Kai wetland restoration by Awarua Rūnaka.
- Te Reo o Te Repo: The Voice of the Wetland is a handbook that highlights a range of mahi (work) undertaken by iwi (tribes) and hapū (sub-tribes) to increase the health and wellbeing of their repo (wetlands).
- Nga-Roto-Ta-Pokapoka – Te Hiku o te Ika dune lakes/wetland restoration was an iwi-led project aimed at increasing skills and knowledge and improve the lake environments.

Adaptation Options

Hard protection/ structural approaches

Bunds

PARA category:

Protect

Hazards addressed:

Cost:

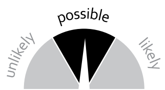
$ | $$ | $$$

Timeframe:

S | M | L

0 20 50 100

Building and/or resource consent:



Less engineered embankments than stopbanks next to a river, the sea or water diversion channels to protect the hinterland from flooding. Bunds can be built quickly, usually made of local gravel or soils, and involve only minor foundation preparation.

Advantages:

- Relatively easy to construct and low construction costs.
- Fairly flexible, can be adapted and managed to accommodate for future conditions.
- Likely low embodied and operational emissions if local materials used.

Disadvantages:

- Loss of natural habitats for flora and fauna through construction and by removing materials (eg from riverbed).
- Can decrease natural character, mauri and the connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Reduced amenity (eg loss of views) and recreational opportunities (eg fishing).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Requires regular maintenance.

Examples:

- Jellicoe Marsh bund in Christchurch.

Gravel bund on Wellington's South Coast

Detached breakwaters and artificial reefs

PARA category:

Protect

Hazards addressed:

Cost:

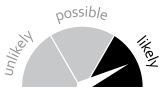
$ **$$** **$$$**

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



A structure made of rocks or concrete, built parallel to the coastline to reduce wave energy at the coast which encourages sediment to build up and make beaches wider. They can be above or below sea level, where the latter may be referred to as artificial reefs.

Advantages:

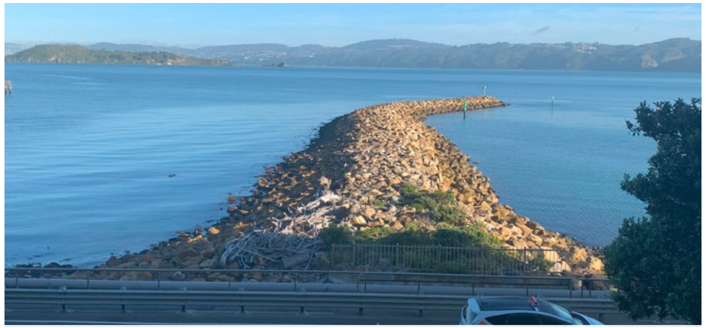
- Can increase recreational opportunities by building up beaches and providing low wave energy areas.
- Can create new habitats for marine species (eg artificial reefs).

Disadvantages:

- Impacts to seabed and kaimoana during and after construction.
- Might reduce amenity (eg visual impacts) and recreational opportunities such as by changing surf conditions.
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Construction materials might be difficult to source.
- Potentially high embodied emissions depending on materials used.

Examples:

- Wellington Seaview Marina.
- Artificial reef creation as part of building the Ngā Ūranga ki Pito-One (Ngauranga to Petone) section of Te Ara Tupua walking and cycling pathway.



Breakwater blocks in at Seaview Marina in Wellington Harbour

Groynes

PARA category:

Protect

Hazards addressed:

Cost:

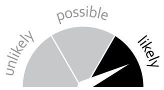
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Groynes are physical structures designed to trap sediment along the coast and restrict the transfer of sand away from the beach through long shore drift. They are placed at 90 degree angles to the shore and are usually made of wood or concrete. While they are aimed at reducing coastal erosion, groynes could have secondary benefits for coastal flooding such as by reducing potential wave overtopping by building up the beach and potentially providing a buffer to protest sand dunes.

Advantages:

- Relatively easy to construct and low maintenance.
- Potential improved amenity and recreational opportunities (eg creation and maintenance of a beach, improved shape of surfing waves).
- Ecosystems might establish in calmer areas down-drift.

Disadvantages:

- Potential loss of coastal habitats for flora and fauna (eg disruption of seabed may affect kaimoana) and disruption of natural processes.
- Can increase erosion to neighbouring sections of coast.
- Can decrease visual amenity, natural character and mauri.
- May impact recreational opportunities (eg creation of rip currents alongside groynes could be dangerous to swimmers).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Potentially high embodied carbon if heavy machinery and concrete used.

Examples:

- Omaha Beach.

Groyne in Oriental Bay

Retaining walls

PARA category:

Protect

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

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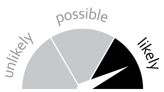
0 20 50 100

Building and/or resource consent:



Structures usually made of reinforced concrete block, concrete, steel or timber, installed to support steep cut or fill slopes by providing structural resistance to movement and draining of groundwater from slope. Deep in ground retaining walls and palisade walls can be used to stabilise landslides without retaining any above ground soil. Living crib walls made of timber, on-site fill material and live branch cuttings can stabilize steep banks and the toe of a slope from minor movements and settlements. Can be small scale (eg on individual property) or large scale.

Advantages:

- Might maintain property/ land values, saleability and insurability.
- Requires little space.
- Mātauranga could be used to guide the design and construction process, especially for living crib walls (eg plant selection, weaving techniques).
- Low embodied emissions if local natural materials used.

Disadvantages:

- Costs usually borne by owner, which might increase inequalities.
- Requires monitoring and maintenance over time.
- Risk of damage from earthquakes (especially for older retaining walls).
- High embodied emissions if concrete or similar and/or imported materials used.

Examples:

- The heritage listed Carlton Gore Road and Retaining Wall is an early civil engineering structure in Wellington designed to improve access between Oriental Bay and Roseneath.

Retaining wall with wall made of timber

Carlton Gore Road and Retaining Wall

Rockfall barriers, catch areas, rock sheds

PARA category:

Protect

Hazards addressed:

Cost:

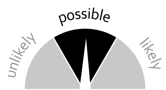
$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:



Rockfall barriers, catch areas, and rocks seeds are all passive protection measures that prevent damage to downslope areas from upslope rockfall source areas. They do not prevent rockfall, but mitigate its consequences.

Advantages:

- Relatively easy to install and maintain.
- Do not take much space to implement.

Disadvantages:

- Does not increase stability of slope against deep seated landslides, only protects development at toe of slope from rockfall hazard.
- Requires regular maintenance (to remove accumulated rockfall debris).
- Can decrease amenity (especially visual impacts).

Examples:

- Debris fencing on Moana Avenue, Nelson.

Rockfall barrier

Sea walls

PARA category:

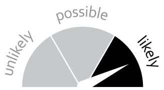
Protect

Hazards addressed:

Cost:

Timeframe:

Building and/or resource consent:



Engineered structures along the coastline with the purpose to deflect wave energy and/or protect the coastal hinterland from storm surges and waves. Seawalls are usually made of concrete, boulders or steel, but can also be made of other materials such as wood, aluminium, fiberglass or biodegradable sandbags.

Oriental Bay sea wall today

Ecological kete-like tiles being attached to the new rock embankment at the southern end of Te Whanganui-a-Tara (Wellington Harbour)

Advantages:

- Can create new habitats if combined with nature-based elements (eg living sea walls by ecological tiles).
- Can maintain property and land values, resaleability and insurability.
- Does not require much space.

Disadvantages:

- May worsen risk from other hazards (eg erosion on other parts of coast), and may result in scour fronting the wall.
- Significant construction costs, often paid by local government with costs retrieved from communities through levies or rates increases. Might increase inequality as often unaffordable for poorer areas.
- Loss of coastal habitats for flora and fauna (disruption of seabed may affect kaimoana) and disruption of natural processes.
- Can decrease natural character, mauri and the connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- Might reduce amenity (eg visual impacts) and recreational opportunities (eg loss of beach due to erosion).
- Might require maintenance and upgrades after events or to adapt to changing conditions.
- Construction materials might be difficult to source.
- Potentially high embodied carbon.

Examples:

- Testing of ecological tiles on Wellington seawalls in Lyall Bay and Owhiro Bay.
- Seawalls to protect the Ngā Ūranga ki Pito-One (Ngauranga to Petone) section of Te Ara Tupua walking and cycling pathway.

Soil nails, and soil and rock anchors

PARA category:

Protect

Hazards addressed:

Cost:

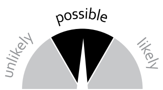
$ **$$** $$$

Timeframe:

S **M** L

0 20 50 100

Building and/or resource consent:



Measures to reinforce large steep slopes and counteract destabilising forces, typically made of steel bars grouted into place. Can be combined with shotcrete to further stabilise slope.

Advantages:

- Can be designed and installed over short timeframe and retrofitted to suit existing landscape.
- Might maintain existing property/land values, saleability and insurability.

Disadvantages:

- High installation costs and can be challenging to install.
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.
- High embodied emissions if concrete and/or imported materials and heavy machinery used.

Examples:

- Rocks Road Nelson.
- Ngaio Gorge slope stabilisation project.

Slope stabilisation on Lennel Road in Wadestown erosion netting, anchoring and spraying of shotcrete

Stop banks and levees

PARA category:

Protect

Hazards addressed:

Cost:

$ **$$** **$$$**

Timeframe:

S **M** **L**

0 20 50 100

Building and/or resource consent:

A continuous elongated embankment that stops water from a river or the sea from flooding nearby land. They are usually made of gravel or soil material with vegetated surfaces.

Advantages:

- Increased recreational opportunities (eg walkways on top).
- Can be combined with planting programmes that can incorporate mātauranga and enhance biodiversity.

Disadvantages:

- Can increase velocity of water and risk of flooding downstream due to loss of natural flood plains.
- Need to consider potential impacts on local drainage.
- Might increase inequality as often unaffordable for poorer areas.
- Loss of natural habitats for flora and fauna.
- Can decrease natural character, mauri and the connection and access to natural environment, including wāhi tapu (eg mahinga kai).
- Reduced amenity (eg loss of views) and recreational opportunities (eg fishing).
- Can incentivise further development in exposed areas which might increase future risk and reduce flexibility to adapt to future changes.

Examples:

- Hinemaurea ki Mangatuna Marae is protected by flood banks.
- Tangoio Marae looked at a range of adaptation options but found that the only feasible option is to protect the Marae by rebuilding the western stopbank and develop it further at its current location.

Stop banks along Te Awa Kairangi/Hutt River

Adaptation Options

Strategic and land use planning

Building/development standards

PARA category:

Accommodate

Hazards addressed:

Cost:

$ $$ $$$

Timeframe:

S M L

0 20 50 100

Building and/or resource consent:

N/A

Sponge city:

YES

Building and development standards and guides, land use plan rules, bylaws, urban development and growth strategies are updated or developed with a focus on reducing exposure and vulnerability to hazards. This could include matters like setbacks from the coast, rivers or cliffs, minimum ground/floor levels, drainage systems, flood proofing, property level water retention, structural specifications or reduced consent durations.

Advantages:

- Opportunities to incorporate sustainable building practices, including nature-based elements (eg raingardens and green roofs).
- Can increase value, insurability and saleability of new and upgraded houses.
- Can increase design life of new and upgraded developments.
- Provides flexibility to adapt to future change.
- Opportunity to integrate emission considerations into design.

Disadvantages:

- Impacts not felt until medium term due to delays in implementation.
- Only applies to new houses, significant upgrades and redevelopments but does not reduce risk to existing houses.
- Increased costs to developers and property owners due to need to comply with new provisions, which might increase inequalities.
- Potentially lengthy plan change processes, delayed implementation.

Examples:

- The Proposed Wellington District Plan requires hydraulic neutrality for more intensive developments (eg through rainwater retention), at least 30% of a residential site to have a permeable surface, and for water sensitive design methods to be incorporated into larger developments (four or more units and non-residential development).
- The Wellington Water Sensitive Urban Design (WSUD) Guide sets out the city's approach to water resource management in urban environments, integrating natural water systems with built form and landscape.

Pro-active strategic relocation

PARA category:

Relocate/ Retreat

Hazards addressed:

Cost: $ $$ **$$$**

Timeframe: S **M** **L**

0 20 50 100

Building and/or resource consent:

N/A

Pro-active relocation planning, zoning and implementation to remove houses, other buildings and infrastructure from areas of high current or future risk. This can be done through public acquisition of high-risk land (eg through voluntary or mandatory buyouts, land swaps, leasebacks, future interests, conservation easements, transferable development rights) and repurposing of original areas (eg re-naturalising them). Ideally includes the identification and/ or provision of low risk land to move to.

Advantages:

- Can eliminate risk to life, buildings and infrastructure in high risk areas.
- Long timeframes allow time for deliberation and planning to occur to ensure beneficial outcomes, including for future generations.
- Opportunity for community to shape new neighbourhoods with access to improved housing, services (health, education) and environmental benefits (eg blue-green infrastructure, reserves, lower emissions).
- Opportunity to re-naturalise origin area to create natural habitats for flora and fauna and enhance mauri.
- Mātauranga could be used to guide the retreat process (eg definition of triggers, signals and thresholds, identification of low risk areas to move to, monitoring of conditions).
- Potential to re-use materials and integrate emission considerations into new developments and create carbon sinks in original area.

Disadvantages:

- Requires significant upfront investment by government, landowners, businesses, infrastructure providers and potentially other organisations (like insurers and banks).
- Potential loss of cohesion, cultural identity, wāhi tapu, wellbeing, sense of place and belonging.
- Potential to perpetuate impacts of colonisation such as land loss.
- Requires coordination of all those affected with well run planning processes based on meaningful engagement.
- Takes a lot of time.
- Currently lack of national guidance, policy mechanisms, processes, funding and implementation support for the implementation of successful retreat.
- Likely to require plan changes and resource and building consents, together with strengthening of legislation.
- Not flexible once retreat process started (due to investment in infrastructure).

Examples:

- Project Twin Streams purchased and removed properties to reduce the risk of flood damage and make stream banks more accessible for restoration planting.
- Māori and other Indigenous peoples have rich histories of relocations, utilising their own Indigenous knowledge, local implementation, and adaptability to natural hazards.
- Managed retreat as one strategic area of the Ka Mate Kaainga Tahi, Ka ora Kaainga Rua the Ngaa Rauru Kiitahi climate change strategy.

Relocating a house

Restoration planting

Re-active relocation

PARA category:

Relocate/ Retreat

Hazards addressed:

Cost:

$ $$ **$$$**

Timeframe:

S **M** L

0 20 50 100

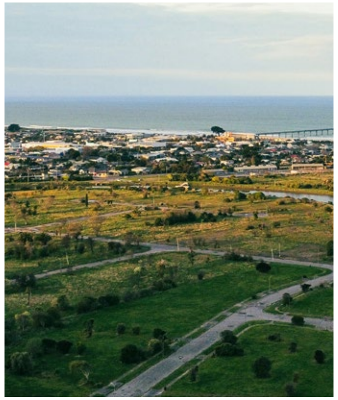
Building and/or resource consent:

N/A

Withdrawal, removal or relocation of people, private and/or public assets due to immediate danger or after hazard has occurred (eg through emergency evacuation, post-disaster buyouts or post-insurance withdrawal buyouts). Significant damage to assets and buildings often occurs.

Advantages:

- Opportunity to re-naturalise origin area to create natural habitats for flora and fauna and enhance mauri.
- Potential to re-use materials and integrate emission considerations into new developments and create carbon sinks in original area.



Christchurch Red Zone

Disadvantages:

- Lack of time to plan can lead to potential loss of livelihoods, housing, infrastructure, sovereignty, cultural identity, wāhi tapu, sense of belonging and community.
- May disproportionately affect vulnerable communities and limit ability for just and flexible adaptation response.
- Significant costs for emergency response, temporary housing and rebuilding.
- Potential impacts to papakāinga and connection to place for Māori.
- Contamination from flooded/ destroyed properties and assets.
- May reduce future generations' ability to adapt.
- Compressed timeline and unstructured retreat process.
- Appropriate locations for resettlement might not be immediately available.
- Requires coordination between multiple stakeholders.
- Potential increase of emissions during emergency response and as limited reuse of materials from damaged houses and infrastructure.

Examples:

- Christchurch Red Zone.

Restricting future development in high-risk areas and/or other activities that increase risk

PARA category:

Avoid

Hazards addressed:

Cost:

$ **$$** $$$

Timeframe:

S **M** **L**

0 20 50 100

Building and/or resource consent:

N/A

Identifying areas of high risk and restricting activities that could increase the risk (eg subdivision, intensification, new developments, social infrastructure) under future climate conditions in land use plans (eg through (re)zoning and limiting/prohibiting activities). Can be done by phasing activities out over time as risk increases (eg temporarily allowing movable houses) or all at once (eg following a hazard event).

Advantages:

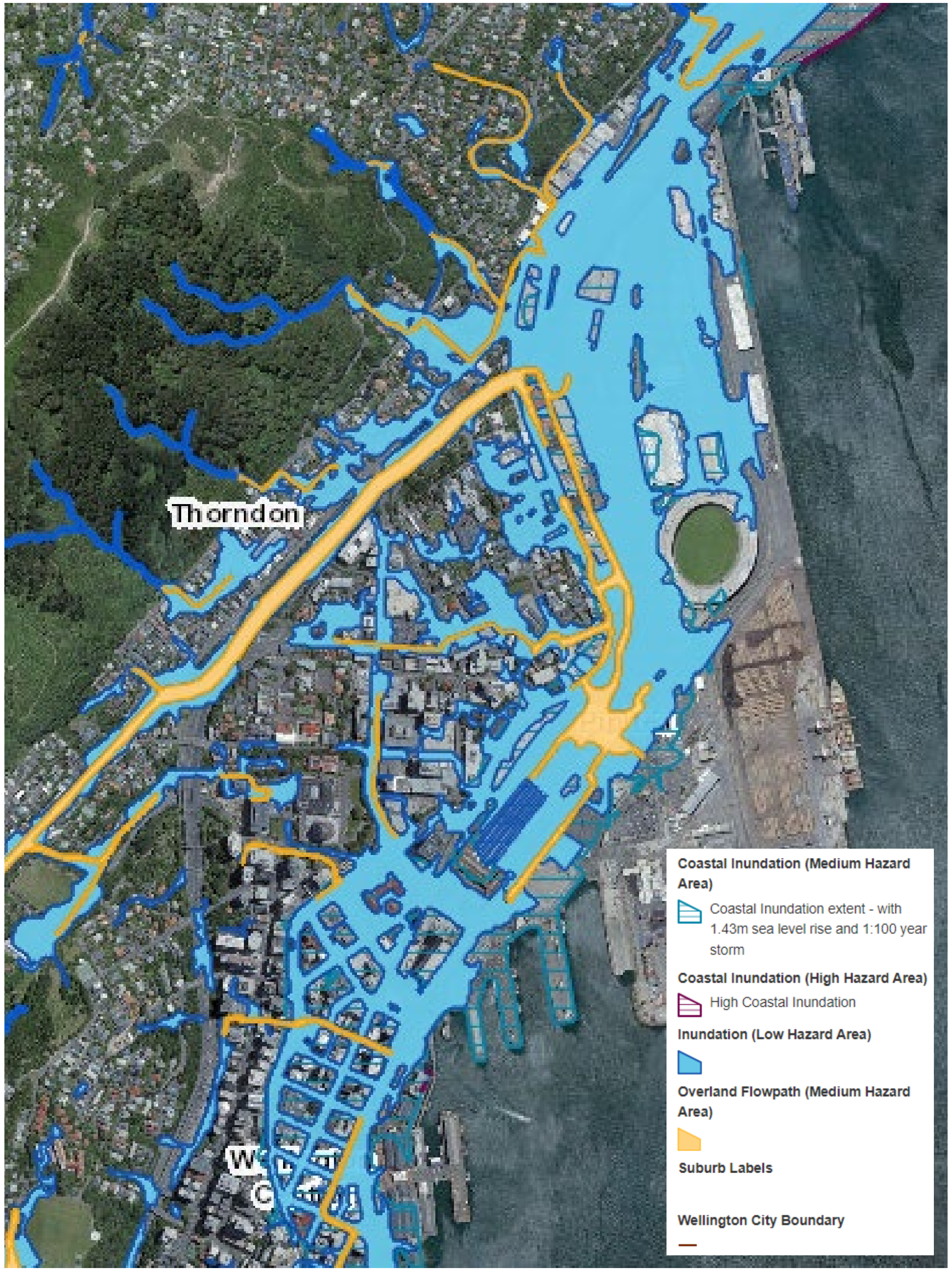
- Can increase value, insurability and saleability of land and houses in low risk areas.
- Costs for plan development and changes usually within normal council budgets.
- Opportunity to enhance environment and te mauri o te taiao (eg by rezoning land as open space or conservation land).
- Mātauranga could be used to guide the planning process (eg identification of areas and sites of cultural significance/wāhi tapu at risk and appropriate responses).
- Increase health and wellbeing through new recreational opportunities.
- Provides flexibility to adapt to future change.
- Reduction in emissions through avoidance of new developments and opportunity to integrate emission considerations into design.

Disadvantages:

- Often long planning processes with hearings and legal challenges.
- Impacts not felt until medium term as it takes time for the building stock to renew.
- Might lead to loss of insurability, saleability and property values in high risk areas, potentially increasing inequalities.

Examples:

- The Wellington District Plan places restrictions on building in high-risk areas (eg restricts the building of new sensitive activities, such as schools, hospitals or residential housing), or requires special design such as higher floor levels.



Flooding and coastal inundation overlays in the 2024 District Plan

Spatial and growth/ development planning

PARA category:

Avoid

Hazards addressed:

Cost:

$ **$$** $$$

Timeframe:

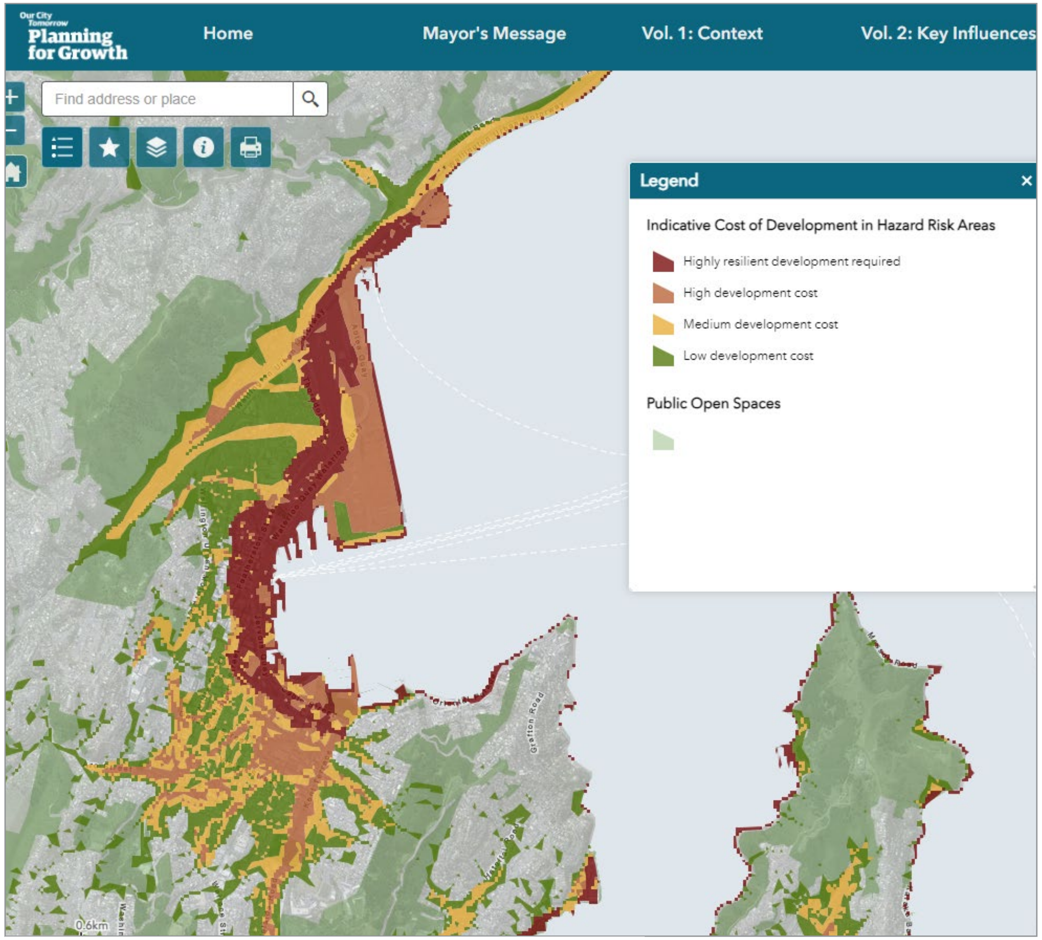
S **M** **L**

0 20 50 100

Building and/or resource consent:

N/A

Spatial and growth development plans set out where and how the city seeks to develop in the medium term. Hazard information is used to identify areas of current and future hazard risk as well as areas free of risk that will be suitable for future development, among other things such as community and transport hubs.



Wellington Spatial Plan map displaying indicative cost of development in hazard risk areas

Advantages:

- Takes an integrated, all hazards approach – combined with a broad focus on community aspirations and needs.
- Can direct development and activities away from areas at risk and/or identify appropriate actions to manage their future use dependent on the level of risk (eg modern building design).
- Can lead to increased and less costly development as well as higher house and land values and insurability in low risk areas.
- Community can provide input and shape the future of their city, with future generations in mind.
- Can help facilitate retreat discussions.
- Opportunity to enhance environment and te mauri o te taiao (eg by rezoning land as open space or conservation land).
- Mātauranga could be used to guide the planning process (eg identification of areas and sites of cultural significance/wāhi tapu at risk and areas of high/low risk).
- Can enable living in papakāinga, and encourage cultural practices such as, tikanga and mātauranga Māori.
- Possibility to integrate emission considerations into new developments and city design (eg 15 minute city).

Disadvantages:

- Costs for spatial plan development and implementation.
- Might lead to decrease in land and house values and insurability in high risk areas.
- Might change the amenity and character of a city.
- Takes time to develop and implement spatial plan.
- Requires coordination of multiple stakeholders (including government agencies, business, local residents, iwi).
- Requires visionary political leadership and/or legislative direction.

Examples:

- Our City Tomorrow: Spatial Plan for Wellington City aims to ensure that new communities are built in less vulnerable locations and new buildings are safe and built with risk in mind.
- 3 Waters Assessment to support spatial plan development.
- Maketu Climate Change Adaptation Plan He Toka Tu Moana Mo Maketu, includes as one of the actions Maketu spatial mapping and planning to show what Maketu might look like in 30-50 years time, in relation to climate change.

Adaptation Option	PARA Category	Hazard/s Addressed	Cost Range	Timeframe	Consent Requirement	Sponge City
Buildings						
Adaptable buildings	Accommodate	Flooding, Coastal Inundation	$$	Medium term	Likely	Yes
Dry floodproofing buildings	Protect	Flooding, Coastal Inundation	$-$$	Short term	Possible	No
Flood pumps	Accommodate	Flooding, Coastal Inundation	$-$$	Short term	Likely	No
Living/green roofs and walls	Accommodate	Flooding	$$	Short to medium term	Likely	Yes
Permeable fencing	Accommodate	Flooding	$	Short term	Possible	Yes
Raised ground levels	Accommodate	Flooding, Coastal Inundation, Landslides	$-$$	Medium term	Likely	No
Rainwater tanks	Accommodate	Flooding, Landslides	$	Short term	Possible	Yes
Wet floodproofing buildings	Accommodate	Flooding, Coastal Inundation	$$	Short to medium term	Likely	Yes
Yard and garden drainage	Accommodate	Flooding	$-$$	Short to medium term	Possible	Yes
Infrastructure general						
Increase capacity and durability of built infrastructure	Accommodate	Flooding, Coastal Inundation, Landslides	$$$	Short to medium term	Likely	No
Infrastructure operation and management	Accommodate	Flooding, Coastal Inundation, Landslides	$$	Short term	Unlikely	No
Stormwater infrastructure						
Beach drainage	Accommodate	Coastal Inundation, Flooding	$$	Medium term	Likely	No
Detention and retention tanks	Accommodate	Flooding	$$	Medium term	Likely	Yes
Diversion channels	Accommodate	Flooding, Landslides	$$	Short to medium term	Likely	No
Existing stormwater infrastructure management and upgrade	Accommodate	Flooding	$$$	Short to medium term	Likely	No
Overland flowpaths management	Accommodate	Flooding, Landslides	$$	Short to medium term	Possible	No
Pervious surfaces	Accommodate	Flooding	$-$$	Short term	Possible	Yes
Pump stations	Accommodate	Flooding, Coastal Inundation	$$-$$$	Short to medium term	Likely	No
Underground drainage of slopes	Accommodate	Landslides	$$	Short to medium term	Possible	No
Nature-based solutions						
Beach grading/scraping/push ups	Protect	Coastal Inundation	$	Short term	Likely	No
Beach nourishment	Protect	Coastal Inundation	$$	Short term	Likely	No
Contour drains	Accommodate	Flooding, Landslides	$	Short term	Possible	No
Creeks and streams restoration	Accommodate	Flooding, Landslides	$$	Medium to long term	Likely	Yes
Dry detention basin	Accommodate	Flooding	$$	Medium term	Likely	Yes
Dune restoration	Protect	Coastal Inundation	$-$$	Short to medium term	Likely	No
Living shorelines	Protect	Coastal Inundation	$	Medium term	Likely	No
Rain gardens	Accommodate	Flooding	$-$$	Short to medium term	Likely	Yes
Riparian planting	Accommodate	Flooding, Landslides	$-$$	Medium term	Unlikely	No
Seaweed restoration	Protect	Coastal Inundation, Landslides	$$	Medium term	Possible	No

Adaptation Option	PARA Category	Hazard/s Addressed	Cost Range	Timeframe	Consent Requirement	Sponge City
Swales	Accommodate	Flooding	$-$$	Short to medium term	Likely	Yes
Terracing	Accommodate	Landslides, Flooding	$$	Medium term	Possible	Yes
Tree pits	Accommodate	Flooding	$-$$	Short to medium term	Possible	Yes
Vegetating hills and slopes	Accommodate	Flooding, Landslides	$-$$	Short to medium term	Unlikely	Yes
Wet pond	Accommodate	Flooding	$$-$$$	Medium term	Likely	Yes
Wetlands: constructed	Accommodate	Flooding, Coastal Inundation	$$-$$$	Medium to long term	Likely	Yes
Wetlands: restored or preserved	Accommodate	Flooding, Coastal Inundation	$$	Long term	Possible	Yes
Hard protection/ structural approaches						
Bunds	Protect	Flooding, Coastal Inundation	$-$$	Short term	Possible	No
Detached breakwaters and artificial reefs	Protect	Coastal Inundation	$$-$$$	Short to medium term	Likely	No
Groynes	Protect	Coastal Inundation	$$	Short to medium term	Likely	No
Retaining walls	Protect	Landslides	$-$$$	Medium term	Likely	No
Rockfall barriers	Protect	Landslides	$$	Medium term	Possible	No
Sea walls	Protect	Coastal Inundation	$$-$$$	Short to medium term	Likely	No
Soil nails and soil and rock anchors	Protect	Landslides	$$	Short to medium term	Possible	No
Stop banks and levees	Protect	Flooding, Coastal Inundation	$$-$$$	Medium to long term	Likely	No
Strategic and land use planning						
Building/development standards	Accommodate	Flooding, Coastal Inundation, Landslides	$-$$	Short to medium term	n/a	Yes
Pro-active strategic relocation	Relocate/ Retreat	Flooding, Coastal Inundation, Landslides	$$$	Medium to long term	n/a	No
Re-active relocation	Relocate/ Retreat	Flooding, Coastal Inundation, Landslides	$$$	Short to medium term	n/a	No
Restricting future development in high-risk areas	Avoid	Flooding, Coastal Inundation, Landslides	$$	Medium to long term	n/a	No
Spatial and growth/ development planning	Avoid	Flooding, Coastal Inundation, Landslides	$$	Medium to long term	n/a	No

Climate Change Response
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Urupare Huringa Āhuarangi
Climate Change Response

Absolutely Positively Wellington City Council
Me Heke Ki Pōneke