AUCKLAND DESIGN MANUAL
TE PUKA WHAKATAIRANGA I A TĀMAKI MAKAURAU

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Site analysis >

Site analysis process

In the Site Analysis phase of design, the project team uses the resource mapping (from the Site Assessment phase) to explore a potential development layout for the site. This includes the following steps, each of which should respond to the principles of WSD:

Develop project objectives based on assessment work, and WSD principles and objectives based on regional, catchment and site priorities .

Thornton Creek Daylighting, Rainier, Washington, USA

Establish an environmental framework appropriate to the site's ecosystem functions and values. This should support potential development with an appropriate level of environmental services and landscape values whilst meeting the objectives of WSD.

Prepare a development framework that responds to site conditions with appropriate development densities, building coverage and infrastructure services.

Review the site context at the regional and catchment scales, and in accordance with proposed site-specific land uses.

Site analysis >

Project objectives

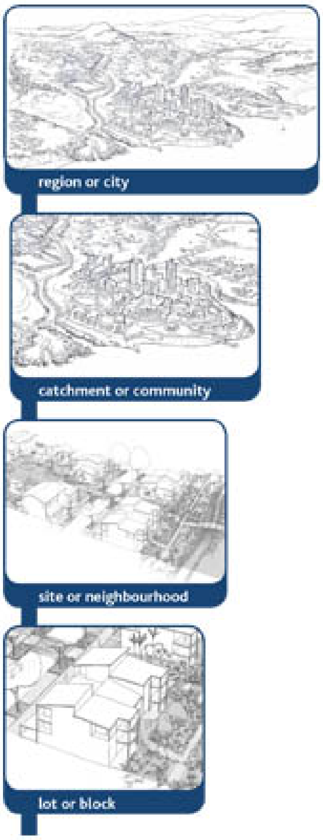
Prior to undertaking the site analysis, it is recommended that the project team meets to develop project objectives.

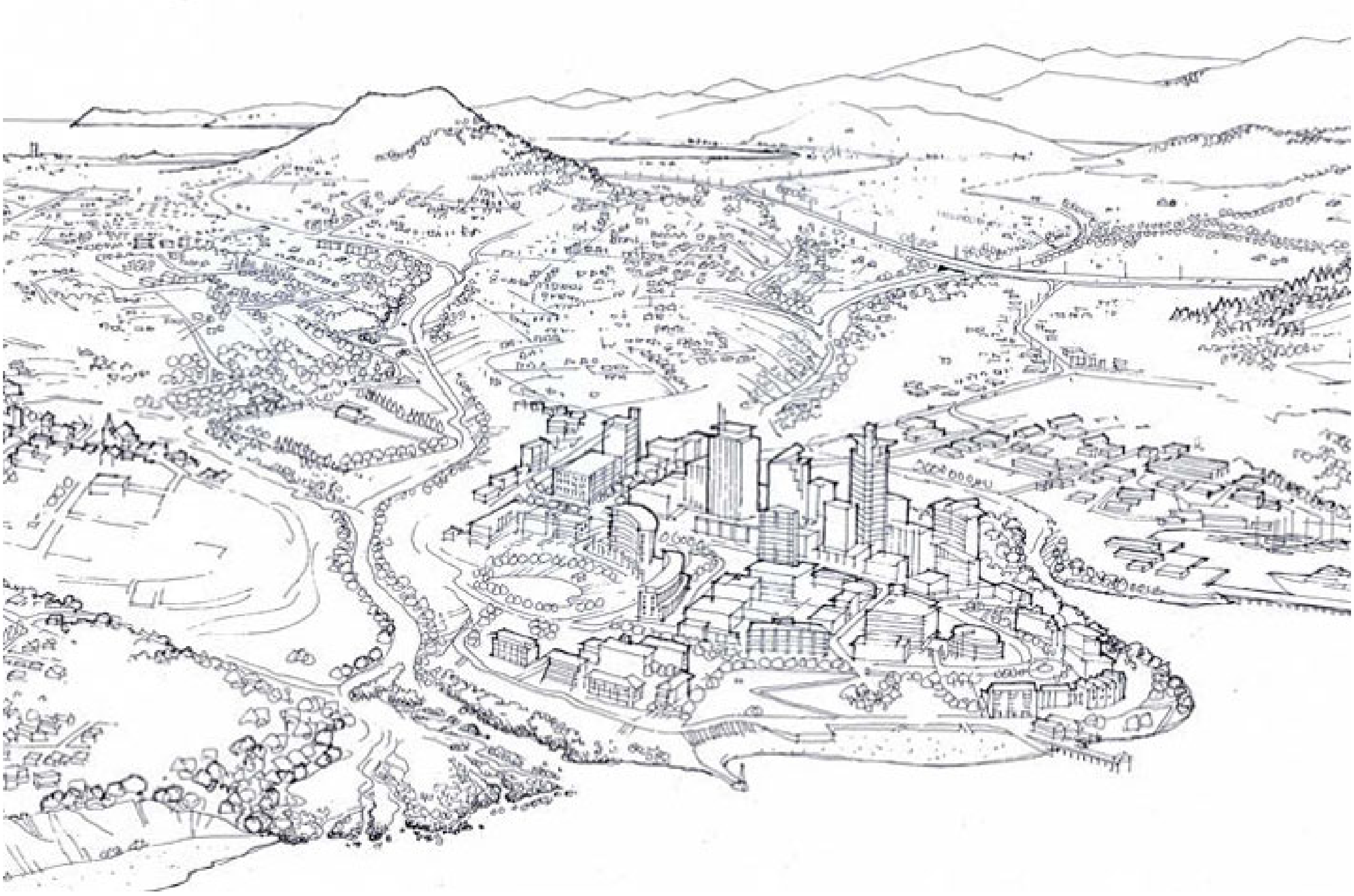
This will set aspirations as well as the minimum requirements for a project in addition to statutory requirements. This should be informed by the WSD objectives introduced in Section B, including:

- Reduce stormwater runoff - reduce stormwater runoff volume and peak flow to predevelopment levels
- Manage stormwater quality - manage stormwater quality to avoid adverse environmental effects
- Minimise soil disturbance - minimise sediment in stormwater runoff, especially during construction, and protect site soil resources from modification
- Promote ecosystem health - Promote the health of regional ecosystems and their associated environmental services through the management of stormwater at the catchment and site scale
- Deliver best practice - deliver best practice urban design and broader community outcomes as part of stormwater management delivery
- Maximise return on investment - achieve maximum value from stormwater management through the consideration of a broad range of benefits
-

Site analysis > Project objectives >

The scales of WSD





The Royal Commission Findings on Auckland Governance (Salmon et al., 2009) called for robust, considered and consistent planning to support the region's ongoing growth and development. At the regional scale, WSD contributes to this process by promoting resilient ecosystem services to support an appropriate growth pattern.

The promotion of WSD principles at the regional scale is based on a clear understanding of the values and connectivity of ecosystem services in the region. It is also a means to promote the collaboration of stakeholders with regulators in planning processes. The WSD principles previously introduced in Section A of this guideline are presented below in consideration of the regional scale.

1. **Promote inter-disciplinary planning and design.** Collaboration between Council units and developers can lead to opportunities for integrated objectives and priorities for infrastructure (environmental, social, property and transport).
2. **Protect and enhance the values and functions of natural ecosystems.** Provide for the protection of representative and rare natural systems in regenerative patterns in order to achieve ecological connectivity and resilient ecosystem services in the region. Water quality requirements are often driven by the goal of protecting regionally significant ecosystems.
3. **Address stormwater effects as close to source as possible.** Cumulative effects become significant at the regional scale. Mitigating the effects of development on the environment is difficult and costly with an "ambulance at the bottom of the cliff" approach. Mitigating issues as close to source as possible avoids these cumulative effects and provides resilient mitigation systems through the removal of central points of failure.
4. **Mimic natural systems and processes for stormwater management.** Increase the resilience of natural systems and processes for stormwater management across the region by promoting appropriate development patterns for headwaters and aquifers, watercourses, inland lakes, isolated wetlands, and coastal areas. Look to broad regional ecosystem enhancement opportunities such as urban forestry, a system of natural floodplains, or creating large scale wetlands.

Catchment scale

The catchment is the most useful spatial planning scale for the implementation of WSD principles. There is a direct causal link between stormwater runoff within a catchment boundary, and potential downstream effects to receiving environments. Catchments are defined by topographic boundaries, which also form discrete land management units and inform the potential layout and intensity of the built environment. Catchment planning requires an understanding of three interrelated processes in the catchment:

- Land use practices generating stormwater runoff and contaminants
- The means in the catchment (natural or structural) to detain, retain, treat, convey and attenuate stormwater runoff
- The values, natural functions and intended uses of receiving environments.

The best means to apply WSD principles at the catchment scale is through the integration of parallel planning processes such as catchment management plans (CMPs), watercourse management plans (WMPs), sustainable catchment programme (SCP) plans and comprehensive development plans (CDPs). These plans can focus on converging infrastructure issues in the catchment to ensure a balance of built and natural environments, and to reflect the values and sensitivities of the receiving environment. The WSD principles previously introduced in Section A of this guideline are presented below in consideration of the catchment scale.

1. **Promote inter-disciplinary planning and design WSD** promotes early consultation between individuals in the Council and the development community. A working group within the Council, potentially including large landowners, can share information and mutually agree objectives and priorities for a catchment. This is a means to ensure infrastructure planning achieves multiple objectives across stormwater management, ecology, urban design and cultural values. This also provides an opportunity to combine engagement with community, iwi and public agencies on a range of issues.
2. **Protect and enhance the values and functions of natural ecosystems.** Natural ecosystems, including vulnerable soils, groundwater aquifers, areas of terrestrial vegetation, wetlands and surface watercourses can be assessed at the catchment scale to ensure they operate as connected and therefore resilient natural systems. This includes retaining and enhancing ecological connections with adjacent catchments for broader regional landscape linkages. Natural systems can be further enhanced in areas of the catchment if they are to specifically moderate the impacts of built environments.
3. **Address stormwater effects as close to source as possible.** WSD promotes the location of land uses based on the capability of directly affected environments. Where increased stormwater runoff is likely, a treatment train can be applied as a combination of landscape areas, swales, raingardens, restored streams, etc. acting in a sequence from the source to the receiving environment.
4. **Mimic natural systems and processes for stormwater management.** At the catchment scale, natural systems and processes can be complemented with interventions such as raingardens, remediated soils and revegetation in upper catchment areas; restored streams, wetlands and swales attenuating flows in mid catchment areas; and broad natural floodplains and enhanced receiving environments in the lower catchment.

Site scale

g as
he site
ve
er-
ment
uffers
these systems from potential impacts of stormwater runoff. A site's ecosystems can also be enhanced from a predevelopment condition to moderate any impacts from development.
3. **Address stormwater effects as close to source as possible.** A site's layout can minimise impervious surfaces and thereby reduce stormwater runoff generation at source. Where runoff does occur, it can be captured and treated from the source to when it leaves the site, in multiple and complementary treatment approaches (a treatment train).
4. **Mimic natural systems and processes for stormwater management.** 'Natural systems and processes' for stormwater management include infiltration, evapotranspiration and open stream systems. Treatment practices that mimic natural sytems and processes include living roofs, raingardens, swales and wetlands. All of these natural systems help to prevent stormwater runoff generation, and capture and treat runoff when it does occur. They also provide a suite of other ecosystem services and amenity benefits for a site, such as the moderation of heat, dust and light.

Site analysis >

Environmental framework

Two of the four principles of WSD refer to natural systems, namely 'Protect and enhance the values and functions of natural ecosystems'; and 'Mimic natural systems and processes for stormwater management'.

An environmental framework such as that in Figure 15 determines the value of existing on-site environmental resources at the regional, catchment and site scale. Site layout is then optimised to protect and enhance on-site resources. An environmental framework is built from the data collected during the Site Assessment phase.

An environmental framework is a means to ensure that sufficient ecosystem services are provided in a site or catchment to support the wellbeing of communities in current or future developments. It ensures the principles of WSD are considered by protecting and enhancing a site's natural systems across open space networks, ecological corridors, receiving environments and enhanced landscapes. A project team will generally consider the following site elements or attributes as part of a combined environmental framework:

- Landscape and natural character values
- Soil and riparian ecosystems
- Biodiversity values to ensure native species resilience
- Ecosystem connectivity to ensure ecosystem resilience.

To assist with the determination of values, Auckland Council has produced several documents which provide guidance for developing an environmental framework. These are:

- TR2009/083 Landscape and Ecology Values within Stormwater Management (Lewis et al., 2010)
- Criteria for the Identification of Significant Ecological Areas in Auckland (Sawyer & Stanley, 2012).

Environmental frameworks are prepared by ecological and landscape specialists to ensure the classification and optimisation of on-site resources is completed correctly. Getting these specialists involved early on in the Site Analysis phase provides the best opportunity to maintain and enhance the environmental resources of a site.

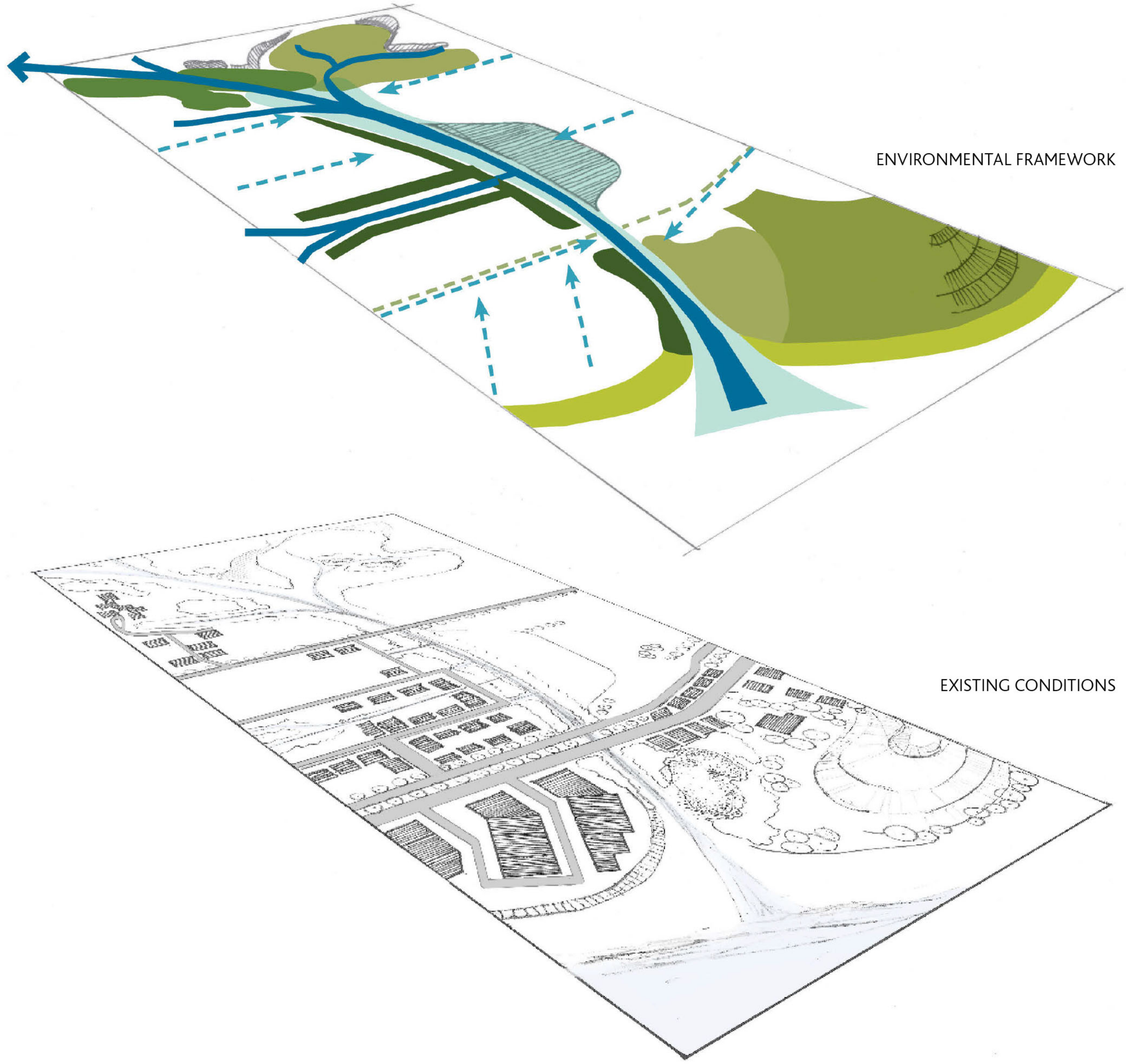


Figure 15: An environmental framework ensures enhanced ecosystem services to support potential development.

Site analysis > Environmental framework >

Landscape and natural character values

An environmental framework preserves the unique landscape attributes of a site by protecting, restoring and buffering significant elements.

Landscape attributes are captured as part of the Site Assessment phase summarised in Tables 1 and 2. The attributes that make up our landscapes include:

- Biophysical elements, patterns and processes
- Sensory qualities
- Spiritual, cultural and social associative activities and meanings.

Kotuku Park, Kapiti

The aim is to maintain and enhance these values within the development form. There are strong networking effects when these attributes are combined into a recognisable landscape pattern i.e. the attributes combined are worth more than the sum of their parts.

For example, when an isolated gully system is connected to an intact stream corridor, it enhances the natural drainage pattern of the site, the associated natural character values, the ecological connections in the catchment, and the landscape coherency. It may also assist in the visual mitigation of buildings and infrastructure. For further information, refer to Section B.

Further discussion on landscape and natural character values can be found in Auckland Regional Council Technical Report TR2009/083 Landscape and Ecology Values within Stormwater Management (Lewis et al., 2010).

Site analysis > Environmental framework >

Soil resources

A pre-disturbance soil survey by a geologist or soil scientist is recommended during the Site Assessment phase to map beneficial soil resources, soil liabilities, and relative geotechnical constraints.

These surveys can direct the location of buildings, infrastructure and environmental systems. For example, stormwater management areas and deep-rooted trees are best located on granular or allophanic soils.

Pre-disturbance surveys may also reveal suitable resources for bioretention practices (sandy loams) or wetlands (organic soils and peats). However, it is important to remember that Auckland soils vary over tens of metres, and unintentional mixing can potentially lend poor properties to 'good' soils.

Further sub-soil surveys may be undertaken if the infiltration rate identified in the pre-disturbance survey is low, or if planting is to take place on the cut faces of earthworked areas.

Discussion on soils can be found in Section B and TR2009/083 Auckland Regional Council Technical Report TR2009/083 Landscape and Ecology Values within Stormwater Management (Lewis et al., 2010).

Site analysis > Environmental framework >

Riparian ecosystems

A fundamental objective of WSD is the protection of streams, wetlands and estuarine environments from the impacts of their contributing catchments.

It also seeks to protect headwater environments, which represent 90% of Auckland streams (O'Brien 1999). Headwater environments are ephemeral and intermittent watercourses upstream of permanent watercourses. A watercourse classification may be carried out (consult an ecologist) as part of the Site Assessment phase to determine the classification of watercourses in the development.

Figure 16: Diversity of stream habitats across latitudinal and longitudinal gradients of a stream environment

WSD promotes the enhancement of these headwater systems for their inherent values (landscape and ecology), their environmental services (including stormwater management), and to ensure the resilience of these systems to catchment change.

An environmental framework must take into account the relative values and functions of riparian systems from a catchment and regional perspective, as well as the vulnerability of these systems to catchment stressors. The framework looks at the long-term sustainability of these riparian systems, including providing for appropriate riparian buffers, flood mitigation and ecological value.

If streams are already affected by existing adverse catchment conditions, the project team may consider rehabilitation of a stream or increasing the stormwater management functions of these systems through some of the responses discussed below.

Promotion of continuous stream corridors
Greenways, also known as lineal parks, wildlife corridors or riverways, were previously discussed in Section B. They are lineal open spaces linking natural, cultural and recreational areas in coincidence with streams or other lineal

landscape features. Greenways provide the framework to protect, conserve and link natural resources and open spaces, including fragmented urban habitats. An example of a greenway in the Auckland region is the Twin Streams project that aligned asset managers and community groups behind a collective vision for two significant Waitakere watercourses and their associated open space. Currently, greenways are being promoted by Auckland Transport and Local Boards for walkways and cycleways while including the "green" elements of streams, green infrastructure and ecological corridors where possible.

Stream corridors in Auckland are often marginal areas for built development due to flooding constraints and climatic conditions, but they can have significant value as open space linkages between coastal open space, ridgelines and volcanic cones.

Protecting and enhancing natural stream morphologies
Streams are dynamic systems that change frequently along their length through natural pool-riffle-run sequences (refer to Figure 16), and across their width from stream margin, to banks, floodplains and tributaries. To ensure a sustainable stream system, a project design team must consider the underlying geology, hydrology and ecology to provide for a stream in equilibrium with its floodplain and catchment.

WSD promotes the use of bioengineering approaches to stream restoration, which utilise natural materials working in combination with appropriate stream morphologies to detain and convey stream flows. Additionally, aquatic diversity can be deliberately included in stream restoration projects through purpose-built habitat or enhanced fish passage.

Promotion of riparian buffers
A riparian zone is the area of land adjacent to streams and rivers that is the transition between land and water (Becker et al., 2001). This includes land from the water's edge, stream banks and adjacent floodplains that are periodically inundated. Riparian buffers and natural floodplains can be accommodated within development as part of a broader open space network, or enhanced for an inherent stormwater management function.

It is appropriate to apply a flexible approach to riparian buffers accounting for the following attributes:

- Geotechnical stability of adjacent land
- Spring seepages, isolated wetlands and extent of flooding
- The values of existing riparian vegetation
- A sustainable buffer width to achieve minimal ongoing maintenance of weeds
- A predicted stream profile based on an urbanised catchment
- The predicted meander alignment of a stream
- Safe public access, including visibility
- Parallel stormwater management treatment opportunities
- Pedestrian and road crossing points
- Priority ecological connections for distribution of flora and fauna between catchments
- Stream habitat diversity.

Site analysis > Environmental framework >

Ecosystem diversity

Ecosystem diversity is to be assessed using the Criteria for the Identification of Significant Ecological Areas in Auckland (Sawyer & Stanley, 2012) published by Auckland Council. Relevant assessment criteria include:

Representativeness - a factor that assesses the types of ecosystems and the species that live in them against Auckland's original ecosystem types

Threat status and rarity - an assessment of the threat of extinction or decline of all levels of biodiversity (genetics, species, communities, habitats and ecosystems) at all scales (site, catchment, region and nationwide)

Diversity - an assessment of the different drivers at different scales including aspects such as competition between species, disturbance history, climatic variables and landform

Uniqueness or distinctiveness - an assessment of whether the environmental resource only occurs in the Auckland region.

Terrestrial habitat diversity
Diversity assessment will consider the regional and catchment significance of site resources. WSD promotes the protection and enhancement of diverse native vegetation types. This may include the following potential land management responses:

Provide a planted riparian buffer to protect existing 'interior' habitat from disturbance and thereby protect unique microclimates and associated habitat diversity

Re-vegetate a site with pioneer vegetation species to develop soils and allow for natural succession processes to occur

Enhance a site by planting complementary flowering and fruiting species to extend food sources for native fauna

Restore multiple vertical vegetation 'tiers' from root zones and litter layers, through herbaceous plants, shrubs, canopy, and emergent trees to form diverse habitat niches (refer to Figure 17).

Plant species diversity
In addition to their natural character and ecosystem values, native plant species have good survivorship and often require less replacement and maintenance than introduced species over the long-term. 'Eco-sourcing' involves the collection of divided plant material or seed from remnant vegetation as close as possible to the location of proposed planting, and ideally from a similar ecotone (a similar environment in terms of climate and elevation). This is a means to protect unique genotypes of plant species, which can also be best suited for the local environment.

Site analysis > Environmental framework >

Ecosystem connectivity

Ecosystem connectivity enables the drift of individuals within a species through an environment in order to provide for different aspects of their life cycle or to populate (reproduce) in other areas.

This assists the long-term resilience of representative native communities.

Figure 18: The potential for ecological connections accross human environments (adapted from Meurk & Hall, 2006)

Linkages can be established by movement corridors and/or 'stepping stones' of supporting habitat across the landscape. Distribution requirements are extremely variable for individual species. Some species, like bellbirds, are unable to traverse even leafy suburbs, while skinks, if they can avoid predation, require only a stone wall or single line of plants to move through the landscape. The Criteria for the Identification of Significant Ecological Areas in Auckland

(Sawyer & Stanley, 2012), published by Auckland Council, contains guidance on connectivity assessments under the criteria of stepping stones, migration pathways and buffers. Various studies have been undertaken, especially for dispersal of bush birds, providing for the general distances traversable by wildlife (Meurk & Hall, 2006) as shown in Figure 18.

Potential ways that an environmental framework might enable ecosystem connectivity include:

- Protect headwaters, springs and isolated wetlands as a source of invertebrate life and nutrient energy
- Promote revegetation of steep slopes and visible ridgelines for upper catchments, while allowing for potential cross-catchment connections
- Ensure there is sufficient area for self-sustaining wetland and floodplain environments and their associated riparian buffers
- Promote diverse native planting for landscape areas
- Form continuous landscape elements such as intact stream corridors
- Protect, enhance or create an urban forest through the collective planting of parklands and streetscapes
- Protect diverse habitats at the interface of coastal, freshwater and terrestrial environments
- Increase diversity within stormwater infrastructure projects such as wetlands for state highways
- Protect and enhance fish passage, including access to additional habitat such as stormwater wetlands
- Provide flowering plants for pollinators, and a variety of nectar and fruit sources for avifauna and lizards.

Site analysis >

Development framework

Resource mapping identifies areas of the site which are optimal for development, or are limited by constraints.

For example, flat areas of land with good aspect and existing access may be ideal to 'cluster' development, whereas gullies or steep slopes may require a more creative design approach in terms of access and architecture. Other development frameworks include infill and brownfield development and mixed use developments. An example of a development framework is shown in Figure 19.

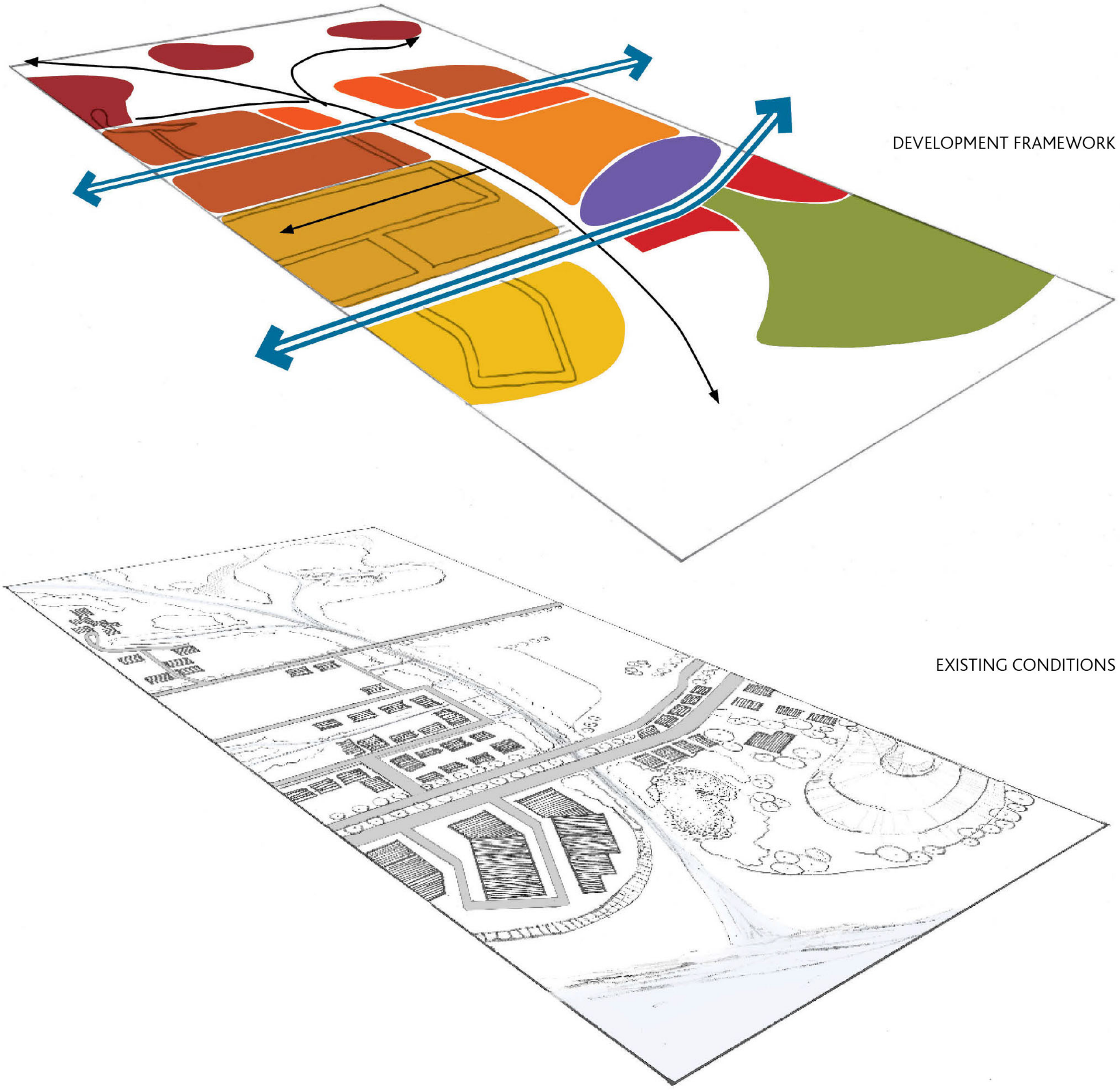
WSD is not a universal solution for land development and there may be instances where a site is too sensitive, or its values are too significant, to suggest development in any way. WSD encourages increased density and mixed use responses within the best development areas, including the retrofit of existing built environments. This preserves a substantial balance area of open space for its values and associated ecosystem services.

Site analysis > Development framework >

Clustered Development

Lot layout is often the most enduring legacy of development.

It is therefore central to a WSD approach that planning provisions allow for a flexible and responsive development form. 'Clustered development' is a potential mechanism to increase density or built form in appropriate areas of a site or catchment in order to preserve the balance of area for ecosystem services. Additional benefits of clustering include:



ponds.

- Directing development to the most amenable sites in terms of aspect and constraints
- An increased level of open space, providing associated market premiums
- The potential for incorporated groups to manage private commons and enhanced amenities
- A heightened sense of community and security, and a critical mass for public transportation.

Often clustering requires an increased level of landscape amenity to balance and mitigate dense built form. This includes enhanced streetscapes and open space amenity, which also ultimately provides the developer with an added value product. Effective design can provide for both increased density and privacy through the careful handling of private to public transitions.

Clustered development is more frequently the result of a structure plan or comprehensive development plan, which precedes resource consent. This is where facilitation between various council departments and land developers is important.

Examples of clustered developments which respond to the natural or cultural landscape are shown in Figure 20.

Figure 20: Above and overleaf, clustering in greenfield or rural environments responds to the natural and cultural landscape.

Figure 20: Above and overleaf, clustering in greenfield or rural environments responds to the natural and cultural landscape

Figure 20: Above and overleaf, clustering in greenfield or rural environments responds to the natural and cultural landscape

Figure 20: Above and overleaf, clustering in greenfield or rural environments responds to the natural and cultural landscape

Figure 20: Above and overleaf, clustering in greenfield or rural environments responds to the natural and cultural landscape

Site analysis > Development framework >

Infill and brownfield development

Two common redevelopment scenarios are infill redevelopment, which increases the density within existing urban areas (refer to Figure 21), and adaptive re-use developments which modify existing buildings and infrastructure for contemporary use.

Redevelopment utilises existing resources to reduce pressures on local infrastructure and direct development away from the region's hinterland. Redevelopment is also a means to create an enhanced environment for an existing site.

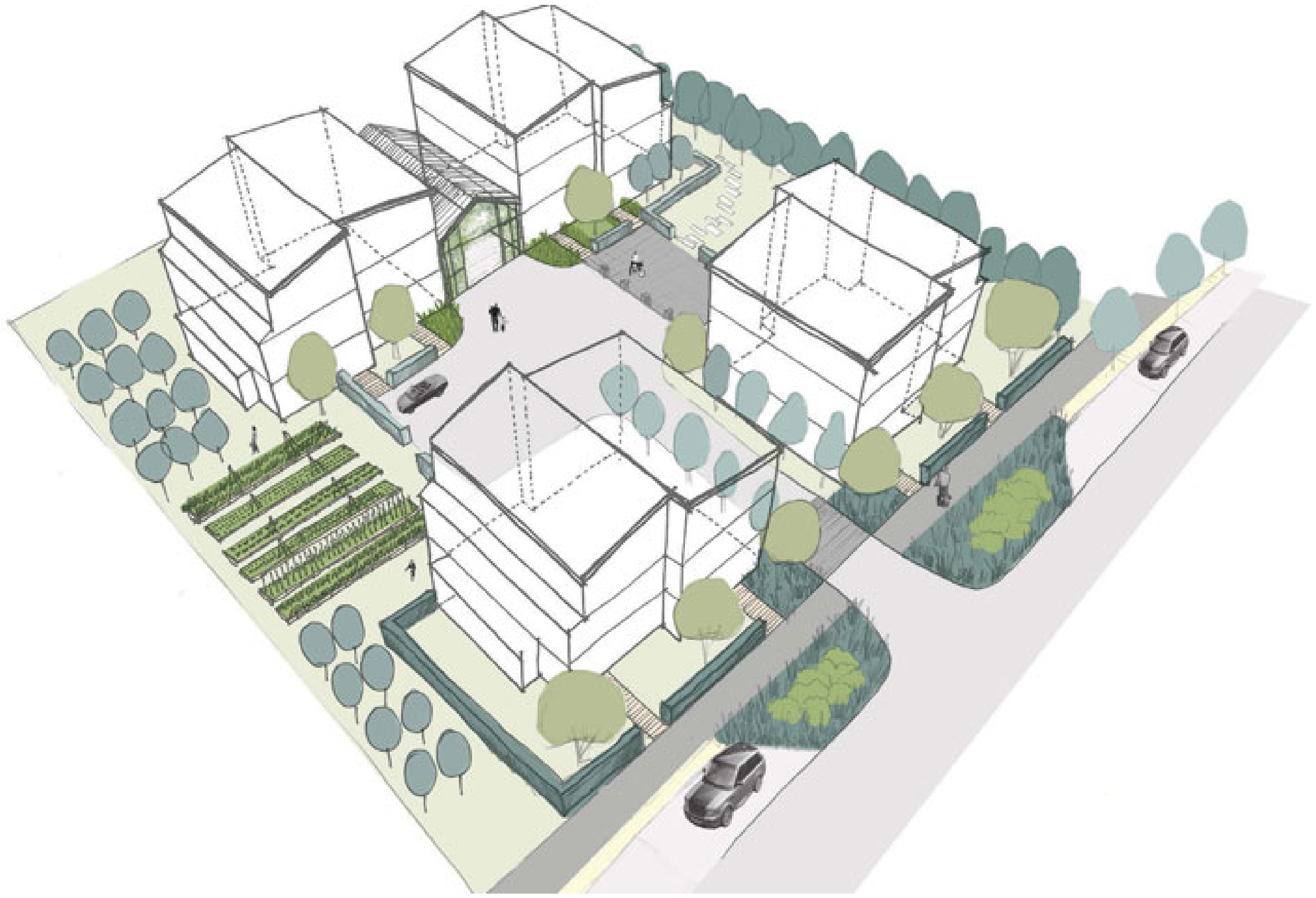


Figure 21: An example of infill redevelopment to achieve higher density, while additionally enhancing ecosystem services for the site

Recent public policy has called for increased affordable housing, higher density around public transport hubs, and the reinvention of areas such as ports of Auckland as a post-industrial waterfront. Redevelopment has also been driven by increased environmental standards relating to stormwater discharges, climate change and pollution prevention for existing activities.

The redevelopment of urban sites provides an additional set of challenges when compared to greenfield sites due to existing services and historic land uses. However, the principles of WSD and the design phases recommended here apply equally to brownfield and greenfield sites. WSD principles are presented below, with specific regard to brownfield redevelopment scenarios.

Promote inter-disciplinary planning and design. Analyse the site for mixed use development opportunities, and the potential retrofit of environmental services. It is important to consider existing community stakeholders to ensure their concerns are adequately addressed and project viability is not compromised.

Protect and enhance the value and function of natural ecosystems. Redevelopment provides the opportunity to redress existing effects of stormwater on the receiving environment, including groundwater from contaminated soils. The integration of 'green' and 'blue' infrastructure into a developed site provides increased opportunities for urban ecology and its associated ecosystem services.

Address stormwater effects as close to source as possible. The redevelopment of a site may include retrofit of pervious paving and landscape areas, relocating buildings to allow shared infrastructure, or increasing the number of floors within the existing building footprint. It is important that opportunities for prevention as well as mitigation of stormwater are considered during the design process, including use of rain water, opportunities for infiltration, and below-ground detention technologies.

Mimic natural systems and processes for stormwater management. The retrofit of a developed site does not preclude green infrastructure since living roofs, planter boxes and tree pits can all be incorporated into architecture or paved areas. The reconstruction of the site can also allow stormwater to be redirected to these treatments. The retrofit of multiple sites may also provide opportunities for centralised natural systems such as vegetated overland flow paths along boundaries and streets, or bioretention in shared open spaces.

Site analysis > Development framework >

Mixed use development

Mixed use communities are areas zoned for more than one activity, with a range of commercial and residential unit options (refer to Figure 22).

They are a means to locate residents close to work and shops and are often located at public transportation hubs, further adding to the 'walkability' of these communities. The development of mixed use centres is a WSD approach operating at a catchment or regional scale, where flexible planning provisions have clustered activities near to existing infrastructure and away from areas of the hinterland or urban open space.

Mixed use development is only appropriate in some areas, and may be an anchor or transition for a broader single use zoning area. It is one of the responses available for the redevelopment of brownfield sites in the region, especially for post-industrial landscapes and logical growth nodes.

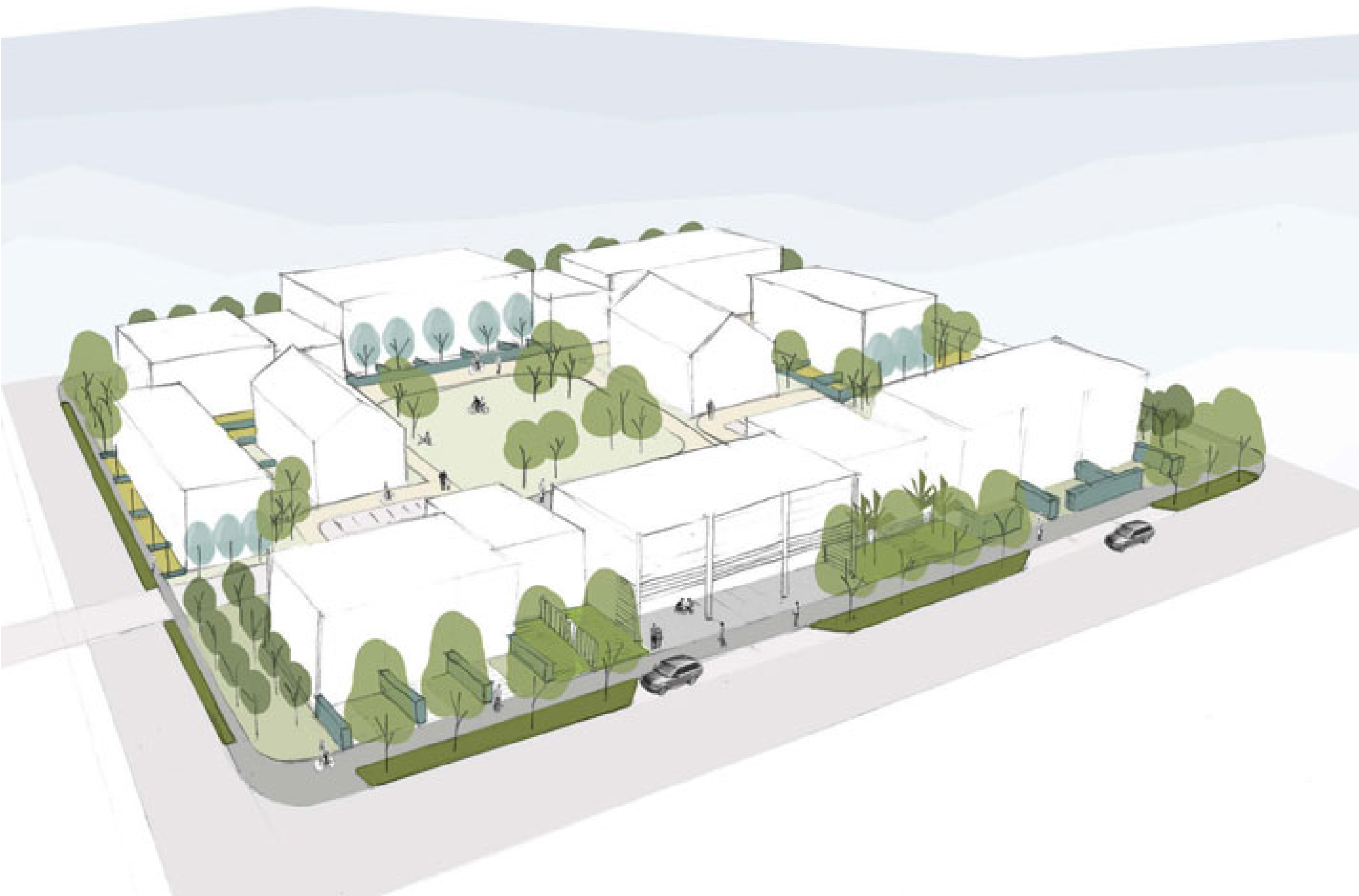


Figure 22: Mixed use development provides opportunities for increase density and diverse responses to stormwater management

Site analysis >

Site context

In accordance with its definition, WSD "operates at the complementary scales of the region, the catchment, and the site". This involves the following steps as part of a comprehensive site analysis:

Review the relative values of a site's resources from a regional scale perspective

Consider a site's relationship with its contributing catchment and receiving environments

Ensure an appropriate site-specific WSD response in accordance with proposed land uses.

Site analysis > Site context >

The regional scale

The Auckland region is a diverse landscape of varying geologies, three significant harbours, abundant coastline, and flat lowland to steep upland environments.

A site's location within the region should ultimately determine its developmental and environmental responses, including consideration of the following regional resources:

- Regionally significant ecosystems
- Receiving environment classifications
- Landscape typologies and sensitive landscapes from regional landscape assessments
- Protection of headwater and groundwater aquifers
- Regional flood management areas

- Productive soils
- Coastal inundation and storm surge effects
- Region-wide ecological linkages
- Open space frameworks
- Public transportation
- Regional growth and intensification nodes
- Combined sewer systems

The urban transect

An 'urban transect' is a planning method used to illustrate a change in urban density from the regional urban centre out to its hinterland. It is intended to ensure an appropriate transition of built form toward urban centres. It is also a means to consider relative bulk and layout of land uses, to provide for appropriate community character relative to a site's location within the region.

The urban transect is a means to express WSD approaches to support relative densities and specialised land uses (refer to Figure 23), including the following broad approaches:

Increasing density near to stream corridors in suburban environments to capitalise on the value of these ecosystems as connected open space

Buffering streams and other ecosystems where high density development is achievable and desirable

The application of stormwater as a resource in civic centres or capture and re-use, to irrigate isolated landscape areas and to integrate as a dynamic element within the urban environment.

Figure 23: The 'urban transect' demonstrates an increase in urban activity and imperviousness, required a corresponding design apprach for stomrwater management and ecosystem services.

Rural landscapes

Conventional models of 'countryside living' are an inefficient use of productive landscapes, with individual house sites requiring significant amounts of infrastructure. Furthermore, it is difficult to justify public transport and other public amenities for low density areas. A more appropriate response to residential living outside the rural-urban boundary (RUB) is within rural town centres, or planned clustered developments that retain viable productive landscapes or ecological reserves.

Suburban residential

Suburban areas have traditionally been associated with unattached housing typologies with prescriptive lot layout and setbacks. WSD approaches require flexible planning rules to cluster built form and provide for more community open space and resilient natural systems (refer to Figure 24).

Riparian environments should remain open through low density residential areas to provide green and blue linkages from the hinterland to urban environments. This helps to provide ecosystem services, to increase residential amenity, and to ensure resilience of neighbourhoods from flooding by directing overland flow to natural floodplain areas. A significant challenge for WSD in suburban areas is to reconcile natural drainage patterns with road networks. This is discussed in more detail in the WSD street typologies that follow.

In addition to enhanced open space areas, suburban residential areas have less vehicle traffic and provide greater opportunities for streetscape amenity and green infrastructure. Larger private yards can also contribute to broader environmental frameworks and on-site stormwater treatment.

Suburban densitities provide opportunities for enhanced environmental services in streetscapes and yards and the integration of streams and wetlands as community open spaces.

1. 'Green' streets with enhanced amenity features such as raingardens increase the effective area of open space.

2. Streams and wetlands contribute to suburban open space for passive recreation and ecosystem services.

3. Back yards captures stormwater and can direct it appropriately across common boandaries. Front yards complment landscape and stormwater management responses in the street.

Urban residential

Higher density residential areas retain less natural environments and rely more greatly on capture and reuse of stormwater, and integrated green infrastructure such as raingardens, planter boxes and tree pits (refer to Figure 25). Where streams do occur, they are likely to be confined within a narrow environmental buffer that is designed with minimum environmental tolerances. Surface watercourses can also occur where there is acceptance of these features within roadways, laneways, and through open spaces.

In more densely built areas, riparian areas and open spaces required designs that optimse stormwater management and ensure ecosystem resilience.

1. Roadways and lanes can integrate tree pits and pervious paving in limited space.

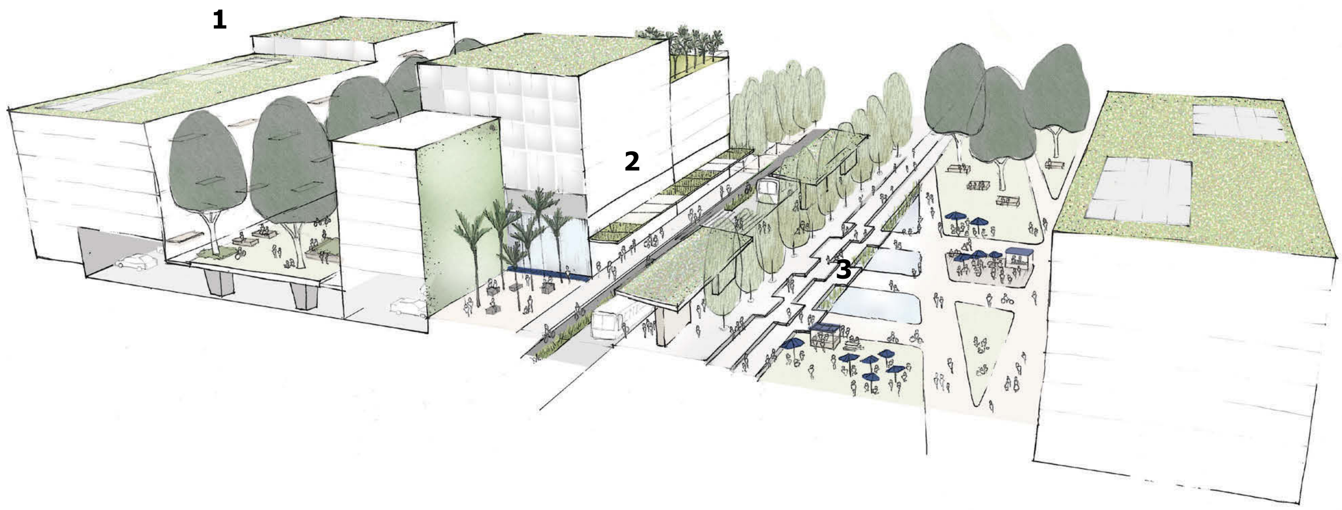
2. Corridors of open space provide environmental services.

3. Riparian areas provide a buffer to protect environmental services and are augmented by appropriate management responses in private yards.

Civic centres

The increased density and impervious surface area associated with civic centres generally results in fewer ecosystem services and increased stormwater flows and contaminants. It is therefore imperative to find design solutions that utilise the natural processes inherent in pervious paving, bioretention (raingardens and tree pits) and subsurface wetland technologies. There is also significant treatment potential available from trees in streets and plazas, where rainfall is captured in canopies and directed via stem flow or overland flows to tree pits.

Architecture can contribute significantly to stormwater management in urban areas, through living roofs, living walls and planted atriums. These contribute valuable urban open space, while potentially capturing and re-using rainfall for passive irrigation and cooling of buildings.



Water appears intermittently in the cityscape of civic or commercial centres and may often be detained underground, or captured and re-used in buildings.

1. Buildings, roofs, podiums and balconies can integrate living roof and living wall tenchologies.

2. Streets and urban plazas direct stormwater treatment to discrete landscape features and urban tree planting.

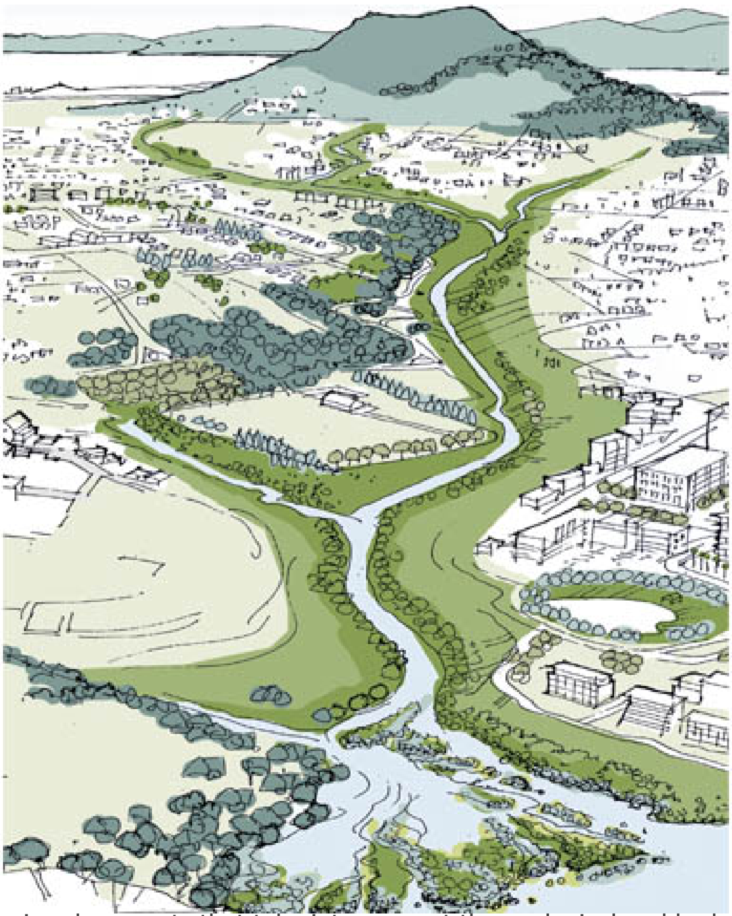
3. Water appears intermittently as water features or is directed to passive irrigation.

Site analysis > Site context >

The catchment scale

Before 2004, Auckland Council's Catchment Management Plans (CMPs) largely focused on stormwater network capacity.

The advent of Integrated Catchment Management Plans (ICMPs) provided scope to focus on specific land use effects, and the relative values and sensitivities of receiving environments (Young & Heijs, 2010). A further change in terminology to Stormwater Management Plans (SMPs) has allowed these plans to address a variety of scales and is the current terminology used at Auckland Council.

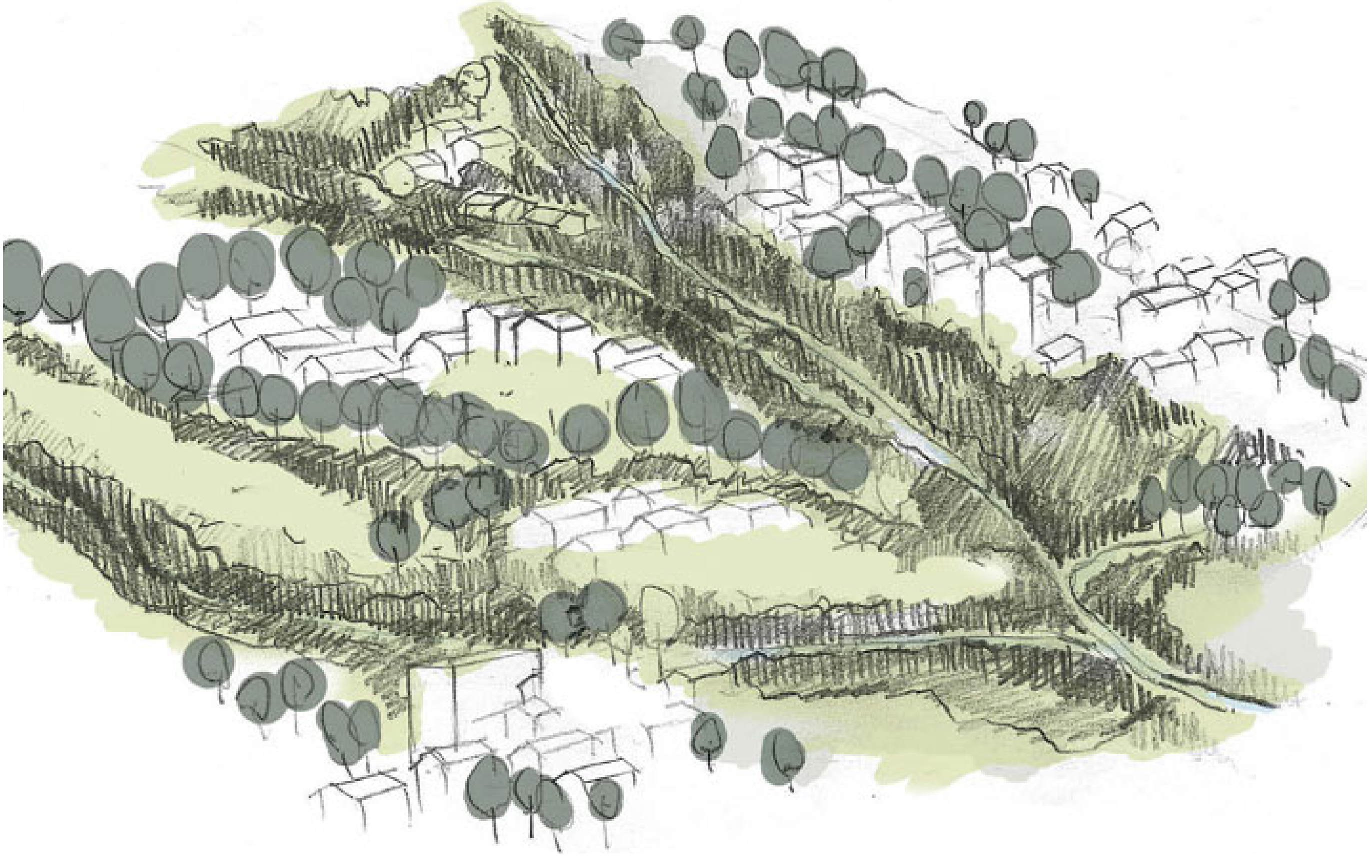


spatially-based land use planning documents that take into account the ecological and hydrological gradients across the catchment to provide an appropriate development response, potentially including clustered and mixed use development approaches.

Some of the planning considerations at the catchment scale include:

- Remnant ecosystem and headwater protection
- Hazards and geotechnical constraints
- Developable aspect and slope
- Existing stormwater management functional areas such as floodplains and aquifers
- Stream buffers offering resilience to land use effects
- Stream corridors to accommodate stormwater management and open space functions
- Flood hazards and overland flow paths
- Regional ecosystem linkages
- Regional infrastructure connections
- Regional growth planning and urban design objectives
- Coastal management

1



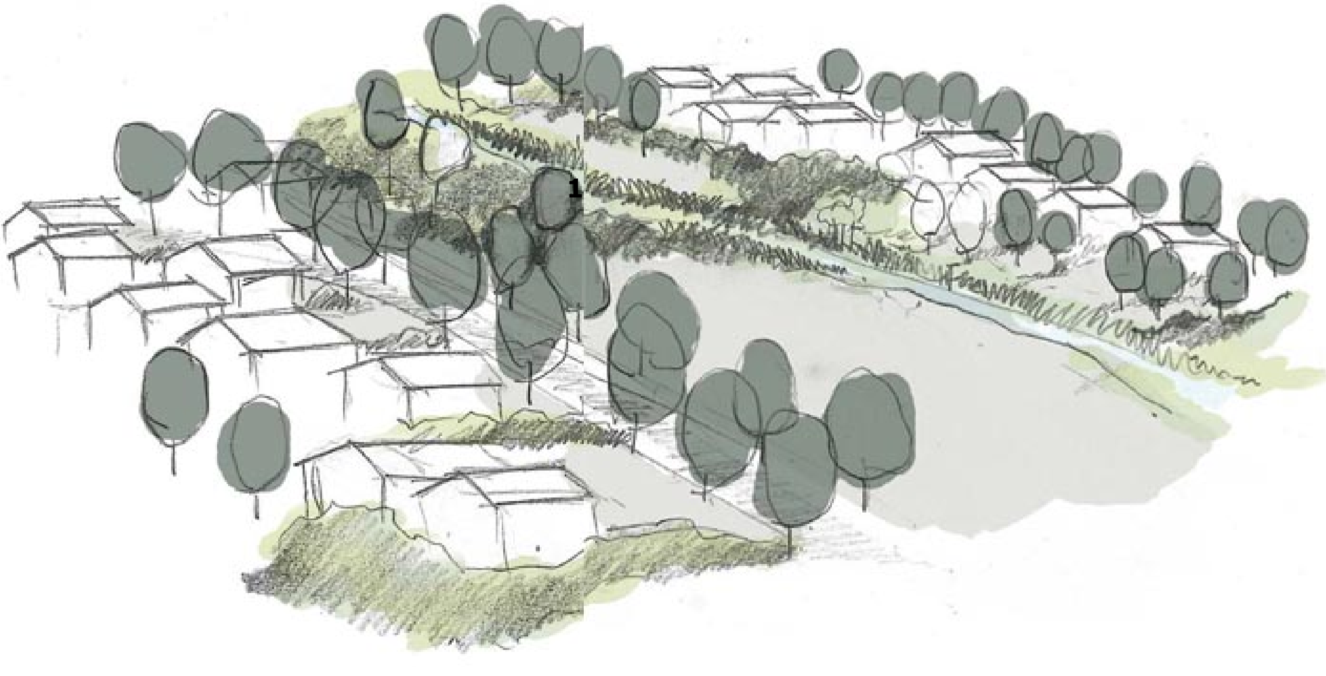


Figure 27: Variation in stormwater management responses relative to catchment position and/or slope.

1. MID CATCHMENT - Managing riparian cooridors

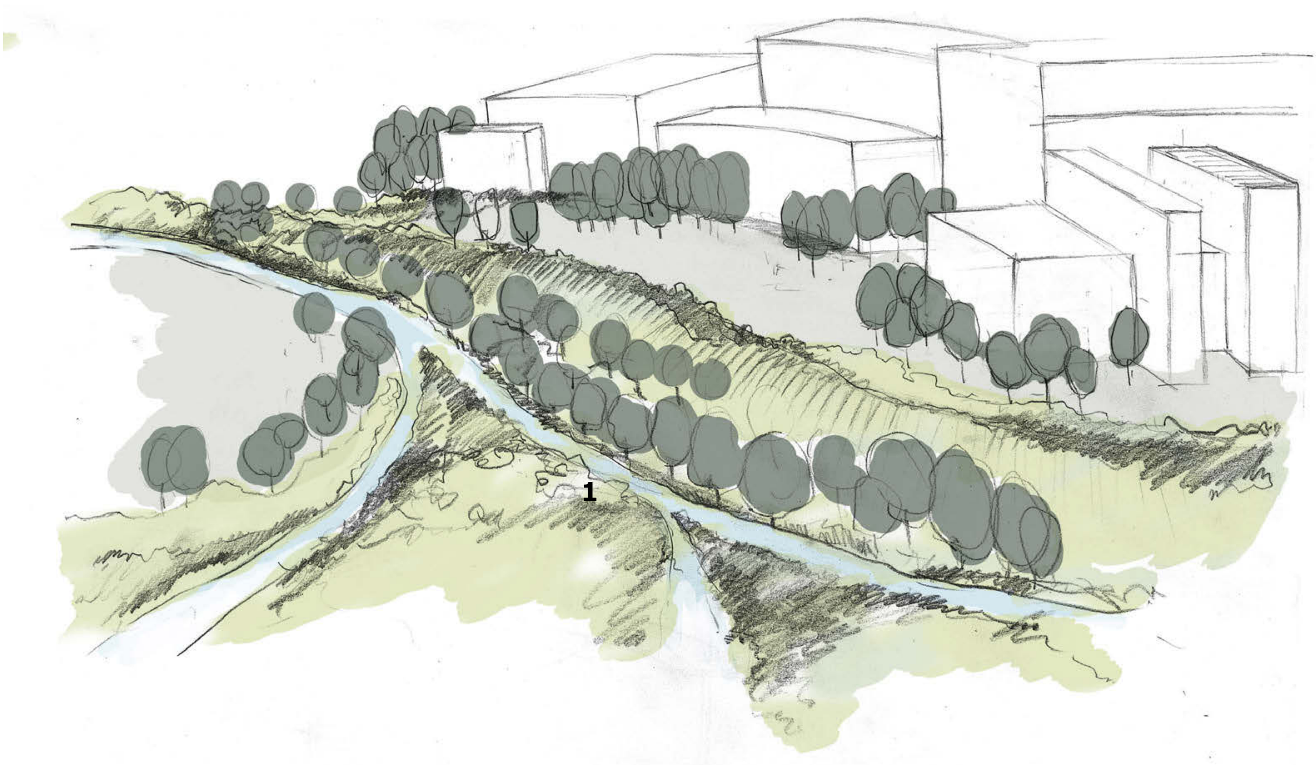


Figure 27: Variation in stormwater management responses relative to catchment position and/or slope.

1. LOWER CATCHMENT - Flood management

Catchment headwaters

Headwater environments make up a significant proportion of Auckland's land area, due to the prevalence of low order streams and intermittent gullies within the region. The steep and intermittent nature of these streams requires vegetation to protect against erosion and to attenuate stormwater runoff to prevent it rapidly concentrating in overland flow paths.

Stormwater management in the upper catchment is often associated with source control, including capture and re-use of rainwater, or retention and treatment in bioretention practices. Groundwater infiltration is also a relevant stormwater management response within Auckland's volcanic fields. Auckland is fortunate to have retained open space associated with many of its volcanic cones, which protects steep slopes and aquifer recharge areas.

The steep nature of headwaters, as well as the need for resource protection, lends itself to a clustered form of urban development, where dense residential or institutional buildings are dominated by planted slopes and generous open space (refer to Figure 27). In rural areas, woodlots and other longer term productive landscapes may be an appropriate response to steeper slopes.

Mid catchment

The mid catchment is generally associated with rolling slopes where stormwater runoff coalesces into larger stream and wetland systems. These riparian systems require the protection of planted buffers and appropriate land management. This protects the natural drainage patterns through the mid slopes and upper valleys of urban environments, which can provide important open space connections along low valley gradients.

Stream and wetland widths can vary according to adjacent land use, with thick vegetation supporting narrow stream corridors in dense urban areas, and wider and more open floodplain environments in suburban neighbourhoods allowing for a combination of diverse riparian habitats and open space opportunities.

Lowland and coastal environments

The primary WSD issues in the lower catchment are protection of coastal and estuarine environments, and the prevention of flooding impacts. In terms of urban form, lowland environments are usually undulating to flat areas, which provide optimal site conditions for large scale, dense and specialised urban typologies such as commercial centres, ports and industrial zones.

The resulting land use pattern is a contrasting environment between the built form and open spaces. Wide open spaces in association with floodplains, estuaries and recreational open space sit directly beside dense development or industrial and commercial precincts.

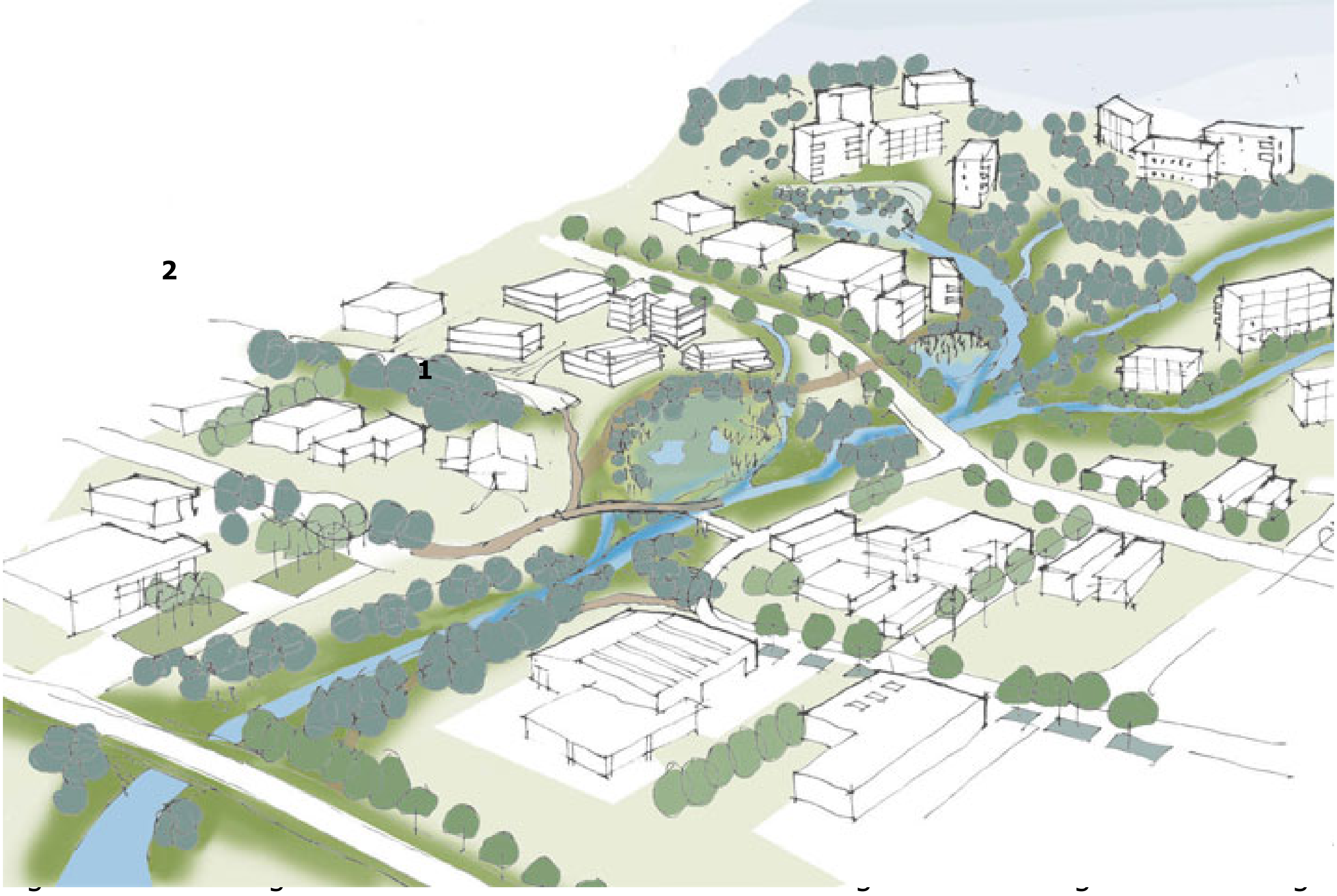
Flat environments often require widely distributed WSD responses such as raingardens and swales. Wetland environments are also common in flat environments, where they can accommodate surface flooding and high groundwater levels.

Careful planning is required to minimise environmental impacts for greenfield situations, and to provide remediation of ecosystems if brownfield development opportunities arise.

Reconciling the urban grid

Urban design principles, discussed previously in Section A, promote a grid-like street pattern to provide for greater community connectivity, traffic dispersal and wayfinding. However, there is inevitably a creative tension between the dendritic pattern of natural stream systems and the rigid street patterns of urban form. The means to reconcile these patterns occurs at the fundamental level of movement within the site. It is a matter of interlacing natural and built elements in the most appropriate ways to rationalise objectives for each system. Some potential responses may include (illustrated in Figure 28):

- Adapting the urban street grid pattern in response to existing topography and landform
- Creating 'naturalised' drainage patterns to receive runoff from increased imperviousness, placed along boundaries and within streetscapes
- Allowing flexibility for both road carriage width and riparian buffers
- At strategic stream crossing points, favouring pedestrian and bike crossings over roads
- Assisting vehicle movements by prioritising street connections and potential stream crossings based on neighbourhood density and travel distances
- Creating streetscapes and street alignments which draw from and extend riparian open spaces
- Increasing neighbourhood cycle/pedestrian connections through stormwater reserves
- Mitigating the occupation of the floodplain by road crossings by enhancing stream habitats elsewhere (internal to blocks)
- Providing for wider stream corridors at road crossings to accommodate bridge abutments, landscape transitions, and habitat refuges above and below culverts.



patterns and enhanced ecosystem systems.

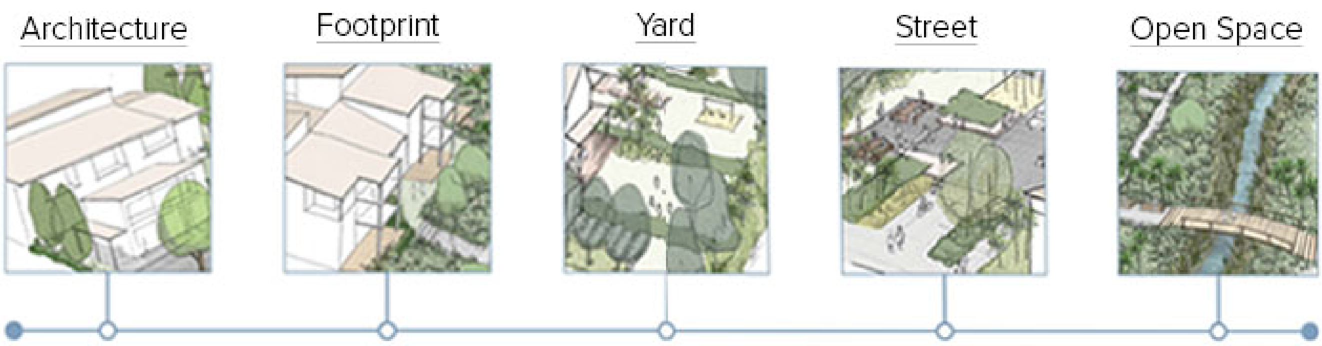
1. Surface water features such as swales and open channels may extend from riparian areas into streetscapes and open space.

2. Options for the street grid include converging roads prior to stream corssings, terminating at streams but continuing as pedestrian crossing, or aligning roads with stream corridors.

Site analysis > Site context >

The site scale

A site layout comprises a number of elements that make up the public and private domain, as shown in Figure 29.



These include the building, the landscape yard, the street and the open space. WSD principles can be applied to each of these elements.

The private lot

Architecture and footprint
The following WSD treatment approaches can be applied within the footprint of buildings and structures:

- Combine the footprints of garages, utilities and ancillary structures to reduce impervious surfaces
- Provide an architectural response to slopes and vulnerable soils, e.g. pole or terraced housing which limits the earthworks required to accommodate the building
- Provide for flexible internal layouts of attached or semi-attached housing typologies to provide for diverse family groups and increased occupancy across land area
- Capture stormwater for re-use in buildings
- Use inert materials for construction that will not contribute contaminants to stormwater
- Consider living roofs, living walls and planter boxes to attenuate and treat stormwater.

Yard
The yard can be a useable open space or a buffer to adjacent land use. It may include private, semi-private, or communally operated areas. Yards can receive stormwater runoff as passive irrigation and contribute to stormwater management in the following ways:

- Share driveways between house lots to reduce impervious areas
- Utilise pervious paving options for drives and paths, and direct stormwater runoff from these surfaces to landscape areas
- Direct overflow from raintanks to purpose-built landscape areas as passive irrigation
- Utilise hedges, swales or filter strips to define boundaries
- Buffer existing natural areas
- Minimise fertiliser and pesticide inputs for landscape maintenance
- Investigate 'no mow' options using native plant substitutes
- Investigate the potential for communal overland flow paths, or even small streams across neighbouring yards

- Use tree planting to define boundaries, as summer shade, or to moderate prevailing winds, while also contributing a stormwater management function
- Investigate opportunities to direct stormwater runoff to raingardens and infiltration basins.

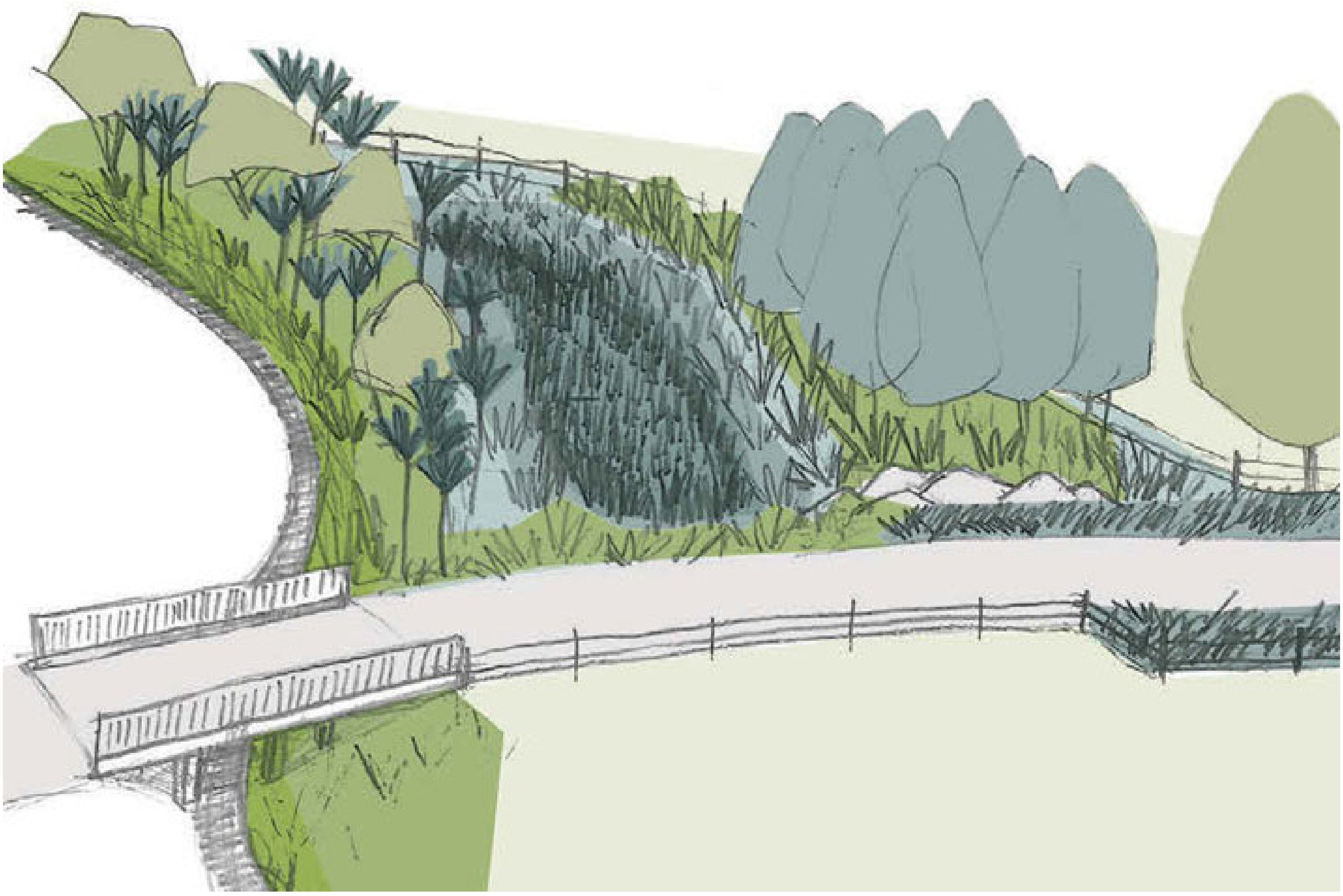


Figure 30: An example of passive treatment of stormwater within the rural landscape

WSD streets
WSD approaches can re-invent the function of streets in our communities to be lineal open spaces, pedestrian friendly environments and living ecosystems. Directing stormwater runoff to street trees and landscape berms not only delivers at-source treatment of stormwater runoff, it also irrigates and fertilises these plants.

The design of 'living street' environments can incorporate aspects of development such as stormwater management requirements, roading hierarchy, priority of transport mode, neighbourhood character and intersecting natural systems. For all WSD treatments, safety should be considered for street environments, including visibility for cars and pedestrians, response to road speeds, and 'turn off' areas for cyclists and pedestrians to escape erratic drivers.

Rural roads
Rural roads usually have increased speeds and less provision for amenity planting. However, there is still potential to enhance planting of swales and filter strips to reduce erosion and sediment entrainment. Parallel wetland systems can be located at the intersection of swales and stream environments to reduce instream erosion and provide further stormwater treatment (refer to Figure 30).

Production tree species can be included alongside swales or encouraged on adjacent boundaries to intercept rainfall, treat nitrogen in groundwater, and provide partial shade. However, tree planting alongside roads should allow for sunlight to pass through in order to foster plant growth in swales and to reduce the likelihood of frost on road surfaces.

Park streets
Park streets refer to street environments that are integrated with adjacent open space areas, including stream corridors and wetlands. Park streets generally have a higher landscape amenity that can allow for appropriate vegetated WSD approaches.

Figure 31: Laneways combine pedestrian and automobile surfaces, providing primary treatment of stormwater and operating as overland flow paths

Laneways and pedestrian-oriented communities
There are examples of traffic-free communities in New Zealand and overseas, where car parking is placed outside of planned communities and generous access is provided for pedestrians and cycles. Another model is a pedestrian-oriented network where pedestrians and cyclists have priority access along building fronts where there are no driveways, while short feeder lanes provide automobile access at the back of houses.

These back lanes are often shared surfaces (with access for both pedestrians and automobiles) that act as semi-private spaces to connect residents within a block (refer to Figure 31). From a WSD perspective a low traffic laneway provides opportunities for pervious paving, above ground detention and overland flow to landscape areas. By removing parking from the front street, it reduces driveways and the carriageway on main roads, providing for more cycleways, street trees and landscape areas.

Industrial subdivisions
Roadways in industrial areas are often very wide to accommodate both extended carriageways and landscape berms. These streets may have sufficient space to accommodate open channels or lineal wetlands. WSD elements can be incorporated into berms or combined with landscape yards of individual lots.

Open channels provide the equivalent ecological function of intermittent streams, which are often lost to accommodate industrial lots. These watercourses can provide for increased flow capacity to reduce flooding risk. Vegetated stormwater features in general can play a part in a spill response, to capture and isolate contaminants before they reach the reticulated network and the receiving environment.

The installation of swales or lineal raingardens in industrial roads must accommodate turning circles for larger vehicles. These can be reduced through shared access points and internal private through-roads (refer to Figure 35). Internal road systems between industrial blocks can reduce traffic circulation requirements for individual lots, which can remove impervious surface requirements and optimise useable land area.

Figure 32: Garden streets blur the distinction between private yards, streets, and open space to form significant streetscape amenity and stormwater treatment opportunities

Garden streets / homezones
These streets, with the equivalent traffic movements of a 'neighbourhood' street, intentionally blur the distinction between streets, open spaces and private yards (refer to Figure 32). Ownership and management of the areas must be agreed between public and private entities. There is significant potential to integrate WSD stormwater responses into garden streets, including the following measures:

Combine automobile and pedestrian movement on the carriageway as a cue for lower speeds and to increase landscape areas in place of footpaths

Redirect or 'choke' the carriageway at specific junctures to slow traffic by increasing the extent of landscape elements, such as raingardens or street trees

Extend streetscapes across private lots and public open space to blur the distinction between roads and neighbourhood. This provides opportunities to retain existing vegetation and landform features as part of the roading corridor.

Provide shared surfaces where the road is a single kerb-less plane (described in further detail opposite). This requires the redirection of stormwater to multiple landscape features or pervious areas, since kerb and gutter systems are no longer applicable.

Provide for diffuse stormwater flows to landscape areas to allow passive irrigation

Provide overland flow paths contained within landscape areas and away from carriageways.

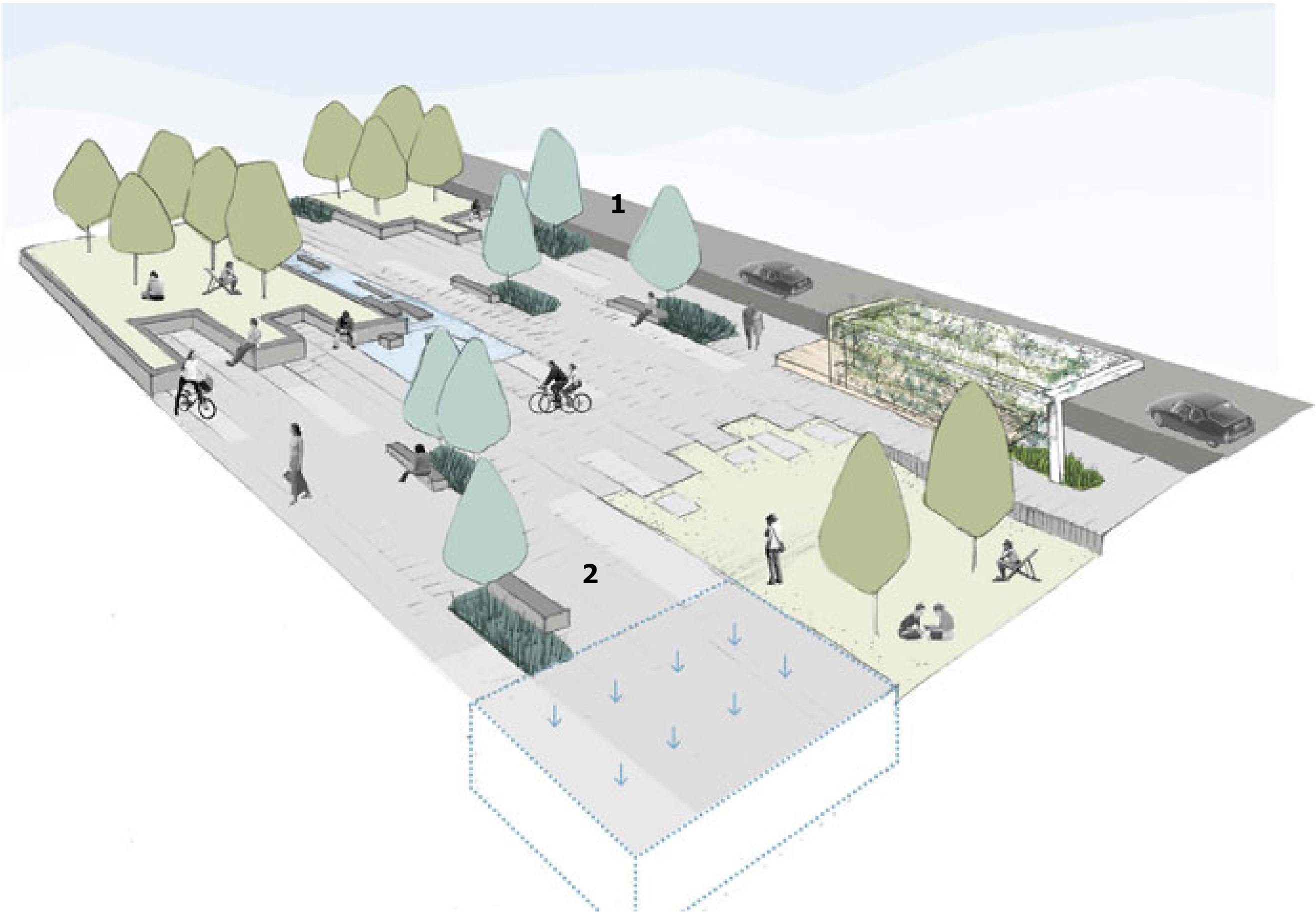


Figure 33: Shared surfaces integrating pedestrian and vehicle movement

1. Landscape features break up carriageways and slow vehicle traffic, while also wicking away surface water in sub-catchment areas.

2. Stormwater directed to previous areas and stored in underground detention for re-use in surface water features and irrigation

Shared space

Shared space environments remove conventional traffic elements such as kerbs to re-prioritise pedestrians above vehicle movement. This may be accomplished in a number of ways, but generally these environments remove the visual cues defining a carriageway such as grade changes, signs, bollards, road markings and lineal berms in order to redirect driver behaviour.

The concept of shared space is based on civility and equitable use of public open space by all users. Shared spaces create an environment that encourages all users to think responsibly about the needs of others. Shared spaces generally function in street environments with less than 150 cars per hour at peak times (Boffa Miskell, 2010).

Shared space provides an opportunity for pedestrians to engage with a wider public realm and a unified space. In this way shared surfaces can be utilised for recreation and gathering. In combination with the removal of kerb and gutter systems, a WSD response is to direct stormwater to multiple landscape features or pervious areas for treatment and/or passive irrigation (refer to Figure 33).

WSD integration with open space

Public open space areas can act as default stormwater management areas by receiving stormwater runoff from adjacent impervious surfaces, as illustrated in Figure 34. Consideration needs to be given to the impact stormwater management structures can have on the amenity and values of the open space and its users. Stormwater reserves should provide the other functions of open space such as natural habitat, public amenity and recreation opportunities.

Combining public open space and stormwater function requires an integrated design approach between asset groups, community stakeholders, and operation and maintenance personnel. Some key considerations are provided below:

- Grade open spaces to allow recreation as well as stormwater attenuation/detention

- Provide pathways with appropriate width, cross slopes and drainage
- Keep structures above the 100 year ARI flood event for safety and to prevent water damage
- Limit the stormwater detention function of formal activity areas to less than 24 hours for a 2 year ARI event
- Design stormwater features that provide for landscape amenity, natural character values, social interaction and education/interpretation as appropriate
- Provide physical and/or visual access as appropriate to natural wetland environments and constructed stormwater features. Integrate with maintenance access where possible.
- Design stormwater management features to augment and/or buffer existing ecosystem functions and values
- Promote biodiversity from wetland to upland environments
- Include WSD responses to hard surfaces and structures such as car parking
- Design swales and watercourses so that they resist erosion and minimise maintenance requirements
- Where overland flow paths are accessible to the public (roads and pedestrian routes) AC CoP specifies a minimum depth of 200 mm and a maximum velocity of 0.6 m/s (see CoP 4.3.5.6).
- Rehabilitate soils and increase regenerating vegetation within open spaces to enhance stormwater attenuation potential
- Optimise the potential for stormwater and its entrained nutrients to be used as passive irrigation for open space planting
- Ensure maintenance regimes avoid close mowing for all areas, and place controls on the application of fertilisers, pesticides and herbicides
- Seek to connect discreet and separated open space areas within a community by linking through covenanted private land and/or 'living street' environments.

Figure 34: Open spaces can provide enhanced stormwater management functions, while also acting as default storage to detail larger storm events

1. Sports fields as floodplain storage for large storm events.

2. Pervious surface treatments applied to overflow parking, play areas, etc.

3. Structures and utlility areas provided with appropriate WSD treatments responses to capture and treat stormwater within 'natural' ecosystems

4. Surface water features and wetlands integrated into aprk environments defended by appropriate ecological buffers

Industrial and contaminated sites
Contamination of soils can occur as a result of agricultural chemicals, industrial processing, vehicle use, storing of hazardous substances, dumping, and migration of contaminants from off-site. Where contaminants are present in the soil or groundwater, the risks may include short-term toxicity, long-term bioaccumulation by plants and animals, or unpredictable synergistic effects in the environment. In these instances, monitoring at variable groundwater levels and at various locations should be undertaken to determine whether to cap, export or phytoremediate contaminants.

In a site that is storing or using contaminants of concern, the potential source should be isolated through rain cover or similar, and any stormwater runoff generated should be separated either to an appropriate discharge location, or to storage for re-use in industrial processes. Part of stormwater management in this instance is appropriate pollution prevention and spill response plans.

Decentralised and discrete stormwater treatment practices such as gross pollutant traps, sand filters, swales or raingardens are appropriate to allow for localised spill containment without disabling wider stormwater systems. The separation of an industrial site into multiple sub-catchments also offers site flexibility for future tenants of the site.

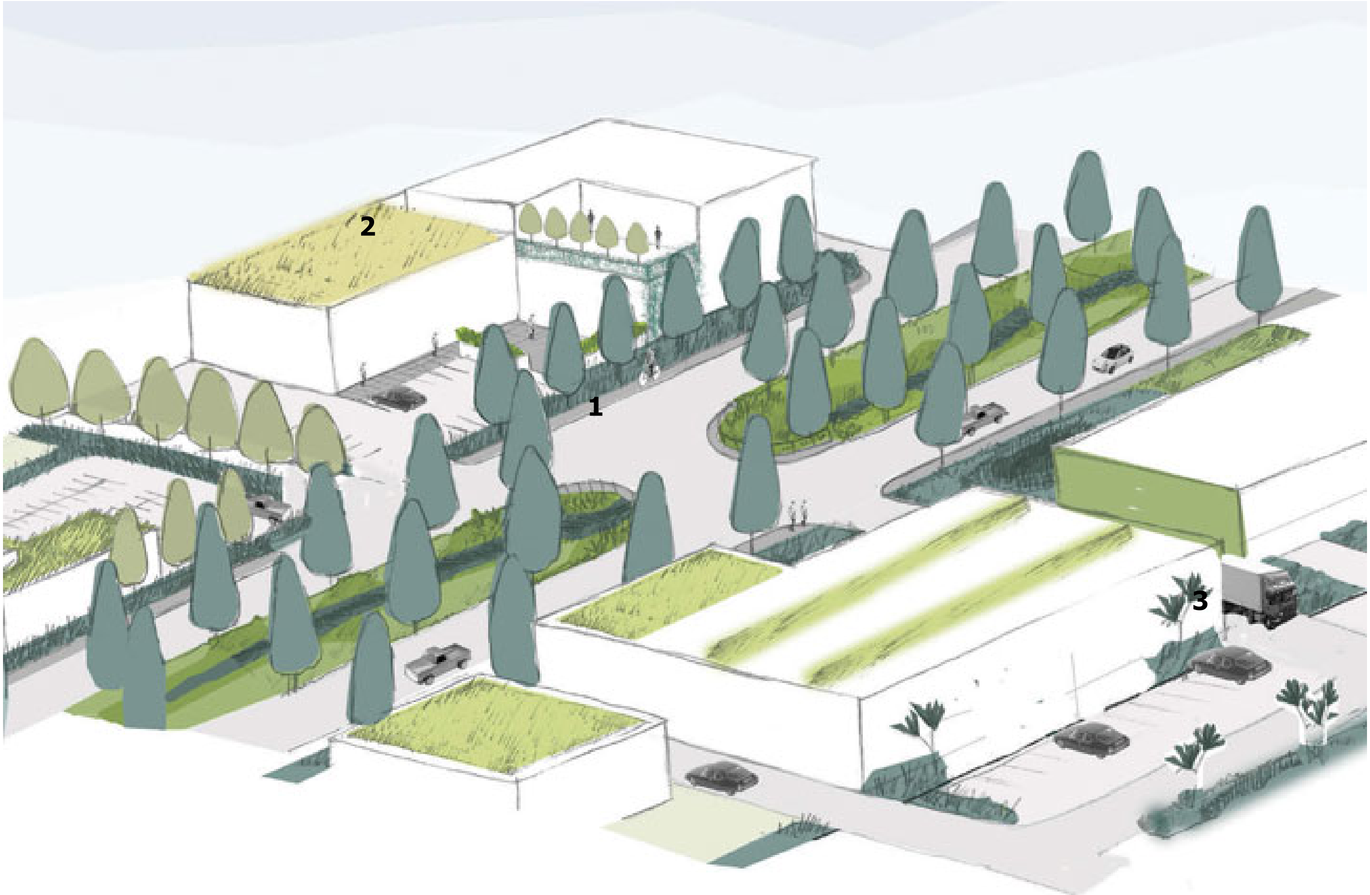


Figure 35: The industrial scale provides opportunities for large scale landscape responses, shared infrastructure, and targeted sub-catchment responses

1. Larger roads with fewer kerb cuts provide an opportunity for swales or streams in the median or berm of roads. These elements are also possible along common side boundaries

2. Living roof and living wall technologies, inlcuding innovative application to frame construction such as rooftop filterstrips and 'brownroofs'

3. Impervious surfaces can be reduced through reconciling internal road networks with 'through' roads between blocks, and shared turning circles and kerb cuts.

Impervious surfaces are significant in industrial sites. However, the efficient use of impervious surfaces in industrial precincts can be provided by shared kerb breaks from main roads to increase landscape berms, and shared internal roads around buildings and between blocks to reduce turn-around requirements and increase available building footprints and staging areas (refer to Figure 35). Stormwater treatment practices such as swales or wetlands can also be shared across common boundaries.

A large volume of stormwater is available for capture and re-use in industrial sites, from large roof and paved areas. Alternatively, frame construction can be strengthened for 'extensive' living roof or living wall technologies. This might include a strip of planting on a strengthened area of rooftop to treat the first flush of contaminants, or brown roof technologies such as xeroscapes (arid, low soil plant systems).