TOOLS AVAILABLE AND PRACTICAL APPLICATION TO MANAGE STORMWATER IN BROWNFIELD DEVELOPMENT

Aidan Cooper CPEng, MIPENZ, Stormwater Solutions Consulting Limited

ABSTRACT

Auckland is changing the way it grows. The draft Auckland Unitary Plan promotes a better quality of life for all Aucklanders, with the goal of creating the world's most liveable city by encouraging access to more housing choice, as well as greater opportunities for recreation and leisure activities for all. The plan places an emphasis on the importance of building stronger, more inclusive communities around Auckland's Town and Local centres which are served by efficient, frequent and reliable public transport. The challenge is to provide brownfield development which also provides a sense of community that meets the stormwater management and treatment required by Council.

To achieve the goal of a quality compact city, developers and council will need to continue to innovate in its management of stormwater.

This discussion paper presents tools available to guide development's stormwater treatment and management within urban areas.

An example of how existing tools can be integrated in an example development within Auckland's urban area which will show how integrated design can provide multiple benefits including:

- Population density increase with the provision of quality housing;
- Quality open space;
- Reduce stormwater peak flows of the developed catchment; and
- Reduce reticulated water consumption.

KEYWORDS

Brownfield, low impact design, integrated design, Water Sensitive Design

PRESENTER PROFILE

Aidan is a Senior Environmental Engineer at Stormwater Solutions Consulting Limited with 12 years' experience of working with developers and contractors to implement low impact developments and water sensitive design solutions.

1 INTRODUCTION

Auckland is changing the way it grows with the realisation that to maintain the proximity of green space, which surrounds the city, and maintain or improve the quality of the region's environment growth patterns need to change.

Design professionals including engineers, planners and architects work with developers and Council to reduce the impacts of green field developments which include the consumption of arable land or recreational spaces, and costs associated with providing new infrastructure (transport, communications, and waters infrastructure etc) to new developments.

To reduce the effects of greenfield development the Proposed Auckland Unitary Plan (PAUP) looks to concentrate the regions' growth within the existing urban boundary. This presents design professionals, developers and council with a challenge and opportunity, to provide quality, more intense development, while maintaining or improving the existing catchment's stormwater quality, quantity and receiving environment. To achieve this design tools are available with the share focus to provide quality development with minimal impact to the environment, both natural and anthropogenic. Design tools available to provide design guidance to deliver the outcomes desired by the PAUP include:

- The proposed Auckland Unitary plan;
- Auckland Design Manual;
- Technical publications; and
- Technical reports.

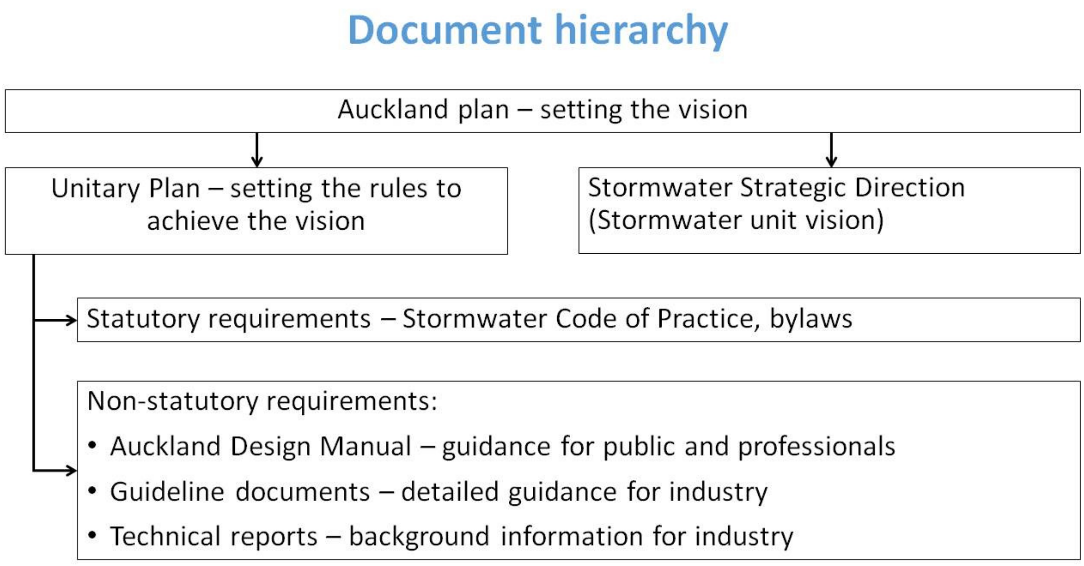


Figure 1: Stormwater design documents hierarchy

2 AUCKLAND PLAN

The purpose of the Auckland Plan is to promote a better quality of life for all Aucklanders, with the goal of creating the world's most liveable city by encouraging access to more housing choice, as well as greater opportunities for recreation and leisure activities for all.

The plan's overall purpose is the provision of a quality holistic low impact development, which minimises impacts of development to both the natural and cultural environments.

3 PROPOSED AUCKLAND UNITARY PLAN

The PAUP provides detailed rules to guide developments to provide quality liveable spaces.

To achieve holistic low impact developments an integrated design approach is required which considers the life cycle of the development and the effects on the environment, community and infrastructure.

Chapters within the PAUP which outline stormwater considerations include:

- Infrastructure (part 3, chapter H, 1.1)
- Earthworks (part 3, chapter H, 4.2.3)
- Flooding (part 3, chapter H, 4.12)
- Lakes, rivers, streams (part 3, chapter H, 4.13)
- Stormwater (part 3, chapter H, 4.14)

3.1 INFRASTRUCTURE

The PAUP outlines activity status of stormwater networks and other related infrastructure, and summarises the permitted activities. Activities related to stormwater treatment devices, erosion protection, culverts and measuring devices (flows structures) is a permitted activity within the PAUP.

3.2 EARTHWORKS

The PAUP requires controls of earthworks to focus on minimising impacts on the environment, which include minimising significant adverse effects on aquatic life within receiving environments. Auckland Council Technical Publication 90 Erosion and Sediment Control Guideline details the best practice erosion and sediment control measures to be implemented for the duration of earthworks.

The final earthworks design must not temporarily or permanently alter the configuration of an existing overland flow path, maintaining the same entry and exit point at the site boundary, and not alter the volume and velocity of water flow.

3.3 FLOODING

The PAUP controls the risk of flooding by implementing specific controls surrounding development within flood plain including:

- Residential development within 1% AEP flood sensitive areas requiring finished floor level at least 500mm above the 1% AEP flood level.
- The restriction of building barriers across flow paths which may impede flow, example fences.
- The placement of controls against secondary risk issues, as result of flooding such as hazards which may be caused as a result of materials being shifted by floodwaters.

Flood vulnerable infrastructure enables a community to function and includes transport and water supply facilities, is restricted to the 0.5% AEP flood plain and must not alter the volume and velocity of water flow or cause additional adverse flooding effects on neighbouring sites.

3.4 STORMWATER

The PAUP provides design requirements to meet obligations of the RMA (section 14 and 15) control of stormwater discharge effects:

- From public stormwater networks (these may include public roads);
- From public roads operated by road controlling authorities;
- To ground;
- From impervious areas other than those connected to public stormwater networks,
- Public roads; or
- Discharges to ground soakage.

3.4.1 STORMWATER MANAGEMENT – FLOW RULES

Stormwater Management Area: Flow (SMAF) have been established to control the effects of new or redevelopment of impervious areas (excluding public roads) which discharge to stormwater network, combined sewers, or streams.

Hydrology mitigation is required when new or redeveloped impervious area is less than or equal to the Impervious Area Threshold of the relevant land use or if the impermeable area comprises of more than or equal to 50% of the total site area.

Stormwater runoff can be discharged directly from the site if the development or redevelopment doesn't give rise to significant adverse effects (including cumulative effects) including outlet erosion, flooding to habitable floors, stream bank erosion.

SMAF flow requirements are further detailed in TR2013/035 and discussed later in this document.

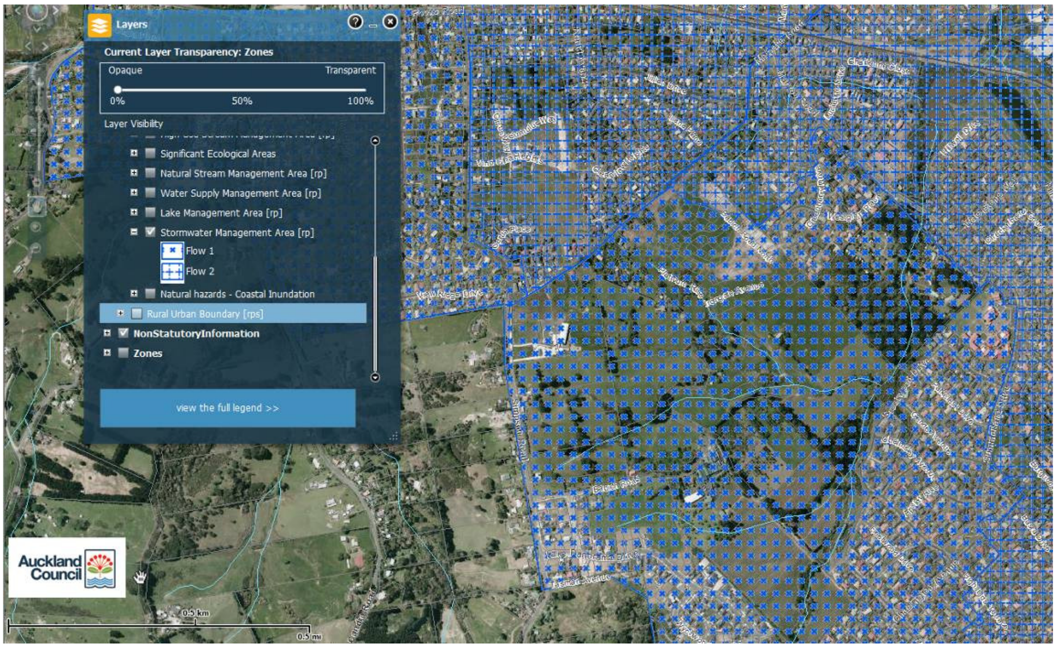


Figure 2: Example map showing SMAF 1 and SMAF 2 zones

3.4.2 STORMWATER MANAGEMENT – QUALITY RULES

The PAUP continues to develop and refine the approach to improve environmental quality, community desires and address gaps in the current approach to stormwater management. The PAUP addresses adverse effects of development through the management of land use and the integration of stormwater treatment within the development.

The PAUP places an emphasis on minimising the generation, and management of stormwater pollutants at or near-source, and taking a risk based approach to thresholds related to pollutants generating potential. The current blanket approach of treatment requirements (75% of TSS) has been revised to focus treatment requirements specific to the land use and pollutant generation potential. Treatment options available to meet the treatment requirements are those currently available within the Technical Publication 10 (TP10). These requirements are discussed further in TR2013/035.

Consideration of stormwater quality is required when areas of new or redevelopment pose risk of high contaminant yield, exceed area limits stated in the PAUP or discharge to sensitive receiving environments. Examples of development may include uncovered parking areas of greater than 1000m^2, high use public roads, or areas of any high contaminant yielding building materials such as roofing, spouting, cladding or architectural features.

3.5 BUILDING CONTROLS

The PAUP emphasises a holistic, integrated, multi-disciplinary design approach proven to have multiple benefits to the environment, infrastructure, and the local and the wider community. Consideration of building controls extends the level of stormwater design considerations beyond infrastructure and the immediate surrounding area to include the wider benefits of the development to the wider catchment, environment and infrastructure.

The PAUP's building controls advocate for developments to provide:

- Integrated design;
- Holistic design;
- Low impact design; and
- Water sensitive design.

The PAUP has outlined development zones (residential, city centre, future urban, etc.) within the Auckland region, each with specific building controls.

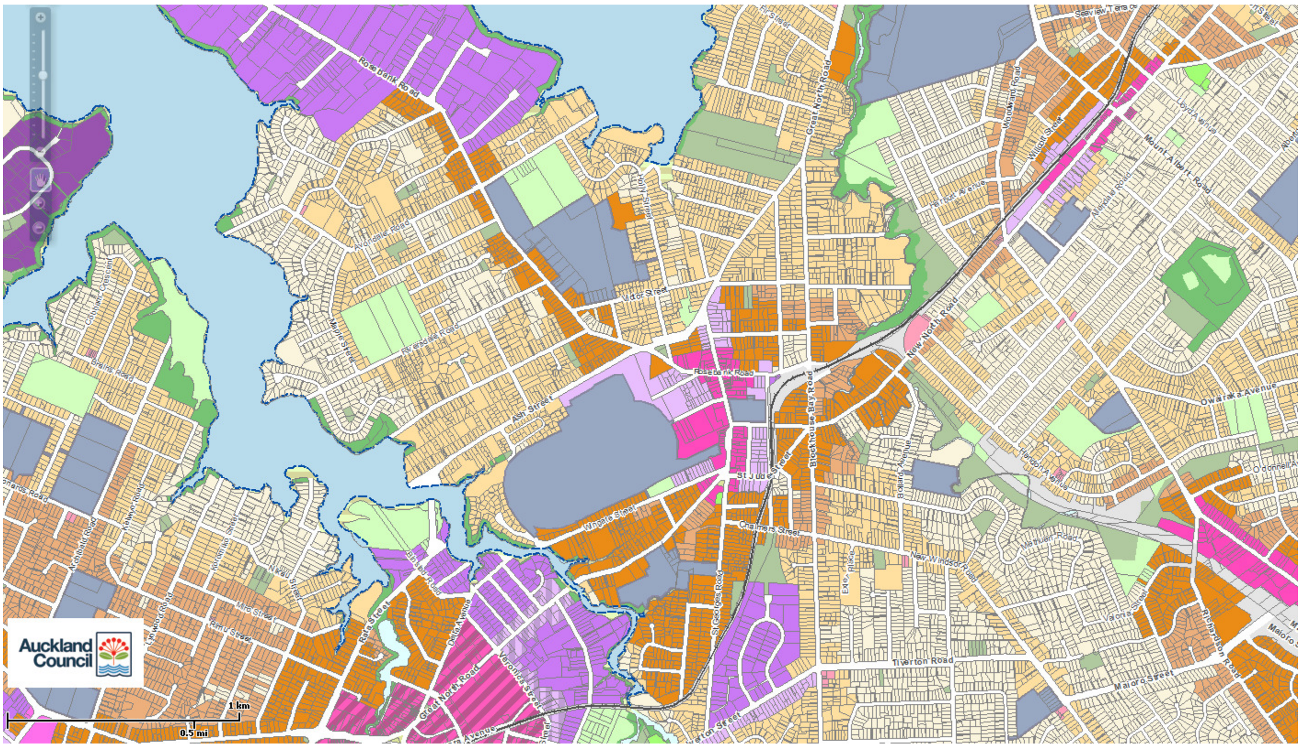


Figure 3: Example map showing development zones

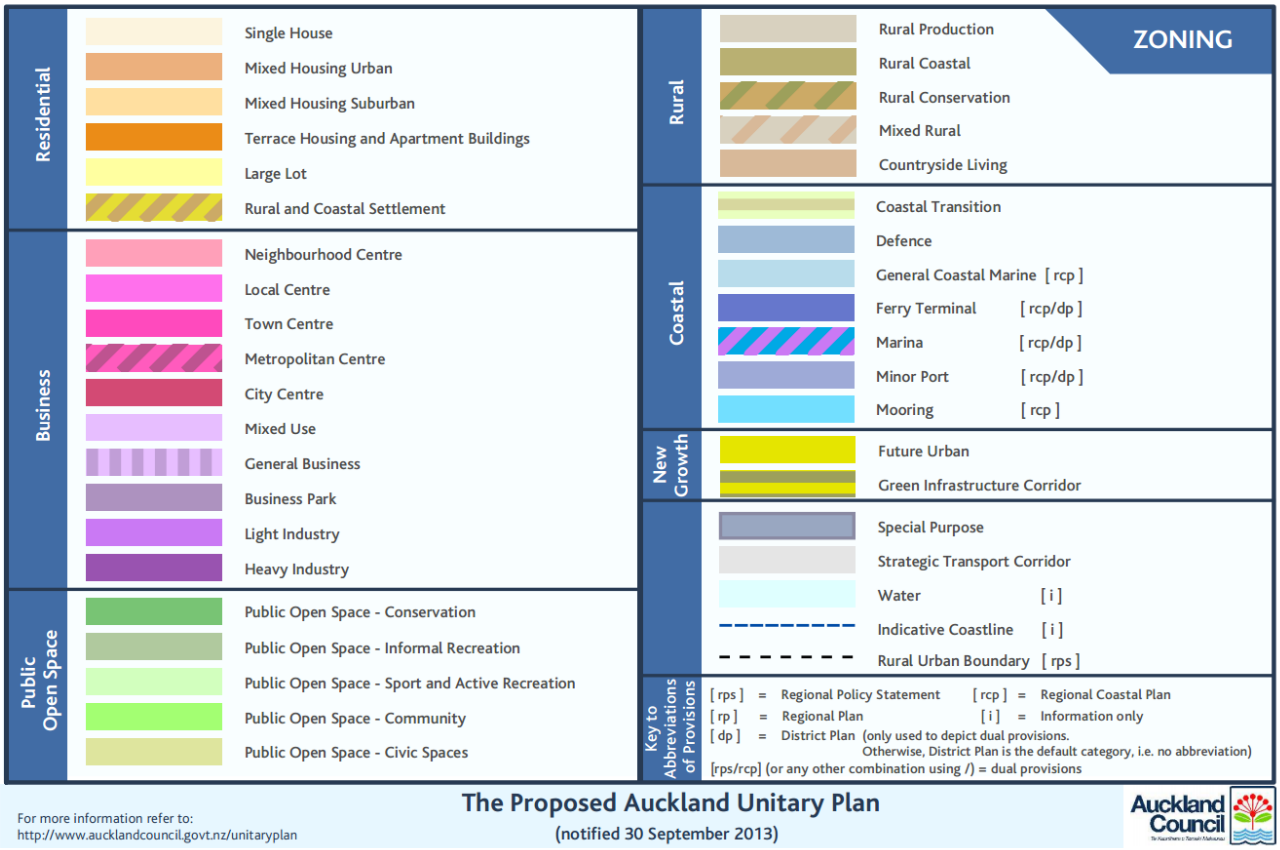


Figure 4: Proposed Unitary Plan Legend

In conjunction with specific building controls the PAUP has specified development control infringements, which if the design fails to achieve would change its activity status (Permitted, Discretionary, or Restricted Discretionary).

Building controls for developments to provide are specified for each activity zone which, if maintained, can minimise time and costs associated with consenting and consultation.

Example development controls which apply to Terrace Housing and Apartment Buildings include:

1. Development control infringements
2. Building height
3. Yards
4. Building setbacks within the Terrace Housing and Apartment Buildings zone
5. Building setbacks adjoining lower density zones
6. Minimum frontage and site width
7. Maximum impervious area
8. Building coverage
9. Landscaping
10. Outlook space
11. Separation between buildings within a site
12. Outdoor living space
13. Maximum building length
14. Minimum dwelling size
15. Daylight to dwellings
16. Minimum dimension of principal living rooms and principal bedrooms
17. Servicing and waste
18. Storage
19. Dwelling mix
20. Minimum floor to floor/ceiling height
21. Universal access

Activity	Large Lot zone	Rural and Coastal Settlement zone	Single House zone	Mixed Housing Suburban zone	Mixed Housing Urban zone	Terrace Housing and Apartment Buildings zone
Residential						
Dwellings	P	P	P	P up to 3 dwellings per site RD 4 or more dwellings per site	P up to 3 dwellings per site RD 4 or more dwellings per site	P One dwelling on a site D 2 to 4dwellings per site RD 5 or more dwellings per site

Table 1 Example activity status of activities in the residential zones.

4 AUCKLAND DESIGN MANUAL

The PAUP is the vision for the Auckland region over the next 30 years and identifies that a renewed focus on good design can help our built environment be more successful and better contribute to Auckland's unique sense of place. To this aim, four principles of good design have been developed:

1. Identity
2. Diversity
3. Integration
4. Efficiency

The Auckland Design Manual (ADM) has been developed by combining the best content, design guides and precedents from the former Auckland region's legacy councils and from around the world into a single resource for design teams to utilise. The ADM aligns with the city's obligations as a signatory to the Ministry for the Environment's Urban Design Protocol which is an initiative committing signatory organisations to specific urban design initiatives. The purpose of the protocol is to use design within our towns and cities to help them become:

1. Competitive places that thrive economically and facilitate creativity and innovation
2. Liveable places that provide a choice of housing, work and lifestyle options
3. Healthy environments that sustain people and nature
4. Inclusive places that offer opportunities for all citizens
5. Distinctive places that have a strong identity and sense of place
6. Well-governed places that have a shared vision and sense of direction

(Auckland Design Manual, 2014)

4.1 ADM DESIGN PROCESS

The ADM details aspects of design which are considered at different scales and gradually focuses in from the overall environment and surrounding area to design detail.

The ADM advocates integrated design to provide quality space at all scales of the project, in the context of the site, setting and public realm; the building as a whole; and the small details. Design considerations and guidance are provided by the ADM at different scales include:

1. Neighbourhoods;
2. Streets;
3. Parks; and
4. Buildings and sites.

5 TECHNICAL REPORT 2013/035

The Unitary Plan continues to develop and refine the approach to improve environmental and community outcomes and address gaps in the current approach to stormwater management. In particular the PAUP seeks to better integrate the management of land use and development and associated adverse effects, with a greater focus on the generation and management of stormwater at or near-source, being consistent with the direction provided by the National Policy Statement for Freshwater Management 2011 (NPSFM), the New Zealand Coastal Policy Statement 2010 (NZCPS) and the Auckland Plan.

Auckland Council (2013)

Technical Report 2013/035 (TR2013/035) details the technical and scientific evidence base, and requirements to support, the provisions developed in relation to land use controls to manage stormwater contaminants and stormwater volume/flow. The report provides some technical explanation to assist in the implementation of stormwater quality and flow requirements.

The stormwater contaminant and volume/flow management rules are achieved through a range of policies including:

- Integrated management of land use and freshwater: Integrate the management of land use development, including redevelopment, and freshwater systems;
- Freshwater systems: Manage land use, development and subdivision;
- Freshwater quality: Manage land use and development, discharges and other activities; and
- Urban stormwater: Manage the adverse effects of land use and development, and the discharge of contaminants from stormwater and networks in urban areas

5.1 STORMWATER CONTAMINANT MANAGEMENT

TR2013/035, as with the PAUP, advocates the reduction and management of stormwater contaminants and manages the primary source of contaminants at source. This design approach minimises the need to manage large volumes of stormwater at a sub-catchment scale, particularly in existing urban areas where space is limited for large treatment devices. By managing contaminants at source the development may achieve benefits to streams and other elements of freshwater systems which may not be provided by sub catchment scale treatment.

To stay consistent with national guidance and Auckland Plan expectations the PAUP seeks to reduce existing adverse effects from contaminant discharges by requiring contaminant reductions / treatment at the time of redevelopment.

The current blanket approach of treatment requirements (75% of TSS) has been revised to focus treatment requirements based on contaminants of concern and receiving environment sensitivity. Treatment performance is expressed as Design Effluent Quality Requirements (DEQR) for key contaminants.

Symbol	Name	Design Effluent Quality Requirement
S	Sediment	TSS < 20 mg/L
M	Metals	T Cu < 10 µg/L, T Zn < 30 µg/L
T	Temperature	Temperature < 25°C

S = sediment, M = metals, T = temperature

Table 2 Stormwater device Design Effluent Quality Requirements

Receiving environment	Land use activity		
	Road, carpark	Roofing	Industrial sites activity area
River or stream	S, M, T	M, T	Appropriate to nature of activities, contaminants and receiving environments
All others	S, M	M	

S = sediment, M = metals, T = temperature

Table 3 Stormwater contaminants of concern

The DEQRs have been generated on the basis that the worst-performing BMP (be it from TP10, a proprietary device, or some other new BMP) provides acceptable treatment / compliance for DEQR's effluent quality for the land use.

Demonstrating compliance with the DEQR is equivalent to demonstrating compliance with 'best practice', and there is no requirement to prove that the water quality from a particular site meets the DEQR concentrations. The DEQR applies to the particular BMP, rather than to the site on which it is used. TP10 devices currently accepted as best management practise to achieve the Design Effluent Quality Requirements from specific pollutants are summarised in Table 4. Broadening the range of indicator contaminants to TSS, metals (copper and zinc) and temperature, for which DEQR must be met, further emphasises the need for an integrated holistic design approach and incorporating elements of design such as building materials, minimisation or elimination of impermeable areas and provision of treatment trains.

Table 7. Ability of TP10 BMPs to comply with DEQRs and to provide enhanced treatment

	TSS		Total Copper		Total Zinc		Temperature	
	DEQR Compliant	Enhanced Treatment	DEQR Compliant	Enhanced Treatment	DEQR Compliant	Enhanced Treatment	DEQR Compliant	Enhanced Treatment
Pond	✓		✓	✓	✓			
Wetland	✓	✓	✓	✓	✓		✓[1]	
Swale	✓		✓		✓		✓	
Filter Strip	✓		✓		✓		✓	
Wetland Swale	✓		✓	✓	✓	✓	✓	
Sand Filter	✓	✓	✓		✓	✓	✓	
Bioretention (lined)	✓	✓	✓		✓	✓	✓	
Bioretention (unlined)	✓	✓	✓	✓	✓	✓	✓	✓
Permeable Paving (lined)	✓		✓		✓	✓	✓	
Permeable Paving (unlined)	✓	✓	✓	✓	✓	✓	✓	✓
Living Roof	✓	✓	✓[2]		✓		✓	✓

[1] Providing the wetland is highly vegetated and well shaded

[2] Providing design is compliant with Auckland Council guidance (Fassman, Simcock, & Voyde, 2010)

Table 4 BMP ability to meet DEQR treatment requirements

5.2 STORMWATER HYDROLOGY MANAGEMENT

The loss of natural water systems and the degradation of their values, particularly streams, are highlighted in the PAUP as significant issues. Past development has resulted in both the physical loss (infilling/piping) and significant modification (such as straightening, channelising, introduction of structures, loss of riparian vegetation) of streams in the urban area, significantly reducing the ability of a stream to support healthy, diverse aquatic ecosystems. The management of land use, outlined in building and development controls in the PAUP, aim to control hydrological effects in areas where stream values have not been significantly compromised by past development supporting healthy in-stream ecosystems and Mana Whenua values. Management of imperviousness will also maintain an efficient functioning existing reticulated stormwater network, control flood risks and, in some older parts of Auckland, avoid an increase of combined sewer overflows.

The PAUP manages stormwater volumes/flows from development in five primary ways:

1. Water sensitive design applied to greenfield development and major redevelopment;

2. Hydrology mitigation in areas identified as high sensitivity/value (SMAF overlays);

3. Impervious area/flow management in areas draining to the combined sewer system;

4. The control of impervious surfaces and runoff volumes in areas outside of the SMAFs/ combined sewer areas (through maximum impervious areas in zones); and

5. The control of discharges from large impervious areas direct to receiving environments or from the public stormwater network.

5.2.1 SMAF AREAS

Stormwater Management Area: Flow (SMAF) areas are those (sub) catchments within the Rural Urban Boundary (RUB) which drains to streams identified as being sensitive to increases in stormwater flows and which have values (or potential values) that can be protected or enhanced through the management of stormwater volumes. SMAF1 catchments discharge to sensitive or high value streams that have relatively low levels of existing impervious area. SMAF2 catchments discharge to streams with moderate to high values and sensitivity to stormwater, generally with higher levels of existing impervious area within the catchment.

The hydrology controls are applied through land use rules (PAUP) that are triggered with the development or redevelopment of impervious surfaces within the SMAF areas. SMAF hydrology mitigation requirements are summarised in Table 5.

Stormwater Management Area	Hydrology mitigation requirement

SMAF1	• provide detention (temporary storage) with a volume equal to the runoff volume from the 95th percentile, 24 hr rainfall event for the impervious area for which hydrology mitigation is required; and • provide retention (volume reduction) of a 10mm, 24 hr rainfall event for the impervious area for which hydrology mitigation is required
SMAF2	• provide detention (temporary storage) with a volume equal to the runoff volume from the 90th percentile, 24 hr rainfall event for the impervious area for which hydrology mitigation is required; and • provide retention (volume reduction) of a 8mm, 24 hr rainfall event for the impervious area for which hydrology mitigation is required

Table 5 Stormwater Management Area - Flow hydrology mitigation requirements

Retention and detention requirements can be met using existing TP10 designs with some minor modifications. Some commonly used devices such as ponds and wetlands are unable to meet retention (volume loss) requirements and would require incorporation with other devices or design elements (treatment train, landscape) to comply with the stormwater planning requirements of the development's catchment.

6 GUIDELINE 04

Guideline Document GD_04, volume 1 introduces the principles and objectives for 'Water Sensitive Design for Stormwater' (WSD), volume 2 guides the design team through a design programme for land development. WSD can be applied to development scenarios in both 'greenfield' (undeveloped) and 'brownfield' (previously developed) situations.

Water Sensitive Design (WSD) promotes land use planning practices that balance land development with the ecosystems services necessary to support it. WSD is an inter-disciplinary design approach, which considers stormwater management in parallel with the ecology of a site, best practice urban design, and community values. WSD aspires to provide multiple public benefits from stormwater management and to develop a unique 'sense of place' for our communities.

A 'greenfield' WSD development directs stormwater to appropriate areas of a catchment, and provides for intensified or clustered development in these locations to minimise land disturbance and earthworks. The result is an effective balance of protected and enhanced natural environments and associated ecosystem services to support the proposed development, and more broadly the life supporting capacity of our communities.

In a brownfield situation WSD promotes the integration of new ecosystem services into the existing built form. This may be responding to existing environmental concerns on a site, to allow for intensified land use activity, or to enhance environments within and adjacent to the site. Reconstruction of buildings can be congregated within the site to provide space to retrofit ecosystem services. This may include the integration of raingardens, living roofs, swales, and mass tree planting, remediation of existing or contaminated soils, rehabilitation of watercourses and wetlands, and stream daylighting.

6.1 WATER SUSTAINABLE DESIGN (WSD) PRINCIPLES

WSD stormwater management principles, aligned with the PAUP and ADM, are summarised in GD04 which offers further guidance for land use planning and land development.

6.1.1 PROMOTE INTER-DISCIPLINARY PLANNING AND DESIGN

GD04 promotes a multi disciplinary design approach which considers WSD principles early in the planning and design process of development or redevelopment. By including the input and skill of multiple disciplines including engineering, landscape, architecture, urban design, etc a project team can identify project risks and opportunities early in the design process and deliver a complementary environmental, economic, and socially beneficial stormwater management outcome.

6.1.2 PROTECT AND ENHANCE THE VALUES AND FUNCTIONS OF NATURAL ECOSYSTEMS

The most efficient means to protect natural systems and processes is by influencing the design by developing land in the most developable areas of a catchment, limiting land disturbance and earthworks, and ensuring a balance of protected, enhanced, and resilient ecosystem services is provided. Protecting and enhancing existing natural systems for their stormwater management function.

6.1.3 ADDRESS STORMWATER EFFECTS AS CLOSE TO SOURCE AS POSSIBLE

WSD mimics a waste minimisation approach to stormwater management by primarily identifying options to eliminate or limit impervious surfaces and by eliminating or limiting pollutant generating surfaces. Reducing the impacts of these surfaces may be achieved through site-specific planning and design responses to intensify development and the selection of building materials.

6.1.4 MIMIC NATURAL SYSTEMS AND PROCESSES FOR STORMWATER MANAGEMENT

GD04 promotes the use of treatment devices which treat at the interface of soil, water, and plant systems. Including physical (e.g. filtration), biological (e.g. microbial action), and chemical (e.g. cation exchange) treatment processes which infiltrate, and transpire stormwater runoff, and capture and transform contaminants.

WSD promotes the integration of fit for purpose stormwater management and treatment tools to meet the DEQR's outlined in the PAUP. These can include a combination of engineered and WSD devices such as treatment wetlands, swales, living roofs, rain gardens, tree pits with conventional and proprietary stormwater treatment and conveyance methods.

7 TECHNICAL PUBLICATION 10

TP 10 devices provide an accepted design approach to meet the DEQR, detention and retention requirements of the PAUP. Design teams are required to align treatment, detention and retention device performance with contaminants of concern, the receiving environment and the development space available.

TP10 provides a multi- faceted, integrated approach to minimising and managing effects and is aligned with GD04 and ADM, and the PAUP. In the context of stormwater management, the 'avoid, remedy or mitigate' concept matches three stormwater management concepts:

- 'Avoid' - Site design and practices which prevent stormwater becoming contaminated by reducing runoff or removing contaminant sources, e.g., use of non-zinc roofing materials, reduction of impervious area e.g. porous paving.
- 'Remedy' - Contamination control

- Source control - practices which separate contaminants or prevent them from contacting stormwater runoff.
- Management practices - work practices that avoid or reduce the potential for runoff to become contaminated.

- 'Mitigate' - Treatment devices which reduce the quantity of contaminants in stormwater or retard the volume of flow e.g. constructed wetlands, detention ponds

7.1 TYPICAL WSD PRACTICES

Water quality ponds detain stormwater inflows to allow suspended solids to settle. There are two main types. Wet ponds have a permanent pool with very slow flow through the pond and dry ponds which have a temporary pool formed by capturing and releasing stormwater at a slow rate. Water quality ponds meet the DEQR's for TSS, Copper and zinc however don't meet the requirements for temperature. Landscape of ponds can promote aerobic decomposition and adsorption of contaminants on to plants providing tertiary treatment benefits by removing some nutrients and further sediment.

Wetlands detain flows to allow sediments to settle, and remove a significant proportion of contaminants by adhesion to vegetation and aerobic decomposition. Vegetation is an integral component of the wetland system and assists each of the treatment mechanisms by reducing water velocities and turbulence, and significant surface area for silt adhesion. Well vegetated and shaded wetlands reduce dissolved metals and nutrients through biological uptake and meet DEQR's.

Detention practices include detention ponds and tanks to intercept stormwater flows, store and release at a reduced rate. Their volume is determined according to flood routing principles outlined (TR2013/035). Their primary function is to reduce flooding and erosion of the downstream channel, however can provide water for flushing and irrigation.

Filtration devices include devices which incorporate sand, or other filter media to remove contaminants from stormwater when it passes through the filter media. Filters generally only service a small catchment area and therefore only give limited hydrological benefit from flow attenuation on a catchment basis.

Infiltration practices including infiltration trenches, soakage pits and unlined porous block pavements collect and hold water below ground promoting soakage to the groundwater table. Soils must be permeable enough to disperse stormwater in a reasonable time and ensure the practice is ready to receive further inflow. Infiltration practices can meet the DEQR and hydraulic requirements of the PAUP.

Bio filtration devices including raingardens, filter strips and vegetative swales utlise plants and organic filter material to remove sediment particles and pollutants by adhesion as it filters through them. Dense vegetation, low water velocity and a long exposure time through the vegetation are required to ensure reasonable effectiveness. Biofiltration practices have multiple benefits including easy incorporation into limited landscape space reducing impermeable area, assisting groundwater recharge and increasing hydrological response times.

Open space and recreation areas are increasingly competing with on-site utilities and access ways, these competing needs require an integrated design approach to meet the treatment and volume requirements outlined in the PAUP. TP10 provides design guidance for specifically localised, de-centralised water sensitive designed stormwater treatment and attenuation devices which can be integrated into development providing treatment and attenuation requirements.

8 PRACTICAL APPLICATION OF AVAILABLE DESIGN TOOLS

A fictitious development demonstrates how a holistic integrated design, using available design guides including the PAUP, the ADM, TR2013/035, Guideline 04 and Technical Publication 10 (TP10), can exceed the stormwater requirements set out by the PAUP and provide a quality water sensitive design, low impact development within an existing urban area.

The exercise set out to:

- Promote the use of public transport, cycling, and walking by locating the development near existing amenities and infrastructure.
- Reduce strain on water infrastructure.
- Provide a "standard kiwi home" floor area.
- Provide community shared space.
- Incorporate sustainable drainage within the landscape and promote habitat.
- Comply with the terrace housing and apartment buildings zone development controls of the PAUP. Complying with development controls of the landuse maintaining a restricted discretionary activity.

8.1 BACKGROUND

The development area was selected as a typical Auckland suburb which has been in filled over time. The study area is located within 1km from the Avondale town centre, which has been identified as a town centre for growth in the PAUP. The development utilised the existing / surrounding infrastructure providing residents access to services, employment, education, retail and entertainment, and public transport. The location of the development promoted walkable neighbourhoods, fostering a sense of community and increasing the vitality of the Centre. The development area's stormwater catchment, which includes road runoff, currently discharges to the Oakley Creek untreated and un-attenuated via an existing stormwater reticulation network. The area is located outside modelled flow paths or flood zones.

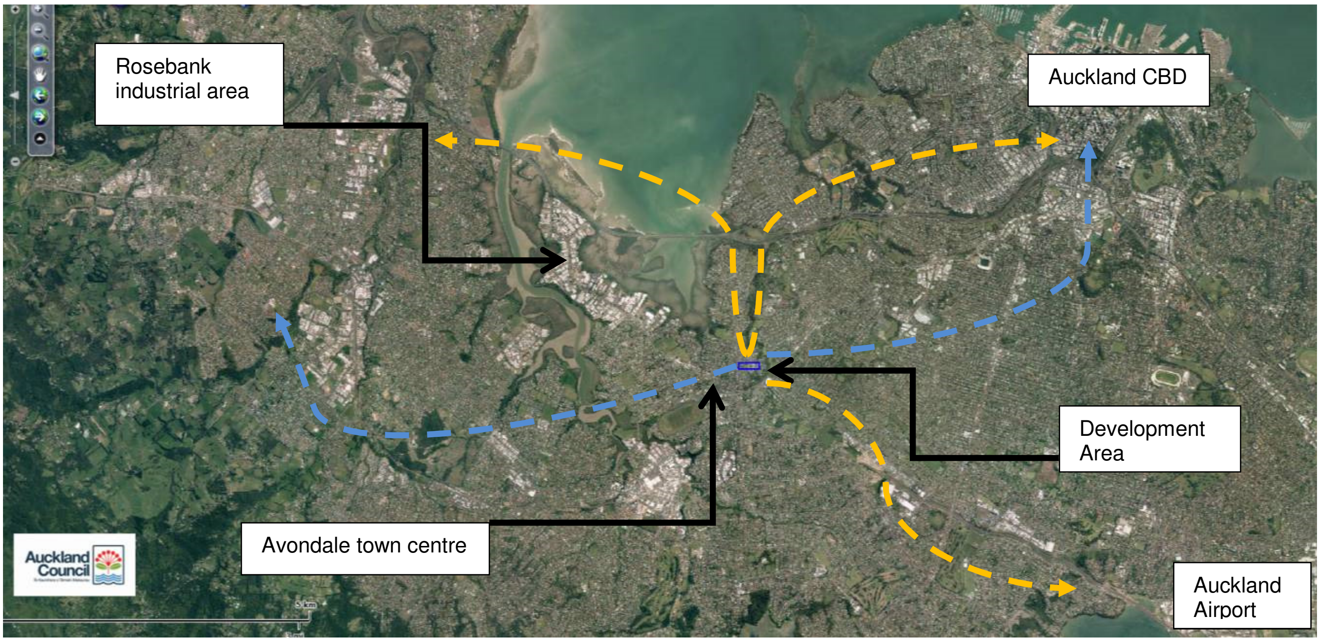


Figure 5: Exercise area, within Auckland showing rail and road links

The total development area is 3 ha and consists of 61, existing homes, consisting of a combination of 1940's weatherboard and brick and tile homes less than 10 year's old. Since the 1960's the development area has experienced a progressive increase of impermeable area, with large ¼ acre sections being subdivided into 300 - 400m2 properties with house roof, driveways, garages, and paved yards; increasing the impermeability of the area from 16%, 1960, to 48%, 2010. Figures 6 and 7.

Figure 6: 1960's aerial photo of the study area

Figure 7: 2010 aerial photo of the study area

To meet the building design controls of the PAUP the desired "typical kiwi family home" living configuration needed to provide ample light and family space, with open space between buildings. A home area was decided by comparing floor areas of new build developments in Auckland including Long Bay, Hobsonville Point and Stonefields. These developments provided new, freestanding homes with three to four bedrooms, multiple bathrooms, multiple living spaces, and a total floor area between 155m^2 and 355m^2.

The development selected an example three bedroom homes floor plan which provided multiple living spaces, three bedrooms and a total floor area of 195m^2 (Figure 8). Parsvnath realestate, 2013. The development complied with the PAUP development zone requirements for terrace home / apartment developments and maintained a restricted discretionary landuse activity. The building height was set at four stories, 13.5m, providing a semi basement parking beneath the buildings, and maintaining building set back of more than 5m from adjoining properties. A total of 256 homes were provided with the floor layout in figure 8, within the 3 ha development area.

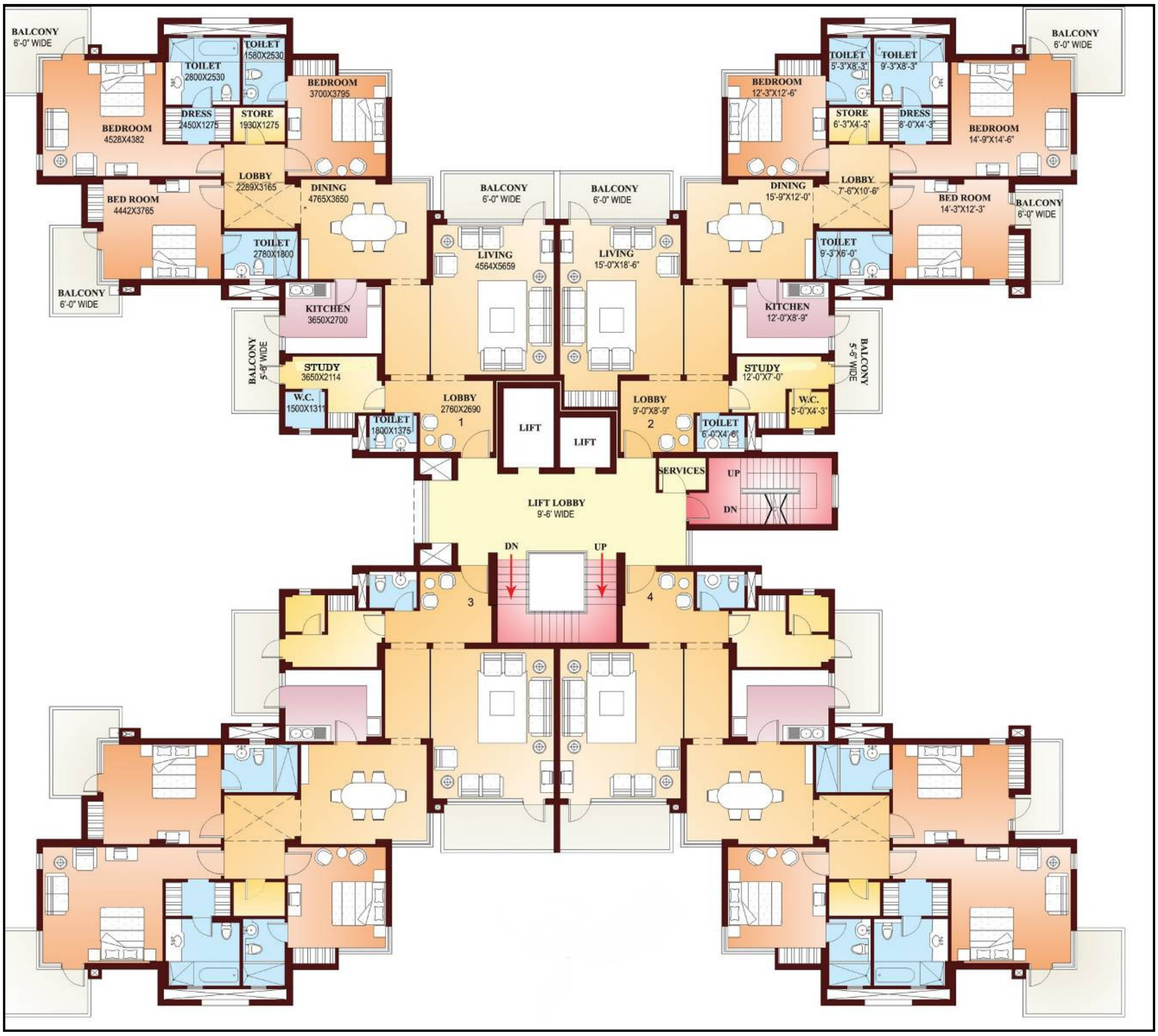


Figure 8: Development floor area

There was an emphasis placed on cooperation across the design disciplines, to provide a holistic low impact, and water sensitive design development. By understanding the existing site conditions and wider area the exercise responded, and positively contributed to its natural and built environment. Design elements of the development were considered to provide multi beneficial outcomes for the residents and the surrounding area. The development recognised the cultural and ecological significance of Ōwairaka (Mt Albert) and Te Auanga (Oakley Creek) by orientating the development maintaining a view shaft to Ōwairaka and providing a green corridor along the centre of the development ecologically connecting the development to Oakley Creek. (Figure 9).

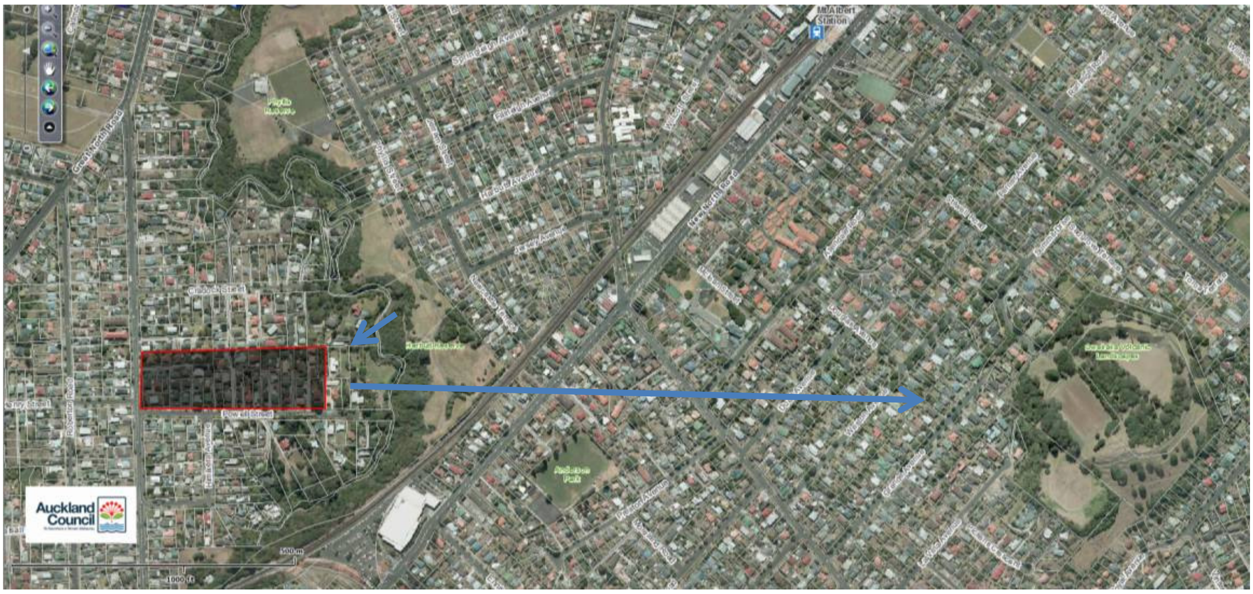


Figure 9: Development highlighting significant features and connections

8.2 WATER SENSITIVE DESIGN

To achieve holistic, low impact and water sensitive design the development minimised the extent of earthworks required by maintaining the existing site gradients, flow paths and overland flow paths of the surrounding environment. A central community open space, with native plants, provided the development an ecological connection to Oakley Creek, a central accessible corridor for services and overland flows and quality safe open space for the community.

Figure 10 Landscape integrated with water treatment and management

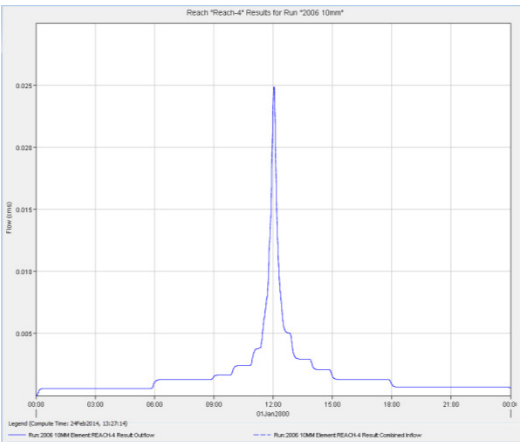
The development maintained the outlined building controls (example boundary distances and parking spaces) of the PAUP the development reduced the total impermeable area and the pollutant generating surface area.

The development collected the 10mm rainfall event from the building roof catchments only, for flushing and irrigation purposes of the residents as underground storage, a total of 100m^3. Due to the number of residents planned for this development it was accepted the volume of water harvested for flushing water would be consumed in less than 24 hours of a rainfall event. Access roads had anticipated low traffic volumes and were below the treatment requirement threshold. However the integrated landscape provided landscape areas, which were modified as small TP10 design raingarden stormwater treatment devices, to receive and treat road runoff. The raingardens were designed to provide treatment, and some attenuation, for the 95th percentile storm event. Overflows from the roof rain water harvesting tanks and road raingardens were directed to a central vegetated swale directing flows, including the 10% and 1%AEP, safely away from habitable floor levels, to Oakley Creek. The design model did not account for losses as a result of plant update or soakage which might occur in the rain garden or filter strip.

The development is fictional and did not consider challenges associated with dealing with multiple land owners, nor did the hydraulic model account for potential stormwater losses as a result of soakage, permeable pavement, or biological uptake within the model, which a real development would need to consider.

Dividing the development into sub catchments to each WSD element, catchment water quality and quantity improvements were able to be determined.

In conjunction with the reduction of impermeable areas directing roof catchment's 10mm event to tanks, for flushing purposes, resulted in a 98% reduction in peak flow from pre development catchment for the 10mm storm event. The 10mm discharge was not completely eliminated due to the sub catchments not directed to storage.



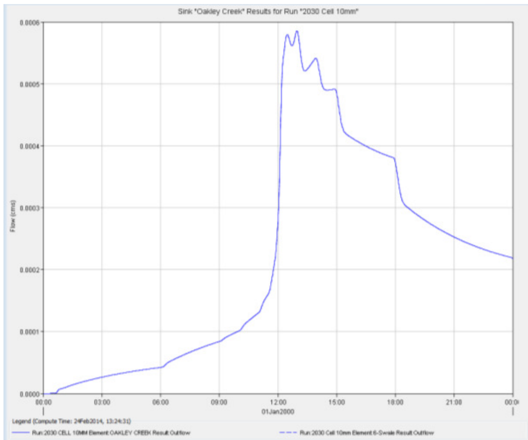


Figure 11 Model results of 10mm total area discharge pre and post development.

Modelled peak discharges of the 95th percentile storm event of the total development area showed a 20% reduction from the pre development's peak discharge.

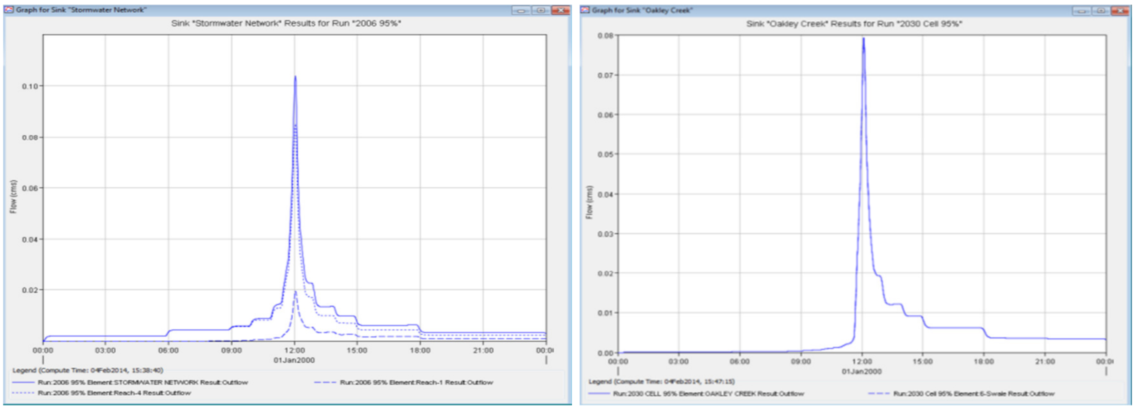


Figure 12 Model results of 95th percentile total area discharge pre and post development.

The development focused on minimising pollutant and stormwater generation by reducing the impermeable surface by 10% from pre development total impermeable area with the incorporation of rainwater harvesting, and bio-retention cells within the landscape a peak flow reduction of 17% of the 10% AEP rainfall event was modeled.

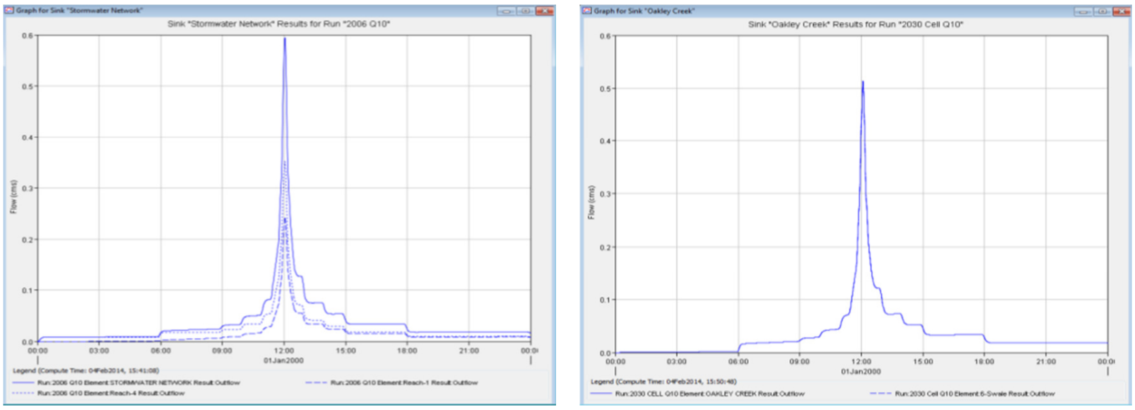


Figure 13 Peak flow pre and post development 10% AEP

The stormwater yield reductions demonstrated were from an existing residential area and it would be expected greater reductions could be realised as existing industrial and commercial zones are redevelopment.

9 CONCLUSIONS

The exercise has demonstrated that an integrated, multi-disciplinary approach to design can provide multiple benefits to the environment (stormwater quality and quantity), infrastructure, and the local and wider community within an existing urban area when redevelopment occurs. The reductions in stormwater peak flow, from residential development, would potentially be larger with an industrial or commercial area redevelopment due to the larger existing impermeable areas.

Extending design considerations to provide multi beneficial outcomes and integrate water sensitive design with planning, heritage, landscape and architecture requirements at early stages of the design process; developments can achieve positive outcomes towards infrastructure, the surrounding community and environment.

10 ACKNOWLEDGEMENTS

The paper would like to acknowledge Samuel Kelsey (JacobsSKM, University of Auckland) for his contribution to this paper and model development and the artistic ability and landscape contributions of David Compton-Moen (JacobsSKM). The contributions and discussions with Rowan Carter, Sam Blackbourn, and Nick Vigar from Auckland Council were invaluable to understand the implications and applications of stormwater design in the PAUP.

11 REFERENCE

Auckland Council (2014a) Water Sensitive Design For Stormwater : Principles, Auckland Council Guideline, Gd_04 Volume One. Auckland Council

Auckland Council (2014b) Water Sensitive Design For Stormwater : Practise, Auckland Council Guideline, Gd_04 Volume Two. Auckland Council

Auckland Design Manual. Auckland Council, viewed 10 February 2014, (http://www.aucklanddesignmanual.co.nz/design-for-auckland),

Auckland Council (2003). Stormwater management devices: Design guidelines manual 2003. Auckland Council

Auckland Council (2013) Defining Hydrologic Mitigation Targets for Stormwater Design in Auckland Technical Report 2013/024, July 2013, Auckland Council

Parsvnath real-estate, viewed 10 December 2013, (http://www.parsvnath.com/residential/gurgaon/parsvnath-exotica/floor-plan-tower-d.asp?pr=exotica)