AUCKLAND'S STORMWATER MANAGEMENT UNDER THE AUCKLAND UNITARY PLAN

Dr. Claudia Hellberg (Auckland Council), Ian Mayhew (4Sight Consulting), David Mead (Hill Young Cooper)

ABSTRACT

A significant challenge facing the Auckland Unitary Plan (UP) is to provide for significant urban growth in Auckland while at the same time addressing widespread existing issues including flooding, degraded water quality and ecosystem health, and loss and modification of streams. The National Policy for Freshwater Management (NPSFM), the New Zealand Coastal Policy Statement (NZCPS) and Hauraki Gulf Marine Park Act in particular direct that water quality and ecosystems should be maintained or enhanced where they are degraded.

In respect of stormwater management, a key approach put forward by Auckland Council (Council) in the UP is a greater emphasis on integrated management of land use and discharges, - moving from a focus on infrastructure and end of pipe management to a more integrated approach that manages land use activities, implements Water Sensitive Design (WSD), and management closer to source, particularly in sensitive areas, combined with a strong approach to reducing the risk of flooding. Key directions include:

- Recognising the need to progressively reduce existing adverse effects to meet the objectives of the NPSFM and the NZCPS while the region continues to grow and develop

- Emphasis on WSD being applied at all stages of development including the recognition that stormwater management should inform development layout and constraints from the outset

- Flooding objectives and provisions aiming to achieve no increase in flooding risk – a specific challenge for Auckland as a growing city, but redevelopment provides opportunities for decreasing existing risk

- Acknowledgement of values and importance of intermittent streams

- Introduction of flow management including retention of flows in catchments of sensitive streams in existing urban areas and greenfield developments

- Taking redevelopment opportunities to address existing effects from impervious areas where practicable

The UP is currently being considered by the Independent Hearing Panel, with decisions expected in mid – 2016.

KEYWORDS

Auckland Unitary Plan, Water Sensitive Design, Integrated Management

PRESENTER PROFILE

Dr. Claudia Hellberg holds the position of Strategic Planning Team Manager in the Stormwater Unit of the Auckland Council. She holds the qualification of Doctor of Engineering from the University of Hanover, Germany, and is an IPENZ Chartered Professional Engineer. Claudia Hellberg has 15 years of experience in stormwater and water resource management.

1 INTRODUCTION

A challenge facing the Auckland Unitary Plan (UP) is to provide for significant urban growth in Auckland while at the same time addressing existing issues including flooding, degraded water quality and ecosystem health, and loss and modification of streams.

The historical approaches to development in Auckland have resulted in a range of adverse effects including:

- river water quality data from the 33 sites in the state of the environment monitoring programme shows that 15 sites were below the NPSFM 2014 Appendix 2 NBLs based on the 2012 monitoring data. The majority of these sites are in or around the urban area and are below the NBLs for either the Escherichia coli or dissolved oxygen attributes. The exception to this is the Whangamarie Stream, which is located in the Franklin area and is the only site in the monitoring programme that breaches the nitrate NBL.Contaminant levels in marine sediments in the settling zones of most urban estuaries and harbours in Auckland are above those that can be harmful to aquatic life and monitoring confirms that ecology is degraded in estuaries that are adjacent to urbanised areas.

- A significant number of urban streams have been lost through piping, or are modified by erosion or the introduction of engineered structures such as channel lining, outfalls and stream culverts;

- Some 16,000 buildings are predicted to flood in the Auckland Region in a 1 % AEP event currently either from their being located in floodplains, overland flowpaths or flood prone areas.

With the growth prediction for Auckland this means an increased pressure to manage stormwater to address effects from urban growth and intensification.

The anticipated intensification of the city, if not well managed, could also result in placing additional people at risk of flooding. This is caused by low lying land being developed, which was previously not of interest to be developed under a single house per lot scenario. Under a more compact city a shift towards terrace housing and low rise apartments increases the likelihood of development disrupting the natural conveyance function of flood plains, displacing flood waters onto other properties, while overall placing more people and property at risk. Further, the increase in impervious surfaces can increase the volume of overland flows, which can cause further flooding effects and is the next progressive step to manage stormwater for new and redevelopments.

Effective stormwater management is key to managing adverse effects, both existing and future, on Auckland freshwater and coastal waterways within urban areas. Council believes that the management of urban hydrology and freshwater systems in a

considered and integrated way throughout the land use planning and development process is essential to achieving improved community and environmental outcomes. The application of a Water Sensitive Design (WSD) approach with an emphasis on avoiding or managing hydrological effects, preferably at or near source, is central to minimising the "hydrological footprint" and associated adverse effects of urban development.

Open watercourses and overland flow paths play an important part in the conveyance of urban runoff with high flows, which is likely to increase in the future with climate change predictions identifying more intense rainfall. Open watercourses are generally able to accommodate more flows along the same flow path, when bank full discharge is exceeded. Whereas pipes have a defined capacity and the inlet structures can also only accept a certain amount of water at a given time. The use of open watercourses and overland flow paths is a more resilient conveyance solution and links in with the retention of watercourses including intermittent streams for ecological reasons.

Council has proposed a range of provisions in the UP to achieve a more integrated approach to land development and stormwater management. These include:

- Over-arching objectives and policies in respect of integrated management, WSD, water quality/flow, freshwater systems and hazards;
- Controls on development, land use and discharges for water quality, hydrology and flooding;
- Controls on subdivision, including the application of a WSD approach, management of development within flood hazard areas and water quality/quantity ;
- Stormwater management requirements for integrated planning processes such as structure plans, and within precinct plans.

The UP is currently being considered by the Auckland Unitary Plan Independent Hearings Panel, with decisions expected in mid – 2016.

2 NATIONAL POLICY FRAMEWORK

The National Policy Statement for Freshwater Management, 2014 (NPSFM), the New Zealand Coastal Policy Statement, 2010 (NZCPS) and Hauraki Gulf Marine Park Act, 2000 (HGMPA) direct that water quality and ecosystems should be maintained or improved where they are degraded.

NPSFM

The NPSFM provides direction for freshwater management within New Zealand. In respect of water quality, the NPSFM seeks to:

- safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems, of fresh water and the health of people and communities (at least as affected by secondary contact with freshwater) in sustainably managing the use and development of land and discharges of contaminants (Objective A1);
- maintain or improve the overall quality of freshwater, while protecting the significant values of outstanding freshwater bodies and wetlands and improving the quality of water bodies that have been degraded by human activities to the point of

being "over allocated". In this context, over allocated means that an identified freshwater objective is not being met (Objective A2);

- improve integrated management of fresh water and the use and development of land in whole catchments, including the interactions between fresh water, land, associated ecosystems and the coastal environment (Objective C). Policy C2 specifically directs councils when preparing or changing regional policy statements to provide for the integrated management of the effects of the use and development of land on fresh water, including encouraging the co-ordination and sequencing of urban growth, land use and development; and land and freshwater on coastal water.

The primary mechanism of achieving these objectives is for regional councils to identify freshwater values in conjunction with iwi and communities and establish freshwater objectives and associated water quality limits for freshwater management units that include all freshwater bodies within their region. These objectives must include the compulsory national values of ecosystem health and human health for recreation and associated limits, and consider all national values and how they apply to local and regional circumstances. Where waterbodies do not meet established objectives (including NBLs), Councils are required to adopt targets and methods to achieve them over time.

Council is currently working through its implementation of the NPSFM. Given the state of many of Auckland's freshwater receiving environments significant improvement will be required to meet NBLs – let alone any higher limits resulting from community aspirations set through the implementation of the NPSFM. However, in the interim, Council has sought to establish an objective of improving overall freshwater quality in the region and progressively reducing the adverse effects of stormwater runoff.

NZCPS

The NZCPS recognises poor and declining coastal water quality in many areas as a consequence of point and diffuse sources of contamination, including stormwater and wastewater discharges as a key issue. In urban areas, contaminants are transported from a variety of land use activities via the stormwater network, overland flows and streams and in some cases groundwater.

The objectives of the NZCPS establishes an objective of sustaining the coastal environment and its ecosystems by maintaining coastal water quality, and enhancing it where it has deteriorated from what would otherwise be its natural condition, with significant adverse effects on ecology and habitat, because of discharges associated with human activity. The Auckland Regional Policy Statement (RPS), included in the UP, identifies large areas (generally harbours and estuaries) where coastal water and sediment quality has been degraded. These degraded areas are the coastal receiving environment for the majority of Auckland's urban land area.

Policy 23 of the NZCPS relates to the discharge of contaminants. Of particular relevance to stormwater is Clause (4) which directs to manage stormwater discharges by taking steps to avoid adverse effects of stormwater discharge to coastal waters on a catchment by catchment basis by:

- avoiding (where practicable) or remedying cross contamination of sewage and stormwater;

- reducing contaminant and sediment loadings in stormwater at source through contaminant treatment and by controls on land use activities;

- promoting integrated management of catchments and stormwater networks; and
- promoting design options that reduce flows to stormwater reticulation systems at source.

HGMPA

A large proportion of Auckland's urban area drains to the Hauraki Gulf Marine Park and hence are subject to the provisions of the HGMPA.

The purpose of the HGMPA is to establish objectives and integrate the management of the resources of the Hauraki Gulf and its contributing catchments. Section 7 recognises "the interrelationship between the Hauraki Gulf, its islands, and catchments and the ability of that interrelationship to sustain the life-supporting capacity of the environment of the Hauraki Gulf and its islands" as "matters of national significance". The management of the Hauraki Gulf and its catchments must recognise the national significance of the Gulf, with objectives of protecting and, where appropriate, enhancing the life-supporting capacity of the environment of the Gulf, its islands and catchments and their natural, historic, cultural and physical resources (section 8).

Natural Hazards

The RMA, under section 30 and 31 places a responsibility on the council to avoid or mitigate the effects of natural hazards. Section 106 provides further requirements in relation to subdivision of land that may result in material damage to that, or other land.

More recently, the government has announced a proposal to include managing the risks of natural hazards as a matter of national importance under section 6 of the RMA.

As a general comment, the legislative framework around natural hazards needs updating. This should reflect the shift towards more of a risk-based approach, but also some guidance on the issues of the nature and extent of risks that are acceptable or not.

3 INTEGRATED MANAGEMENT APPROACH

A key approach put forward by Auckland Council in the UP to give effect to national policy direction and to assist in improving community and environmental outcomes is a greater emphasis on integrated management of land use and stormwater discharges. This requires a move from a focus on infrastructure and end-of-pipe management at a development stage to a more integrated approach that seeks to achieve improved outcomes throughout the full range of processes under the UP.

Key mechanisms of achieving integrated management include Structure Plans and area specific Precinct Plans. These can be used to establish an overall concept for stormwater management, applying a WSD approach, which is then given effect to through subsequent stages including subdivision and land use development. Taking a high level approach at the concept and planning stages is important as the range of tools that are available to mitigate adverse effects, particularly those associated with WSD, become more limited and constrained as development proceeds.

As a result of this integrated approach stormwater provisions proposed by Council are spread across the UP. For example:

- RPS and Auckland wide provisions include:

- the adoption of integrated land use and water management planning processes, including structure and precinct plans, and consents for both greenfield and major redevelopment including the application of a WSD approach during planning design and implementation;

- aligning all phases of land development to the outcomes of the integrated planning processes;

- avoiding the permanent loss or significant modification of steams unless necessary and no practicable alternative exists;

- utilising the opportunities provided by land use change, development and redevelopment to restore freshwater systems and improve the quality of fresh and coastal waters;

- controling land use in conjunction with discharges.

- Structure plan requirements include consideration of stormwater catchment plans and discharge consents and provide an emphasis on WSD, including the retention of natural water systems and the primary use of on-site flow and quality controls to manage stormwater;

- Subdivision provisions seek the management of stormwater to be consistent with structure plans, precinct plans, discharge consents and any relevant stormwater management plan and in particular provides for the implementation of this approach at a site level, including the implementation of WSD;

- Subdivision provisions include a flooding assessment considering whether lots are being created without a building platform outside the flood plain, which should be avoided;

- Stormwater management provisions include stormwater discharge consent requirements that have regard to a range of matters including WSD; any overarching plan such as a structure or precinct plan; and controls on land use activities to manage stormwater quality and quantity (flow);

- Flood hazard was a key component (amongst others) as part of the decision making process whether areas should be proposed to be up-zoned.

The aim has been to provide a comprehensive and integrated approach that seeks to avoid adverse effects in greenfield developments to the extent possible and mitigate and progressively reduce adverse effects in existing urban areas.

A layering approach has been proposed that provides an over-arching concept for stormwater management, applying a WSD approach to the extent practicable, which is then given effect to through subordinate processes. However, in recognition that development processes do not always follow the same path or are of a different nature or scale, the provisions seek to consistently apply similar requirements to ideally achieve the same outcomes, whatever path is followed.

4 KEY DIRECTIONS

A range of key shifts have been proposed through the UP. Some of the key ones are discussed in this section.

4.1 REDUCTION OF EXISTING ADVERSE EFFECTS

The State of the Environment reporting in Auckland documents the poor state of many Auckland's freshwater bodies and marine environment. This was summarised in support of the UP provisions as including:

- Most urban streams display degraded instream health (as measured by the macroinvertebrate community index (MCI)) such that the average current condition of Auckland's urban streams (an MCI of 68) is below what is considered a considered a "poor" state (MCI of 80) by national guidelines.

- An assessment of the river water quality data from the 33 sites in the state of the environment monitoring programme shows that 15 sites were below the NPSFM 2014 Appendix 2 NBLs based on the 2012 monitoring data. The majority of these sites are in or around the urban area and are below the NBLs for either the Escherichia coli or dissolved oxygen attributes. The exception to this is the Whangamarie Stream, which is located in the Franklin area and is the only site in the monitoring programme that breaches the nitrate NBL.

- Many urban streams have water quality with metal concentrations that exceed the most permissive ANZECC Guidelines for copper and zinc for the protection of 80% of species.

- Contaminant levels in marine sediments in the settling zones of most urban estuaries and harbours are above those that can be harmful to aquatic life and urban stormwater is a significant contributor to these elevated contaminant levels. Monitoring confirms that ecology is degraded in estuaries that are adjacent to urbanised areas, and parts of some estuaries and harbours which receive mainly rural runoff may be impacted primarily by sediment rather than contaminants.

These degraded states are dominant in urban areas and marine areas receiving flows from urbanised catchments and have resulted from established activities. In this context, a planning framework that only addresses effects from new activities would not be sufficient to achieve the required and/or desired improvements in water quality.

Provisions sought by Council in the UP trigger improvements to be put in place at the time of redevelopment. These include:

- Policies as specified above applying to redevelopment and progressive reduction in adverse effects;

- The application of WSD to both development and redevelopment;

- Land use rules that apply to re-development as well as new development;

- The inclusion of rules that require mitigation to be applied to an entire area/site once more than 50% of the area/site is being redeveloped;

- Rules regarding redevelopment within flood plains require an assessment to reduce the risk from flooding, either through changes to the flood extent, or more likely in lot by lot redevelopment through changes to the dwelling and the activity.

4.2 WSD APPLIED AT ALL STAGES OF DEVELOPMENT

The application of WSD was intensely debated during the UP hearing process. Council's aim is a shift in the approach to greenfield and large scale redevelopment in particular to incorporate integrated land and water planning and into the design and planning phases of development and apply and implement a WSD approach. This includes a shift towards avoiding (as far as possible) the creation of adverse effects and maintaining or restoring hydrology and freshwater systems where possible rather than an end-of-pipe, device-led approach to mitigating effects. Such a shift is necessary, if Auckland is to maintain or ideally improve the state of its aquatic receiving environments.

WSD provides a more holistic approach to stormwater management, combining planning and natural and engineered stormwater management approaches to integrate urban stormwater management into the city landscape and minimise the environmental impacts of urbanisation, and in particular hydrological effects.

Council recognises that WSD includes a wide range of tools and options some, or even all, of which may not be suitable or appropriate in specific circumstances. However, the aim is a genuine attempt to minimise adverse hydrological and other adverse effects and the "hydrological footprint" of development, recognising that greenfield development will generally offer greater opportunities for more comprehensive approaches than typically provided by redevelopment.

Discussions through the plan process sought to resolve the definition and application of WSD to the point where a revised definition of WSD was proposed and generally agreed:

> *Water Sensitive Design (WSD) approach means an interdisciplinary approach to land use and development planning, design and implementation which integrates land use and water management, to minimise adverse effects on freshwater systems and coastal environments, particularly from stormwater runoff.*
>
> *Some of the tools and techniques that can be used for stormwater management under a WSD approach (noting that there are other tools and techniques and that not all tools and techniques will be appropriate for any particular site) include:*
>
> a. *Keeping and enhancing freshwater systems, including intermittent and permanent streams.*
>
> b. *Keeping or otherwise providing overland flow paths.*
>
> c. *Minimising changes to predevelopment hydrology in stream catchments, including maintaining soil infiltration, base flow, groundwater recharge, and reducing runoff volumes and the duration and intensity of flows which cause erosion and habitat degradation.*
>
> d. *Minimising impervious area on individual sites including through site design, clustering of houses, use of pervious paving and provision of open or vegetated spaces.*
>
> e. *Minimising the generation of contaminants, including minimising the use of high contaminant yielding building materials.*
>
> f. *Mitigating stormwater contaminants and runoff at or close to source.*
>
> g. *Using green infrastructure which also provides other benefits and values and can be integrated into the urban landscape.*

As discussed above, WSD is anticipated as a key method of avoiding, as far as practicable, and otherwise mitigating adverse effects of stormwater runoff in greenfield areas and to assist in reducing adverse effects as a result of major redevelopment and is given effect to in the UP through:

- RPS and Auckland-wide objectives and policies;
- Structure plan requirements and in some individual precincts;
- Subdivision, including the protection of streams and natural drainage elements;
- Stormwater discharge and stream provisions and rules.

4.3 NO INCREASE IN FLOODING RISK

In the preparation of the UP, more of an 'avoidance' stance was proposed to be taken to flood hazard management. That is, a greater emphasis was to be placed on avoiding further development in flood plains. This approach recognised the limitations of previous mitigation-based approaches, as well as the long term cumulative consequences on flood plain function from incremental development.

While structure planning in greenfield areas has generally sought to design new urban development in a way that avoid development in the 1% AEP flood plain, in the existing urban areas, the legacy plans inherited by the Council set out a variety of 'mitigation' approaches to managing flooding risks.

Provisions for flooding were discussed in the UP hearing as part of the natural hazard section. As a general principle the avoidance of risk from flooding in newly to be developed areas was agreed. How far avoidance of risk can be mandated on land already zoned for urban purposes was widely debated, including how much risk is tolerable and who carries the risk.

Some parties (such as the Insurance Council) sought a reduction in risk. Others considered that given the overall compact city approach, a degree of risk should be accepted otherwise the compact city strategy may be weakened. Council's approach focused on residential and related activities (more vulnerable activities) and sought to 'dampen' down the potential for further development of these activities through zoning and development controls. Previous mitigation based strategies (such as habitable floors above flood levels) were not seen to be adequate within an intensifying city where cumulative effects of more development and more people in flood plains will mount.

An interesting component of this discussion was the interface between the Resource Management Act and the Building Act / Building Code. The latter prescribing that buildings are to be designed to ensure no surface flows enter the habitable floors in an event up to the 2% AEP; while the general standard for flood management is the 1% AEP. With this industry standard in mind and the objective of avoiding an increase in risk, and where possible reducing it, the council advocated for a strong emphasis on not allowing more vulnerable activities in the floodplain, while acknowledging that some properties in existing urban areas are fully within the floodplain and there is no possibility to stay outside the floodplain and fully avoid the risk. In these cases a minimisation of the risk through appropriate design would be expected.

In the Council's view, the Building Act and Building Code cover part of the effects of flooding (such as effects on the building itself). However, other risks, e.g. the risk to

other properties through for example displacement effects, are rather a resource management issue and should be addressed under the UP provisions. The discussions held during the UP hearing process made it clear that the distinction between the two acts in regard to flooding is not self-explanatory. A review of the Building Act and Building Code to align it with industry standard would be beneficial and would take away some of the lengthy discussions.

A key focus for council stormwater engineers was to inform zoning decisions as part of an integrated management approach and a first step towards avoiding flood risks where possible. The need to 'align' flood management objectives with zoning decisions was seen to be an important component of the overall strategy. The flood management rules sit in an Auckland wide section of the UP, and refer to non-statutory flood plain information held on Council's GIS system. While technically the flood plain rules sit 'alongside' the zoning controls and should modify how individual sites develop, there is still the potential for mis-alignment between outcomes where land is zoned for further development. In particular are landowners and developers arguing that the decision to zone land for more intensive development must imply (implicitly or explicitly) that additional flood risks are to be mitigated, rather than avoided.

In a comprehensive GIS exercise the flood information layer was overlaid with the zoning layer and in an automated process determined whether or not at least one building platform (8m x 15m) would be possible to be located outside the floodplain.

In addition to this automated process an individual property assessment was carried out at locations where the floodplain was considered unreliable or inaccurate. The locations were generally identified for individual assessment where one or more of the following criteria were met:

1. Upstream catchment small and unlikely to cause a floodplain;
2. Resolution of the floodplain mapping was coarse and zoning along the floodplain extents may be impacted;
3. No overland flowpath;
4. A small floodplain area;
5. Close proximity to flood prone area.

The individual property assessment involved a manual review of the accuracy of the floodplain giving consideration to the contributing upstream catchment size, the floodplain methodology derivation method (e.g. Rapid Flood Hazard Assessment), site contours, stormwater asset data and aerial photography. “Google Streetview” imagery was used in some cases. The result of the individual property assessments was that additional areas were identified for higher density development because the floodplain was considered inaccurate. The GIS floodplain layer was not modified.

The provisions in the UP distinguish between different types of activities. The provisions for ‘more vulnerable’ activities (such as residential developments and care centers) in the floodplain are looked at more carefully in regard to flood risks, while for activities identified as ‘less vulnerable’ (such as industrial and commercial) the provisions in the UP focus mainly on the effects from these activities on other properties upstream and downstream only.

4.4 VALUES AND IMPORTANCE OF INTERMITTENT STREAMS

A shift in the UP proposed by council is to provide greater management and protection for intermittent streams in the same or similar manner as permanent streams. This is based on the increased knowledge about the value and importance of intermittent streams.

The roles, functions and values of headwater, including intermittent, rivers have been well described internationally and it is recognised that collectively these determine the chemical, physical and biological integrity of downstream waters. This includes:

- Maintaining downstream water quality and hydrology (Alexander et al, 2007)
- Providing contaminant storage and transformation functions (Dieterich and Anderson, 1998; Tzoraki et al, 2007);
- Providing for groundwater recharge and discharge (Winter, 2007)
- Storage and retention of eroded sediments (Dieterich and Anderson, 1998)
- Provision of organic matter and food resources to downstream reaches Wipfli et al, 2007; Kaplan et al , 2008)
- Maintaining local and catchment scale biodiversity Meyer et al, 2007; Arscott et al, 2010).

Whilst much of this evidence is international in origin, there are a small number of New Zealand based studies of intermittent streams that demonstrate similar findings locally. The absence of water in intermittent streams is often considered to be an indication of lesser values. However, Storey and Quinn (2013) found that 37 of the 53 taxa found in nearby permanently running water survived in the dry substrates of intermittent rivers in Hawke's Bay. Similarly in Auckland, Parkyn et al (2006) found that intermittent streams contained biological communities that were not significantly different from those of permanently flowing waters. Storey et al (2011) re-analysed this Auckland dataset, supporting the previous findings, but also noting that intermittent stream communities were important in maintaining catchment scale diversity and concluded that based on biological values, there is no reason to manage intermittent and permanent rivers differently. This also aligns with the RMA definition of a river as a "continually or intermittently flowing body of fresh water".

Council's proposed provisions in the UP respond to this information by applying the same provisions to intermittent stream reaches as those for permanent streams. The aim of retaining Auckland's remaining streams as far as possible is supported by stronger objectives and policies and a non-complying consent activity status for the reclamation (including piping) of streams.

4.5 HYDROLOGY MANAGEMENT

The management of urban hydrology is a specific focus of the stormwater management and wider provisions of the UP. As shown in Figure 1 urban development, if un-mitigated, has a significant impact on the amount of stormwater that runs off from impervious urban areas.

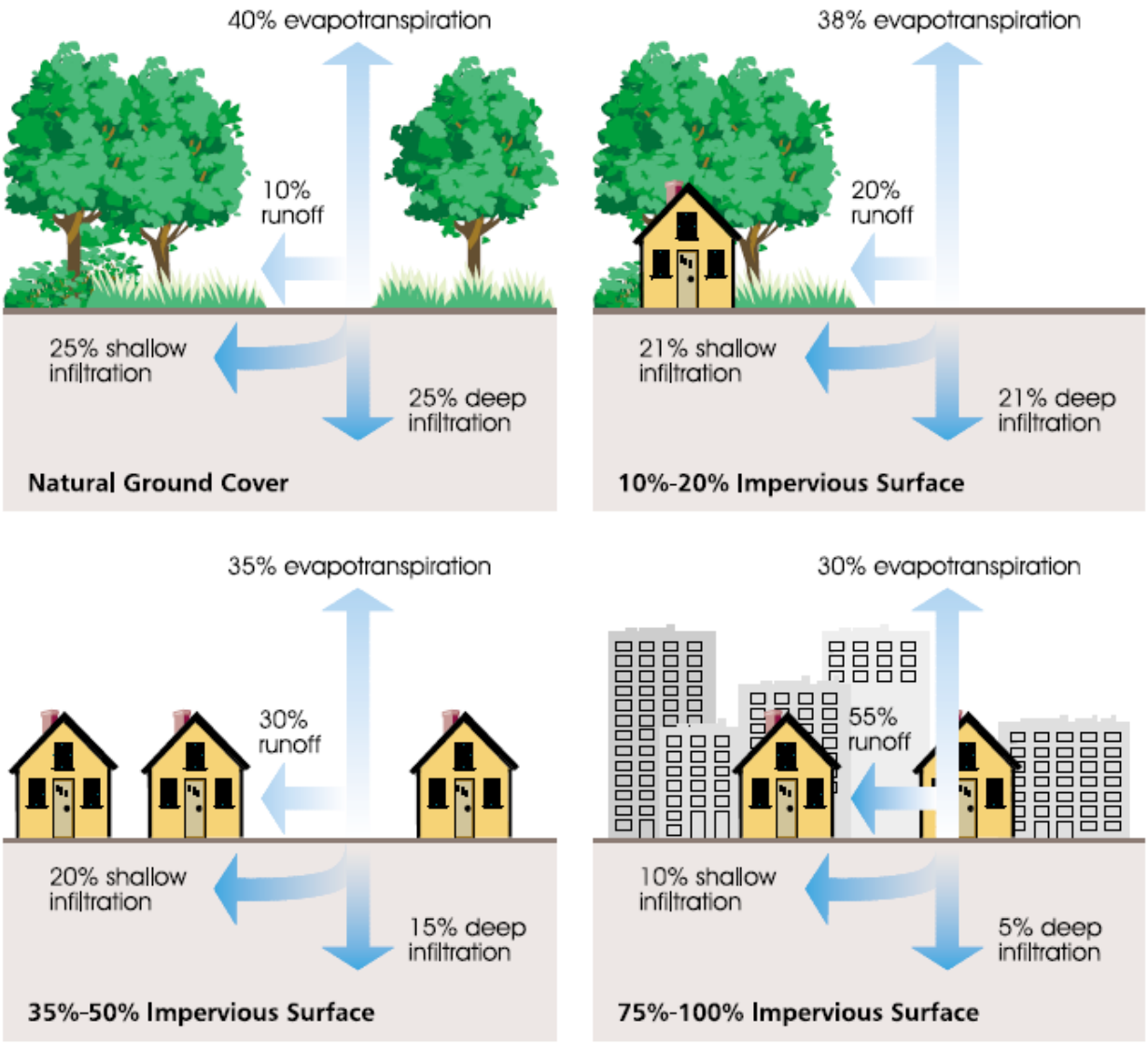

Figure 1: Impacts of urban development on Hydrology (Source: Prince George County, 1999)

In a natural catchment, hydrologic processes such as evapotranspiration, interception, depression storage and infiltration result in a smaller percentage of rainfall being transformed to stormwater runoff. In an urban catchment, these hydrologic processes are disturbed and the runoff volumes and peak flows increase due to the increase in the impervious area. The impervious areas reduce the amount of rainfall being lost by interception, evapotranspiration and depression storage. As shown in Figure 1, the runoff coefficient (the fraction of rainfall which is converted to runoff) increases with the increase in catchment impervious cover.

Historically, the traditional approach for the design and the management of urban stormwater was based on conveyance. In this approach, the stormwater system design is based on conveyance efficiency where stormwater runoff is removed as quickly as possible from the site and discharged directly into the receiving water bodies. This approach had the primary aim of the prevention of flooding problems. In essence stormwater runoff is treated as a nuisance and thus transported in a manner that is of "out of sight and out of mind". Experience has also shown that this traditional approach can create stream bank erosion and channel enlargement and associated loss of in-stream habitat. Additionally, the rapid conveyance of stormwater does not always fully

solve flooding problems – in some instances it merely transfers them elsewhere downstream.

End of pipe solutions, such as detention ponds or other measures to attenuate flow rates and treat stormwater at the outlet of drainage systems, can be applied to reduce adverse effects. However detention, which involves holding the stormwater runoff and releasing it at a controlled rate, does not reduce the volume of stormwater runoff.

The awareness of the importance of managing hydrology and reducing stormwater volumes to protect for stream health has increased significantly. Hydrology management and tools such as WSD are not new concepts, but rather reflect the increase in the level of sophistication of urban stormwater management to prevent or reduce environmental degradation and achieve multiple ecological and community outcomes.

This evolution in stormwater management is not unique to New Zealand. Fletcher et al. 2014 summarised this trend pictorially as follows:

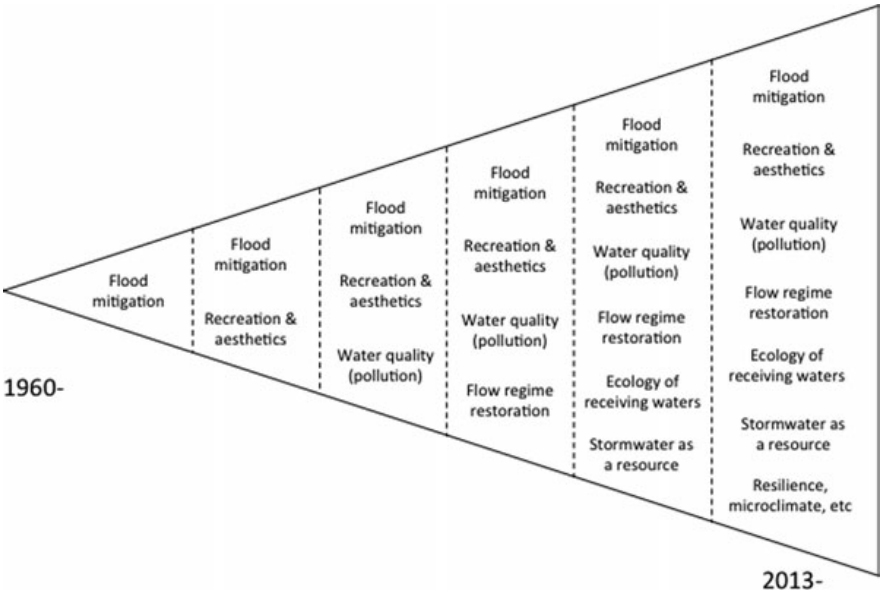

Figure 1: Increasing integration and sophistication of urban drainage management over time (source: Fletcher et al. 2014)

Managing hydrology and minimising hydrological change requires a multi-faceted approach that:

- Minimises changes from pre-development hydrology through a combined approach involving conservation and protection of important hydrologically functional natural landscapes, together with careful/sensible site design (that minimises site disturbance and manages the amount and size of impermeable area);

- Manages post-development stormwater using distributed, decentralized micro/lot-scale controls to manage stormwater runoff at/near source rather than at the end of the pipe where possible;

- Seeks to preserve predevelopment hydrology conditions (e.g. temporary storage (detention) and infiltration (retention)) through controlling runoff volume, peak runoff rate, flow frequency/duration, and water quality;

- Utilises natural flow paths and streams to convey stormwater in preference to channel and piped systems to help slow water flow through the system and retain the time of concentration of flows within the catchment.

In part, these outcomes are achieved through the application of a WSD approach as discussed above. However, the UP also contains specific provisions relating to hydrology management including:

- Retention and detention requirements and/or hydrological outcomes for greenfield development in the stormwater discharge provisions;

- WSD and the protection of natural drainage systems in subdivision and stormwater discharge provisions and structure planning requirements;

- Hydrology control requirements (retention and detention) for the development of impervious areas in sub-catchments that drain to identified sensitive/high value streams – these are called Stormwater Management Area: Flow or SMAF as they have become commonly referred to.

In general, greenfield and larger redevelopment offer an opportunity to manage stormwater hydrology more comprehensively. In order to provide flexibility to find the best stormwater solution for a specific area to be developed, the provisions in the PAUP for hydrological mitigation are "outcome focused" and Council's expectation is that the full spectrum of options are considered and the optimal solutions applied to achieve the desired outcomes. However, specific hydrology mitigation requirements have been proposed to provide a straightforward path in already urbanised areas in sensitive stream catchments (SMAF) and for small scale developments, with a default to a more comprehensive assessment where these are not able to be met.

4.6 TAKING REDEVELOPMENT OPPORTUNITIES TO REDUCE EXISTING ADVERSE EFFECTS

As discussed above, an important objective of the UP is the progressive reduction in the existing adverse effects of stormwater runoff and wastewater discharges on communities, freshwater systems and coastal waters. This was proposed in the context of Auckland's already degraded aquatic environments; the directions provided by the NPSFM, NZCPS and HGMPA; the extent of existing flood effects and Council's aspirations in its Auckland Plan.

Within the urban context, the primary method of achieving this is to take the opportunities provided by redevelopment to apply WSD and other stormwater management requirements. This is achieved by a range of provisions including:

- policies that seek to apply WSD and other measures to brownfield redevelopment;

- adopting regional land use controls (RMA s30 and s 9(2)) that apply to both development and re-development.

The significance of the use of regional land use controls is that they are not subject to existing use rights as district land use controls (RMA s 9(3)) are.

This approach does not require existing development to meet new stormwater management requirements. However, as redevelopment occurs, it is expected that the same standard of stormwater management will be adopted in line with the requirements for new development. To further reduce existing adverse effects, as discussed above, Council has proposed a rule which requires controls to be applied to all of the area/site once more than 50% of the area/site is being redeveloped.

In addition to avoiding additional risk through new developments, it was acknowledged that redevelopment of existing urbanised areas offers opportunities to reduce flood risks. This can for example be achieved by relocating existing housing so that the new housing lies outside of (what may be modified) floodplains. Generally, area or sub catchment wide redevelopment will be more beneficial than small site-by-site redevelopment. Investment in enhancement of stream corridors and flood management facilities is likely to be needed at the same time.

5 CONCLUSIONS

The historical approaches to development in Auckland have resulted in a range of adverse effects including:

- river water quality data from the 33 sites in the state of the environment monitoring programme shows that 15 sites were below the NPSFM 2014 Appendix 2 NBLs based on the 2012 monitoring data. The majority of these sites are in or around the urban area and are below the NBLs for either the Escherichia coli or dissolved oxygen attributes. The exception to this is the Whangamarie Stream, which is located in the Franklin area and is the only site in the monitoring programme that breaches the nitrate NBL.

- Contaminant levels in marine sediments in the settling zones of most urban estuaries and harbours in Auckland are above those that can be harmful to aquatic life and monitoring confirms that ecology is degraded in estuaries that are adjacent to urbanised areas.

- A significant number of urban streams have been lost through piping, or are modified by erosion or the introduction of engineered structures such as channel lining, outfalls and stream culverts;

- Some 16,000 buildings are predicted to flood in the Auckland Region in a 1 % AEP event currently either from their being located in floodplains, overland flowpaths or flood prone areas.

With the growth prediction for Auckland this means an increased pressure to manage stormwater to address effects from urban growth and intensification.

In respect of stormwater management, a key approach put forward in the UP is a greater emphasis on integrated management of land use and discharges - moving from a focus on infrastructure and end of pipe management to a more integrated approach that manages land use activities, implements WSD and management closer to source, particularly in sensitive areas, combined with a strong approach to reducing the risk of flooding.

Importantly stormwater and flood management should not be seen as an additional item to be covered, when developing, but should inform every step of the development, from planning through to implementation.

ACKNOWLEDGEMENTS

Many people contributed to the stormwater management and flooding provisions in the UP, both on behalf of Auckland Council and also through submissions and evidence on the UP provisions.

While many of the stormwater and flooding management issues and provisions discussed in the paper were the subject of vigorous discussion, mediation and evidence, parties were focused on achieving workable provisions that addressed the challenges facing Auckland – both in terms of providing for significant future growth while progressively addressing the existing issues.

All of these contributions have helped inform the IHP and assist in their decision making process.

REFERENCES

Alexander, R.B.; Boyer, E.W.; Smith, R.A.; Schwarz, G.E.; Moore, R.B. (2007). The role of headwater streams in downstream water quality. Journal of the American Water Resources Association 43:41-59.

Arscott, D.B.; Larned, S.T.; Scarsbrook, M.R.; Lambert, P. (2010). Aquatic invertebrate community structure along an intermittence gradient: Selwyn River, New Zealand. Journal of the North American Benthological Society 29: 530-545.

Dieterich, M.; Anderson, N.H. (1998). Dynamics of abiotic parameters, solute removal and sediment retention in summer-dry headwater streams of western Oregon. Hydrobiologia 379: 1-15.

Kaplan, L.A.; Larson, R.A.; Bott, T.L. (1980). Patterns of dissolved organic carbon in transport. Limnology and Oceanography 25:1034-1043.

Meyer, J.L.; Strayer, D.L.; Wallace, J.B.; Eggert, S.L.; Helfman, G.S.; Leonard, N.E. (2007). The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association 43:86-103.

Parkyn, S.; Wilding, T.K.; Croker, G. (2006). Small headwater streams of the Auckland Region Volume 4: natural values. Auckland Regional Council Technical Report 310.

Prince George County (1999). Low-Impact-Development- Hydrologic- Analysis. Maryland, USA

Storey, R.G. & Quinn, J.M. 2013. Survival of aquatic invertebrates in dry bed sediments of intermittent streams: temperature tolerances and implications for riparian management. Freshwater Science 32:250-266.

Storey, R.G.; Parkyn, S.; Neale, M.W.; Wilding, T.; Croker, G. (2011). Biodiversity values of small headwater streams in contrasting land uses in the Auckland region. New Zealand Journal of Marine and Freshwater Research 45:231-248.

Tim D. Fletcher, William Shuster, William F. Hunt, Richard Ashley, David Butler, Scott Arthur, Sam Trowsdale, Sylvie Barraud, Annette Semadeni-Davies, Jean-Luc Bertrand-Krajewski, Peter Steen Mikkelsen, Gilles Rivard, Mathias Uhl, Danielle Dagenais & Maria

Viklander (2014): SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage, Urban Water Journal, DOI: 10.1080/1573062X.2014.916314

Tzoraki, O.; Nikolaidis, N.P.; Amaxidis, Y.; Skoulikidis, N.T. (2007). In-Stream Biogeochemical Processes of a Temporary River. Environmental Science & Technology 41: 1225-1231.

Winter, T.C. (2007). The role of ground water in generating streamflow in headwater areas and in maintaining baseflow. Journal of the American Water Resources Association 43:15-25.

Wipfli, M.S.; Richardson, J.S.; Naiman, R.J. (2007). Ecological linkages between headwaters and downstream ecosystems: Transport of organic matter, invertebrates, and wood down headwater channels. Journal of the American Water Resources Association 43:72-85.