MANAGING WATER QUALITY IN URBAN AREAS

The increasing need to recognise and manage urban stormwater

Although several enacted or proposed legislative changes in New Zealand relate to water quality or water infrastructure, no effective strategy for managing urban stormwater has or will be put in place nation-wide. Problems caused by urban stormwater are largely unmonitored in New Zealand, despite evidence of harm in Auckland and Porirua Harbours dating back to the 1990's. The lack of acknowledgement of the seriousness of this issue and its potential long run economic, social and environmental costs is in direct contrast to policy approaches in England, America and Australia. These countries provide an example of problems caused by urbanisation, which are likely to be repeated in New Zealand, in the absence of more strategic infrastructure and land use planning.

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Overview

The public attention given to managing water quality in New Zealand has increased, particularly in relation to the *Proposed Freshwater Reforms* (that is, proposed amendments to the existing *National Policy Statement for Freshwater*), changes to the *Resource Management Act* announced in the *Resource Management Reform 2013: Summary of Proposals* and changes to the *Local Government Act 2002* regarding infrastructure provision and planning.

Despite the above, no effective national policy or strategy seems to be proposed, to protect water quality in or near urban areas, from a principle source of water pollution, being contamination from urban stormwater. In the same way that the Parliamentary Commissioner for the Environment has revealed a direct connection between increased acreage of land used for dairying and a decline in water quality in the report *'Water Quality in New Zealand: Land Use and Nutrient Pollution*' (2013); evidence is piling up both within New Zealand and overseas (particularly within America and Australia), that an increase in land area for urban development will lead to a decline in water quality, particularly in the absence of specific management activities to control stormwater. This means, that as urban areas expand to provide additional housing and commercial developments, threats on urban water quality increase.

There appears to be a significant disconnect in understanding the linkages between the natural environment (largely managed by regional councils) and land use and development (largely managed by district councils) in New Zealand. Environmental indicators are largely limited to biophysical indicators. That is, whilst water quality per se is being measured, the effect of urban expansion on water quality largely is not. Strategies to protect or improve water quality are unlikely to be effective, unless it addresses problems arising from land use activities.

It is unclear why the NZ Government has not accepted recommendation 13 of the *Local Government Efficiency Advisory Group*[1] reproduced below:

"The Government should review national goals for drinking water and wastewater[2] *to ensure that there is an appropriate balancing of community costs, health risks and environmental outcomes."*

Rather than using measures to reduce the quantity or flow of waterwater or improve its quality before entering watercourses at or near its source, as has occurred in Australia; the New Zealand Government is pursuing objectives for water bodies as a collective. It is considered that this end-result approach is less likely to be successful than more direct measures, which better manage land use activities which have led to water quality issues.

Concern is raised regarding the mixed messages and terminology used in government reports. The '*Report of the Ministry for the Environment for the Year ended 30 June 2013'*, outlines that the Ministry's mission is *"environmentally stewardship for a prosperous New Zealand".* Is the Ministry for the Environment saying that their mission is to take care of environmental resources in such a manner as make New Zealand rich and successful or that environmental resources are to be used like any other asset to achieve maximum economic gain? This is the literal translation of their mission statement.

[1] Report of the Local Government Efficiency Advisory Group (2013) Department of Internal Affairs, New Zealand

[2] Stormwater is typically classified as a type of wastewater.

The above mission statement appears well removed from the functions of the Ministry as set out in section 31 of the *Environment Act 1986,* the Act that created the Ministry, with its overriding objectives of:

> "*ensure that, in the management of natural and physical resources, full and balanced account is taken of—*
>
> *(i) the intrinsic values of ecosystems; and*
> *(ii) all values which are placed by individuals and groups on the quality of the environment; and*
> *(iii) the principles of the Treaty of Waitangi; and*
> *(iv) the sustainability of natural and physical resources; and*
> *(v) the needs of future generations"*

The '*Report of the Ministry for the Environment for the Year ended 30 June 2013*' adds that *"for New Zealanders to be prosperous, resources must be allocated efficiently to generate the most benefit while avoiding pollution and damage to the natural environment or public health."* The problem with such statements is that they ignore the fundamental conflict between maximising economic growth and maximising environmental protection. The concept of 'sustainable management of effects' (the current purpose of the *Resource Management Act 1991*) inherently implies that there is limit on the extent of development/profit that can be pursued, whilst maintaining (let alone improving) environmental values. The reality is pollution and damage to the natural environment are not being avoided and the big question is what environmental/social costs are we willing to accept, to achieve our desired economic and housing affordability goals?

The need for trade-offs was acknowledged in the 2009 Cabinet Paper for a *'New Start for Fresh Water*':

"*We recognise that trade-offs will need to be made, and not everyone's needs and expectations will be met in all places at all times…*

The issue underlying all others is that we are hitting resource limits. In some parts of New Zealand we are already exceeding the amount of water that can be taken from and/or the amount of pollution that can be absorbed by waterbodies without damaging the environment, economic potential or other values. When accommodating all interests would result in a breach of these limits, difficult decisions and trade-offs between values need to be made."

Most people would accept that there is a need to allow for additional urban growth expansion in New Zealand for both economic and social reasons. Rather than presenting a picture of being able to "have it all", I consider a better outcome is likely to arise from an explicit recognition of the costs of urban expansion. A fundamental problem in urban planning is that some costs, including the cost of poor quality housing, pollution, flood damage and life-time operational costs of supporting infrastructure, have often been under-estimated or obscured.

Decades of homeowners have had the real costs of their infrastructure, subsidised by ratepayers and/or taxpayers. This applies to both new infrastructure provision in greenfield residential areas[3]

[3] New Zealand Institute of Architect's Incorporated submission on the Housing Accord and Special Housing Bill (2013) refers to the Australian '*The Costs of Urban Sprawl (1): Infrastructure and Transport Report*' conducted by Parsons Brinckerhoff and Curtin University of Technology, which identified that "*for each new block on the urban fringe compared to redevelopment there is an infrastructure subsidy from various levels of government of around $A85,000."*

and in existing urban areas where existing infrastructure has had to be upgraded to meet new standards or to increase capacity.

Continued reliance on hard engineering solutions to overcome capacity or environmental problems is becoming increasingly expensive. The use of green engineering measures may have had lower long term operational costs as strongly advocated by the Philadelphia Water Department and New York City (America), in addition to substantial benefits in terms of lowering risk of flooding, maintaining water quality, maintaining biodiversity, higher visual amenity and providing recreational opportunities. Information is emerging around the world about unanticipated long-term costs from traditional drainage approaches to manage increasing volumes of stormwater, such as:

- Auckland Council's allocation of $973.8 million to address stormwater and flooding issues in their long-term plan[4];
- Philadelphia Water Department's commitment of $US1.2 billion in 2009 dollars to reach water quality goals[5];
- New York City's commitment of $US5.3 billion in 2010 dollars to reduce combined sewerage overflows in the city by 34% [6]and
- The identified need for the Thames Drainage Tunnel in London to cope with stormwater drainage volumes at an estimated cost *of* £3.8billion in 2008 dollars[7].

Although predominantly caused by pollution arising from farming activities, the *Lake Taupo Protection Project* and the clean-up operation for *Lake Ellesmere*, provide an example of the high cost of rectifying significant water pollution problems after they occur.[8]

The report of the Local Government Infrastructure Advisory Group[9] indicates that local government within New Zealand has interpreted sustainable development in terms of infrastructure provision, as requiring infrastructure to have the capacity to support future population growth, rather than infrastructure which has sustainable effects on the natural environment.

The comment in the above report on 'green engineering for water' that *"infrastructure systems (and consequent impacts on natural environments) could benefit from the wider adoption of such practices"* is unduly weak in light of the volume of international evidence of problems caused by urban strormwater and the demonstrated benefits of using more sustainable forms of infrastructure known as 'green engineering', 'low impact urban drainage', 'water sensitive urban design', 'total water cycle management' and 'sustainable urban drainage solutions'. Various reports in New Zealand, including those produced by the *'Land and Water Forum'* and 2013 Cabinet Paper on *'Improving Infrastructure Delivery and Asset Management'* show a lack of focus on water quality issues in urban environments and the holistic management/costing of infrastructure.

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[4] Auckland Council (2012) '*Auckland Council Long Term Plan 2012-2022'*

[5] Philadelphia Water Department (2011) *'Amended Green City Clean Waters, The City of Philadelphia's Program for Combined Sewer Overflow Control, Program Summary'*

[6] Halcrow Group Limited (2013) *'Drainage Strategy Framework for Water and Sewerage Companies to Prepare Drainage Strategies'*, London

[7] Environment Agency (2013) *'An assessment of evidence on Sustainable Drainage Systems and Thames Tideway Standards: A report by the Environment Agency for the Department for Environment, Food and Rural Affairs'*, Final Report, United Kingdom

[8] Stuff News Edition dated 02/02/13 identifies a cost of $NZ6.8 million to remove an additional 18 tonnes of nitrogen from Lake Taupo and Stuff News Edition dated 26/08/11 identifies that the $NZ6.1 million clean-up operation for Lake Ellesmere could take 25-30 years.

[9] *Report of the Local Government Infrastructure Advisory Group* (2013) Department of Internal Affairs

Water quality issues in New Zealand appear to largely concentrate on water quality issues applicable to rural environments, particularly issues arising from the agricultural use of land, in terms of water allocation for irrigation and pollution connected to the dairy industry. Given that approximately 85% of the New Zealand population reside in cities, water quality management also needs to accompany urban areas where the majority of the population live, work and play.

Adverse effects from stormwater have been identified in New Zealand for almost twenty years. Will it take another 20 years to put in place an effective strategy for this problem? If we wait this long in the face of clear scientific evidence from overseas that an increase in impervious cover will lead to a decline in water quality, we should be acknowledging that such a delay will be at the cost of water quality and more waterbodies being harmed to the point of no-return in the meantime.

The following section of this report describes recent and proposed legislative changes which relate to water quality or water infrastructure, and points out their limitations in dealing with the specific issue of urban stormwater.

The report than goes on to identify key problems and conclusions from overseas and New Zealand based research on the issue of urban stormwater. The last section provides a long list of quotes of problems caused by urban stormwater in New Zealand and abroad. This literature review was limited to easily available sources of information which can be downloaded from the internet without charge. The purpose of the literature review was to demonstrate the extent of existing information already widely available, which pinpoints that urban stormwater needs to be actively managed to avoid significant economic, social and environmental costs. This literature review is not intended to form an exhaustive list of research on the topic, but rather an easy to understand starting point.

Legislative Changes

Freshwater Reforms[10]

What will the changes do?

1. Requires regional councils to set freshwater objectives.
2. Sets national bottom lines for two compulsory values, being ecosystem health and human health when engaging in certain types of water recreation.
3. Identifies assessment criteria for the regional council to consider when determining applications for discharges.
4. Requires regional councils to outline methods for achieving freshwater objectives.
5. Requires regional councils to monitor process towards or achievement of freshwater objectives.

Limitations

1. Strategy imposes an obligation on regional councils and not on district councils.
2. Traditionally lack of involvement of regional councils in the control of activities on land, such as subdivision and construction of buildings/infrastructure, which will ultimately determine the quantity and quality of urban stormwater entering waterbodies.
3. Objections for water management do not need to be set by regional councils until 2030, well past the anticipated timing for major urban growth expansion encouraged by the New Zealand Government's package of reforms. Even then, considerable time may be needed to achieve the objectives decided upon and regional councils could argue that the reversal of impacts from 'historical activities' is not reasonable practical.
4. It is possible that new urban development occurring prior to 2030, could be declared a 'historical activity', that prevents freshwater objectives from being reasonable practical in the long term.
5. Objectives chosen could treat water in multiple catchments as a single freshwater management unit, which may allow less developed (rural) water catchments to disguise a decline in water catchments where urban expansion is occurring.
6. No explicit reference is made to problems caused by urban stormwater. Reference to stormwater is limited to the definition of diffuse discharges.
7. No minimum standards or objectives to be set for total nitrogen and phosphorous levels in rivers, which are more likely to be affected by urban stormwater than lakes.
8. Objective A2 and B4 refers to protecting the significant values of outstanding freshwater bodies, rather than all watercourses. Outstanding freshwater bodies are likely to be located outside of urban areas.

[10] Described within the Ministry for the Environment (2013) *'Proposed Amendments to the National Policy Statement for Freshwater Management 2011: A discussion document'*. Wellington: Ministry for the Environment

9. Stormwater runoff which is not collected by the drainage system is largely unmonitored. Within piped drainage systems, it may be difficult to separate out effects/volumes between different types of wastewater. Individual business and household connections to drainage systems typically do not require discharge consents. Stormwater is inherently difficult to monitor.

Changes to Resource Management Act 1991 (2012-2013 Reforms)[11]

What will the changes do?

1. Remove the hierarchy between existing section 6 (matters of national importance) and section 7 (matters to have particular regard to).
2. Deletion of the ethic of stewardship, finite characteristics of resources, maintenance and enhancement of the quality of the environment from the list of matters to have particular regard to.
3. New matters of national importance added, which includes benefits derived from the use and development of resources, availability of land to support changes in population and urban development demand and the efficient provision of infrastructure.
4. Replacement of the '*protection of habitats of trout and salmon'* with '*maintenance of aquatic habits, including significant habitats of trout and salmon'* as a RMA principle.
5. Replacement of '*intrinsic values of ecosystems'* with '*the effective functioning of ecosystems'* as a RMA principle.
6. New methods added in the principle section of the RMA which require Councils to "*ensure that restrictions are not imposed under this Act on the use of private land, except to the extent that any restriction is reasonably required to achieve the purpose of this Act".*
7. Change to section 31 (functions of territorial authorities) to ensure that there is a minimum of 10 years zoned capacity to meet the demands of a growing population.
8. Reversal on the presumption that subdivision is not permitted, unless explicitly identified. That is, subdivision becomes a permitted activity, *"unless it contravenes a national environmental standard, or a rule in a plan or proposed plan…"*
9. Change to s32 evaluations to explicitly quantify economic growth and employment opportunities arising from plan changes, with no explicit requirement to identify other specific costs or benefits.
10. Change to s76 to remove blanket protection of trees (or a certain type of tree) on urban allotments (up to 4,000m^2 in size).

Limitations

1. Changes to the principle section of the RMA encourage additional urban growth, with accompanying infrastructure development, at the same time that the weighting given to environmental effects of development is decreased.

[11] Covering the approved *Resource Management Amendment Act 2013* (2013 No. 63) and proposed changes to the Resource Management Act 1991 contained in the Ministry for the Environment's '*Resource Management Reform 2013: Summary of Proposals'.*

2. Changes to the principle section of the RMA effectively introduce a new test, for any new rules which further restrict/control the use of privately owned land in the interests of promoting the sustainable management of resources.
3. No reference to possible adverse effects associated with additional urban development or tools to manage these effects.
4. Compliance with the principle and purpose of the RMA is not identified as essential for development approved under the *Housing Accord and Special Housing Areas Act 2013*.
5. Changes to s32 evaluations could make it harder to adopt plan changes which reduce or limit economic growth or employment opportunities on the grounds that additional environmental protection is warranted. The need to explicitly identify economic costs and benefits could potentially prioritise limited funding for plan changes to the quantification of economic effects, and away from the identification of environmental or social effects.
6. The ability of Councils to require landowners to retain trees on urban allotments is reduced, with possible flow on effects in terms of reduced water absorption, greater urban stormwater runoff and increased sedimentation of watercourses.
7. The cumulative effect of the above provisions, could be to reduce the ability of Councils to require active stormwater management in new housing areas.

Local Government Act 2002 (Amendments 2010-2013)[12]

What do the changes do?

1. Purpose of local government (section 10) amended to delete reference to social, economic, environmental and cultural wellbeing.
2. New purpose of local government (section 10b) added, "*to meet the current and future needs of communities for good-quality local infrastructure, local public services, and performance of regulatory functions in a way that is most cost-effective for households and businesses".*
3. Definition of good quality defined as *"efficient, effective and appropriate to present and anticipated future circumstances".*
4. Core services for local authorities identified, including '*network infrastructure'*.
5. Mandatory performance measures for local authorities introduced (section 261) in relation to stormwater drainage and flood protection. Actual measures identified in 2013, which need to be reported in 2015/16 annual reports.
6. Need for Councils to review, following each local election, the cost-effectiveness of current arrangements for providing good-quality local infrastructure (including its management, funding and delivery provider).
7. Additional reporting requirements in long term plans and annual plans covering effects on rates, debt and levels of service from proposals to be pursued.
8. Each Council to prepare an infrastructure strategy covering at least 30 years.
9. Changes to development contributions policy, principles and methodology, which is a frequent source of funding for new infrastructure in urban growth areas.

[12] Included changes made to Local Government Act in 2010 and the proposed *Local Government Act 2002 Amendment Bill (No. 3)* anticipated to be adopted mid 2014.

10. Specific requirements for assessment of water and other sanitary services, to include *"the actual or potential consequences of stormwater and sewerage discharges within the district."*

Limitations

1. Reduced emphasis on managing environmental and social resources.
2. Cost-effective, good quality or efficient infrastructure does not need to be environmentally sustainable. Emphasis is on financial costs.
3. No bottom lines are set as to environmental standards for infrastructure to meet.
4. Non-financial performance measures for stormwater drainage have little relationship with environmental sustainability. That is, good performance could be recorded, even with an increased contamination of water from urban stormwater runoff.
5. Performance measures need to be reported, not acted upon.
6. Infrastructure strategy needs to consider the need to maintain or improve public health and environmental outcomes or mitigate adverse effects upon them. However, it does not necessarily need to report on these outcomes, improve them or actively prevent harm before it occurs.
7. Little measurement or recognition of total long-term economic, environmental and social costs from the poor management of urban stormwater, which is likely to lead to the under weighting of benefits from more sustainable forms of drainage infrastructure.
8. Lack of time to transition to new requirements (particularly for development contributions) could lead to some Councils being unable to demand development contributions in the face of anticipated urban growth, reduce funding for infrastructure provision and could place further financial pressure on Councils to minimise the upfront cost of infrastructure delivery. This approach could lead to higher operating costs for infrastructure over the long term.
9. Uncertainty as to how Councils can measure the effects of urban stormwater runoff. Whilst the recognition of potential consequences is a positive step, it is far removed from the active encouragement/requirement for stormwater management adopted by other governments.

Housing Accord and Special Housing Areas Act 2013

What are the changes?

1. Legislation has the express purpose of increasing residential land and urban housing supply.
2. Minister needs to consider whether adequate infrastructure exists or is likely to exist in proposed special housing areas.
3. Fast tracking of resource consents and the ability to apply for development not consistent with operative District and Regional Plans.
4. Hierarchy of matters identified for consideration in the assessment of resource consents.
5. Statutory prohibition of public notification of resource consents for qualifying development within special housing areas.

Limitations

1. The purpose of the Act has no consideration for the social and environmental effects of urban expansion, particularly rapid urban expansion.
2. Exclusion of the Act from the list of legislation which the Ministry for the Environment needs to consider its effectiveness for achieving the objectives of the *Environment Act 1986*.
3. Possibility that the Act encourages urban sprawl and property speculation, whilst discouraging more time-consuming strategic forms of urban planning such as spatial planning, concept planning, master planning and precinct planning.
4. Lack of clarification on how to assess ability to provide adequate infrastructure for special housing areas or resource consents. For example, it is uncertain how Auckland Council will provide adequate infrastructure to meet its target of 39,000 additional houses within 3 years contained in the *Auckland Housing Accord*.
5. Uncertainty as to whether territorial authorities will be responsible for supplying and funding new infrastructure for new development approved under the Bill, through existing and amended infrastructure provisions under the *Local Government Act 2002*.
6. Increased pressure to rapidly increase housing stock has the potential to sideline environmental issues, in the achievement of housing targets and other government priorities of the day.
7. Scope is provided for the approval of development with is inconsistent with the purpose and principles of the Resource Management Act, local planning provisions and New Zealand Urban Design Protocol.
8. Inability of any scientific, technical, community or environmental group to make a submission on resource consents, regardless of circumstance.
9. The rush to make more land available and build new houses could lead to development which has higher long-run costs.
10. The cumulative effect of the above provisions, could be to reduce the ability of Councils to require active stormwater management in new housing areas.

Possible Combined Effect from Legislative Changes

1. Increased impetus to build housing quickly.
2. Increased impetus to supply additional infrastructure to service new housing quickly.
3. Additional time constraints on strategic land use and infrastructure planning.
4. Increased pressure to provide new housing and supporting infrastructure at reduced upfront cost.
5. Increased potential for unintended social, economic and environmental medium and long-term costs by favouring development at the lowest short-term economic cost.
6. Shift in balancing of considerations, towards economic criteria.
7. Increased financial pressures on Local Government and incentives to minimise the upfront cost of infrastructure provision.
8. Anticipated increased reliance on traditional drainage solutions.

9. Uncertainty as to whether the Government's push to increase consistency between Councils and reduce the cost of housing supply would result in the abandonment of policies/provisions encouraging active stormwater management adopted by more forward-thinking Councils (e.g. Auckland Council).
10. Anticipated reduction in water quality in areas where urban growth occurs.
11. More strategic focus on managing water quality in rural and urban areas in the medium to long-term. The establishment of freshwater objectives by regional Councils in 2030, has the potential to put New Zealand on a par with the American and Australian impetus to research and document localised stormwater effects, which occurred in these countries circa 2000. Mechanisms to address identified problems could be another decade away (2040).

Literature Review of Stormwater Problems in New Zealand

Areas within New Zealand affected by stormwater pollution

- Auckland Harbour, Orakei Basin and Auckland beaches;
- Urban streams in Hamilton
- Porirua Harbour;
- Wellington coast;
- Hutt and Wainuiomata rivers and Waiwhetu and Kariori streams (Wellington region); and
- Avon/Otakaro and Heathcote/Opawaho Rivers (Canterbury region).

Key Findings of Literature Review in New Zealand

- There are no national standards for what contaminants are to be discharged via either wastewater or stormwater.[13]
- Stormwater generally has little or no treatment, contains sediments and bacteria, as well as persistent contaminants.[14]
- The water quality of rivers and streams, lakes, wetlands and groundwater in the Wellington region is being polluted by discharges and contaminants arising from urban and rural land uses.[15]
- There is substantial evidence that urban development is harming the very water bodies beside which New Zealand's cities were founded.[16]
- As the proportion of pastoral and/or urban landcover increases, water quality and macroinvertebrate health tend to decline while nuisance periphyton and macrophyte growth increases[17].
- Territorial authorities in the Wellington region hold consents authorising the discharge of diluted untreated or partially treated wastewater to rivers and streams during times of very heavy or sustained rainfall. On average, wet weather wastewater overflow discharges typically occur at least two to three times a year[18].
- The failure of sediment control mechanisms have resulted in large volumes of sediment entering streams in the Porirua Harbour catchment[19].
- Pollutants from roads, stormwater and sewerage systems have fouled Porirua Harbour, particularly the Onepoto Arm with public health warnings starting to appear in the late 1970's[20].

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[13] *Report of the Local Government Infrastructure Efficiency Advisory Group (2013)* Department of Internal Affairs

[14] Greater Wellington Regional Council (2013) *Regional Policy Statement for the Wellington Region*

[15] Ibid.

[16] J. Moores, C. Batsone, M. Green, S. Harper, A. Semadeni-Davies, J. Gadd and R. Storey (2013) *'A Tool for Evaluating Stormwater Management Outcomes across the Four Wellbeings'*

[17] Perrie A, Morar S, Milne JR and Greenfield S. 2012. '*River and stream water quality and ecology in the Wellington region: State and trends*.'

[18] Ibid.

[19] Ibid.

[20] Porirua City Council (2012) *'Porirua Harbour and Catchment, Strategy and Action Plan'*

- Heavy rain within central Auckland currently results in sewerage overflows onto city beaches.[21]
- Untreated stormwater causes water pollution in receiving environments, such as the coastline, harbours, marinas, streams and ground aquifers.[22]
- It is difficult to obtain information on the performance of wastewater services because it is not aggregated or published. Anecdotal information suggestions substandard performance and non-compliance with conditions on consent on the part of many smaller plants.[23]
- Many urban waterways remain highly polluted from the effects of overflowing sewer pipes, stormwater runoff from surfaces such as roads and discharges from processing facilities, including wastewater treatment plants.[24]
- The severity of the effect that stormwater run-off has is usually proportional to the area of urban land use. Drainage systems need to be designed to reduce the amount of impervious surface area causing stormwater. [25]
- Stormwater is a major hazard affecting the quality of aquatic receiving environments in Auckland's urban areas. It has been clearly demonstrated that urban streams have the poorest water quality, sediment quality and biological quality of all in the streams in the Auckland region.[26]
- The Impervious Cover Model first proposed in the United States in 1994, projects that hydrological, habitat, water quality and biotic indicators of stream health begin to decline sharply when total impervious cover in smaller catchments reaches 10%. The accuracy of this model has since been extensively tested in the US, Canada, New Zealand and Australia.[27]
- Increased concentrations and loads of several chemical pollutants in stream water appear universal in urban streams.[28]
- Stormwater in our urban, semi-urban and rural environments needs to be managed differently.[29]
- Urban stormwater flows need urgent attention.[30]
- Urban stormwater quality is often similar to that of secondary treated sewerage.[31]

[21] Auckland Council (2012) '*Auckland Council Long Term Plan 2012-2022*'
[22] Ibid.
[23] Water New Zealand (2011) '*Future Face of Urban Water Services in New Zealand: A Discussion Document'.*
[24] Land and Water Forum (2010) *'Report of the Land and Water Forum: A Fresh Start for Fresh Water*'
[25] NIWA (2010) '*Waikato River Independent Scoping Study'* Appendix 18 on Urban Stormwater
[26] G.N. Mills & R.B. Williamson (2008) '*The Impacts of Urban Stormwater in Auckland's Aquatic Receiving Environments: A Review of Information 1995 to 2005'.*
[27] Thomas Schueler (2007) Statement of Evidence in Environment Court Case
[28] URS (2007) *'Final Report – Literature Review: Urban River Contaminants'*
[29] Statement by the then Minister for the Environment reported in NZWERF's (2004) *'On-Site Stormwater Management Guideline'*
[30] Office of the Parliamentary Commissioner for the Environment (1998) *'The Cities and Their Profile: New Zealand's urban environment'*
[31] Ministry for the Environment (1997) *' The State of New Zealand's Environment'*

Key Findings of Literature Review of Overseas Sources

- Stormwater runoff from impervious areas has significant negative impacts on water quality nationwide in America.[32]
- The American EPA [Environment Protection Authority] Office of Water has found that a leading source of water pollution is stormwater runoff from urban and developing areas. The EPA has confirmed that there is a direct relationship between the amount of impervious cover and the biological and physical condition of downstream receiving waters.[33]
- Over 250 studies in America have shown that increases in impervious area associated with urban development act as both a collection site for pollutants and generate greater quantities and additional types of contaminants. Thousands of American waterbodies are listed as impaired for stormwater-source pollutants. [34]
- Annual discharges from hundreds of combined sewer overflows in New York City were estimated in 2010 at 30 billion gallons (114 cubic million litres).[35]
- By 1999 the American EPA considered pollution from all diffuse sources, including urban stormwater pollution, to be the most important source of contamination in the country's waters. Urban runoff was identified as a critical source of contamination, particularly for waters near cities. A significant proportion of stormwater pollution can be prevented with proper planning.[36]
- Ecological stress is clearly apparent when impervious cover reaches between 10 to 20% of the area of a watershed.[37]
- Two hundred years of unregulated, unmanaged urban stormwater has contributed to many severe public health problems and expensive natural resource losses in America.[38]
- Americans are spending millions on the symptoms of stormwater pollution instead of trying to control the root cause. Even a partial accounting shows that hundreds of millions of dollars are lost each year through added government expenditures, illness or loss in economic output due to urban stormwater pollution. The ecological damage is at least as significant.[39]
- It is estimated that 39 million cubic meters of storm sewerage enters the tidal reaches of the Thames River in London in a typical year from combined sewer overflows.[40]
- On 5 and 6 June 2011 after heavy rainfall over 900,000 tonnes of storm sewage was released into the River Thames from the tidal combined sewer overflows. Approximately 26,000 fish

[32] American Rivers (2013) *'Petition for a Determination that Stormwater Discharges from Commercial, Industrial and Institutional Sites contribute to Water Quality Standards Violations and Require Clean Water Act Permits'*
[33] Ibid.
[34] Ibid.
[35] Halcrow Group Limited (2013) *'Drainage Strategy Framework for Water and Sewerage Companies to Prepare Drainage Strategies',* London
[36] American National Resources Defence Council (1999) *'Stormwater strategies, Community Responses to Runoff Pollution'.*
[37] Ibid.
[38] Ibid.
[39] Ibid.
[40] United Kingdom Environment Agency (2013) *'An Assessment of Evidence on Sustainable Drainage Systems and Thames Tideway Standards'.*

deaths occurred along a kilometre stretch of this river. This event had a significant economic cost.[41]

- Hydrological modelling in England and Wales predict a median increase in 1 in 10 year flood events of 51% by 2040 from the combined effects of climate change, population and housing growth and a mean (average) increase of about 92%. The increased chance of sewer flooding from shortfalls in the capacity of the combined sewer drainage network, translates into a predicted significant increase in the number of properties flooded, and increased frequency of flooding for those already at risk.[42]
- Once hard surfaces exceed 2 per cent of the area of a catchment, the health of downstream waters begins to be adversely affected.[43]
- Sewerage overflows into metropolitan creeks and waterways through many overflow points throughout Melbourne, Australia. As urbanisation and hard surfaces increase, floods will become more regular and increasingly severe unless mitigation action is taken. [44]
- 5,100 million litres per year of stormwater is generated across the municipality of the City of Port Philip (Melbourne). This stormwater carries significant pollutant loads including 778,000 kilograms per year of suspended solids, 1,600 kilograms per year of total phosphorous and 11,400 kilograms per year of total nitrogen. This stormwater drains directly into Port Philip Bay, adversely impacting on its ecology and on the tourism and amenity values of Port Philip's beaches.[45]
- At least 1,000 waterbodies in England have a significant urban diffuse pollution problem. [46]
- England and Wales experience widespread pollution from combined sewer overflows, treatment works overflows and storm tanks discharges.[47]
- Stormwater source control measures are required for all new development in most of the other countries studied. Changes in planning regulations have been an important driver for delivering new methods.[48]
- Integrated approaches to surface water drainage are essential to maximise the benefits of drainage investment for society.[49]
- There are no nationwide standards for stormwater, flood risk or surface water management in New Zealand.[50]
- Stormwater runoff from increased impervious cover has devastated stream systems in Philadelphia, America.[51]

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[41] English Department for Environment, Food and Rural Affairs (2012) '*National Policy Statement for Waste Water: A framework document for planning decisions on nationally significant waste water infrastructure.'*

[42] Mott MacDonald (2011) '*Future Impacts on Sewer Systems in England and Wales.*

[43] State Government of Victoria (Australia) Department of Environment and Primary Industries (2013) *'Melbourne's Water Future: A fresh approach to urban water'*.

[44] Ibid.

[45] City of Port Philip (Australia) (2010) *'Water Plan – Toward a Water Sensitive City. Take Local Action: Be part of the Solution'.*

[46] English Department for Environment, Food and Rural Affairs (2012) *'Tackling Water pollution from the urban environment: Consultation on a strategy to address diffuse water pollution from the built environment.'*

[47] MWH (2011) *'Comparing the Arrangements for the Management of Surface Water in England and Wales to arrangements in other countries'.*

[48] Ibid.

[49] English Department for Environment, Food and Rural Affairs (2010) '*Surface Water Management Plan Technical Guideance'.*

[50] Ibid.

- In South East Queensland (Australia) total pollution loads from urban stormwater are projected to increase by more than 50% by 2026.[52]
- Solely managing stormwater quality using a best practice approach is insufficient to adequately mitigate all the impacts of urbanisation.[53]
- Decades of urban development in South East Quality have had a measurable adverse impact on the health of region's waterways. If traditional urban development practices are continued, the predicted growth in population by approximately 1.33 million persons or 575,000 dwellings by 2026, will lead to further deterioration of already stressed waterways[54].
- Total-sustainable-load modelling studies indicate that the if water quality in Moreton Bay is not to deteriorate significantly by 2026, the package of management interventions to be applied in South East Queensland needs to include application of best practice water sensitive urban design to all new urban development and retrofitting of such measures to the existing urban landscape.[55]
- Economic drivers for the adoption of water sensitive urban design include an increased understanding that it costs much more to rehabilitate degraded waterways than to protect waterways from degradation, and that often only rehabilitation is possible, not restoration.[56]
- Urbanisation of a catchment commonly results in up to a four-fold increase in stormwater pollution loads to local waterways.[57]

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[51] Philadelphia Water Department (2011) *'Amended Green City Clean Waters, The City of Philadelphia's Program for Combined Sewer Overflow Control, Program Summary'.*

[52] State Government of Queensland (Australia) Department of Environment and Heritage Protection (2010) *'Urban Stormwater Quality Planning Guidelines'.*

[53] Ibid.

[54] South East Queensland Healthy Waterways Partnership (2007) *'South East Queensland Healthy Waterways Strategy 2007-2012'*

[55] Ibid.

[56] Ibid.

[57] State Government of New South Wales (Australia) Department of Environment and Conservation (2006) *'Managing Urban Stormwater, Harvesting and Reuse'.*

Quotes regarding Urban Stormwater/drainage issues in New Zealand

Report of the Local Government Infrastructure Efficiency Advisory Group (2013) Department of Internal Affairs[58]

"Some smaller communities have wastewater[59] facilities that are inadequate in terms of public or environmental health…Some councils also face difficulty in achieving compliance with wastewater and stormwater resource consent conditions. For example, a report by Environment Southland shows that of the 26 sewage discharge resource consents held by Invercargill City, Southland District and Gore District councils, only six were classed as fully compliant and six were found to be significantly non-compliant…We are anecdotally aware that the situation exemplified by Southland is not uncommon in the rest of New Zealand.

There are no national standards for what contaminants are to be discharged via either wastewater or stormwater…Wastewater is the biggest waste by volume in New Zealand. Approximately 1.5 billion litres of domestic wastewater is discharged into the environment daily".

Greater Wellington Regional Council (2013) *Regional Policy Statement for the Wellington Region*[60]

"Urban streams are affected by stormwater discharges, especially when there are high proportions of impervious cover – such as roofs and roads – in the catchment. Stormwater, which generally has little or no treatment, contains sediments and bacteria, as well as persistent contaminants – like heavy metals – which accumulate in stream sediments and eventually in the coastal environments where the streams discharge. These contaminants affect freshwater fish and invertebrates and can have chronic long-term adverse effects on river and coastal ecosystems. Urban land uses also affect water quality in rivers and streams and can cause other pressures on freshwater habitat by creating the demand to pipe or fill in small streams….

The water quality of rivers and streams, lakes, wetlands and groundwater in the region is being polluted by discharges and contaminants arising from urban and rural land uses."

Statement also refers to the intended development of a regional waste strategy and regional stormwater action plan.

J. Moores, C. Batsone, M. Green, S. Harper, A. Semadeni-Davies, J. Gadd and R. Storey (2013) *'A Tool for Evaluating Stormwater Management Outcomes across the Four Wellbeings'* published as part of the conference papers for the 8th South Pacific Stormwater Conference and Expo[61]

"There is substantial evidence that urban development is harming the very water bodies beside which New Zealand's cities were founded. Urbanisation has resulted in the expansion of the built environment along riparian and coastal margins and the use of streams and estuaries for the disposal of urban stormwater. Parts of Auckland's harbours, for instance, have suffered from

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[58] www.dia.govt.nz/...Infrastructure...Expert-Advisory-Group.../LG- Infrastructure-Efficiency-Expert-Advisory-Group-Final-Report.doc Accessed 4 January 2014

[59] Stormwater is often classed as a type of wastewater. Stormwater often enters waste water drainage systems, particularly during storm events.

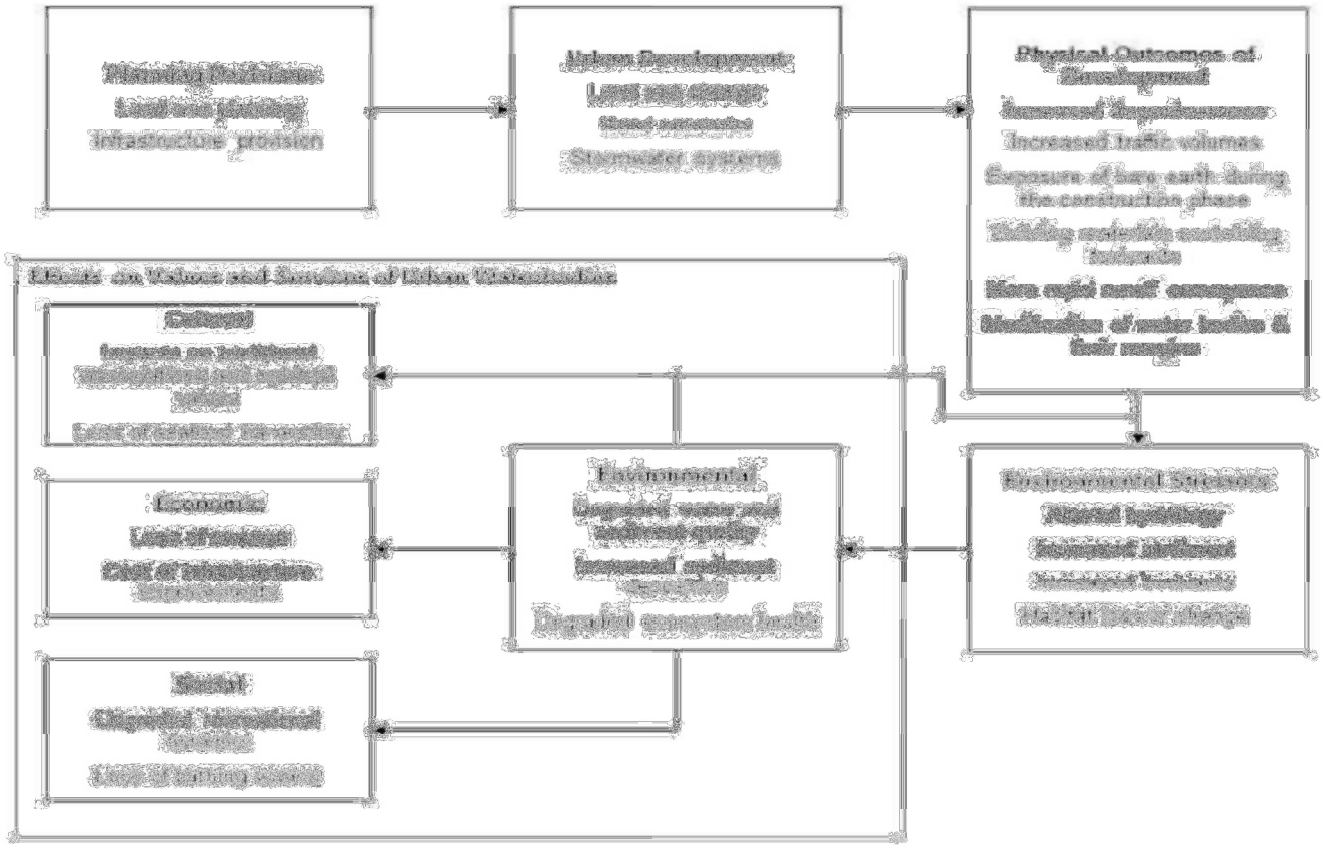
[60] http://www.gw.govt.nz/rps/ Accessed 4 January 2014. Although the policy was officially adopted in 2013, it was largely written by 2009, when it was first notified.

[61] Authors of report work for the National Institute of Water and Atmospheric Research Ltd. and Cawthron Institute http://sustainablecities.org.nz/wp-content/uploads/Moores-et-al-Stormwater-2013.pdf Accessed 4 January 2014

increased rates of sedimentation, toxic metal accumulation, reduced ecological health and a growing unsuitability for recreation and the harvesting of shellfish (Auckland Regional Council, 2010).

Unless alternative, sustainable forms of urban development and stormwater management can be found, the impacts of historic urbanisation are likely to be exacerbated by continued urban growth."

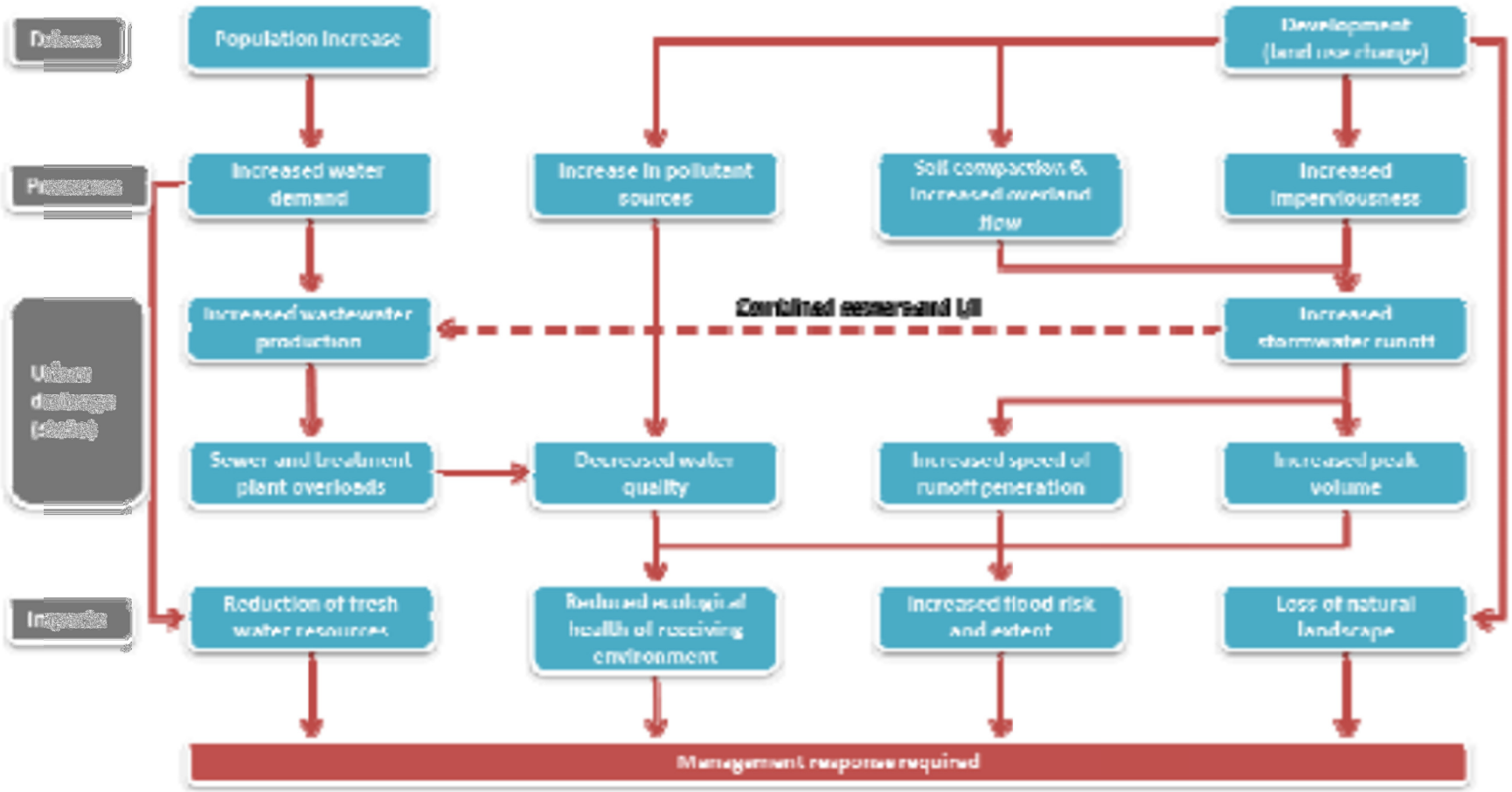
Figure 1: Four wellbeings approach to understanding the effects of urban development on the values and services of water bodies. Examples to illustrate these relationships are shown.



National Institute of Water and Atmospheric Research (NIWA) Website

The diagram on the following page shows how urbanisation impacts on urban receiving environments using the DPSIR (Drivers, Pressures, State, Impacts and Responses) framework for reporting environmental issues.[62]

[62] Source: http://www.niwa.co.nz/sites/default/files/images/dpsir_model_diagram.png
Accessed 04 January 2014


Population Increase
Development (land use change)
Increased water demand
Increase in pollutent sources
Soil compaction & increased overland flow
Increased imperviousness
Increased wastewater production
Combined sewer and UI
Increased stormwater runoff
Sewer and treatment plant overloads
Decreased water quality
Increased speed of runoff generation
Increased peak volume
Reduction of fresh water resources
Reduced ecological health of receiving environment
Increased flood risk and extent
Loss of natural landscape
Management response required

Perrie A, Morar S, Milne JR and Greenfield S. (2012) '*River and stream water quality and ecology in the Wellington region: State and trends*.' Greater Wellington Regional Council, Publication No. GW/EMI-T-12/143, Wellington[63]

"Analysis of water quality, periphyton and macroinvertebrate data collected at 55 SoE [state of environment] sites (46 in the case of periphyton) over the period July 2008 to June 2011 found clear linkages between river and stream health and catchment land use…As the proportion of pastoral and/or urban landcover increases within a site's upstream catchment, water quality and macroinvertebrate health tend to decline while nuisance periphyton and macrophyte growth increases."

"Generally defined as rainwater collected from roofs, driveways, roads, carparks and other sealed surfaces, stormwater in the Wellington region is piped directly into rivers and streams, generally without any treatment. During its travels, this stormwater picks up sediment, rubbish and a variety of other contaminants, including metals, hydrocarbons, herbicides, pesticides, nutrients and pathogens. General stormwater discharges are a permitted activity under Greater Wellington's existing RFP [Regional Freshwater Plan] (WRC 1999) and so do not require a resource consent…"

"Several territorial authorities also hold consents authorising the discharge of diluted untreated or partially treated wastewater to rivers and streams during times of very heavy or sustained rainfall. During these conditions, stormwater can directly infiltrate the sewer network, resulting in overflows" affecting the Hutt and Wainuiomata rivers, Waiwhetu and Kariori streams and the coast. *"Greater Wellington's resource consent monitoring records indicate that, on average, wet weather wastewater overflow discharges typically occur at least two to three times a year."*

"Greater Wellington pollution incident records, along with compliance assessments of consented earthworks sites, confirm a number of instances where sediment control mechanisms (eg, silt ponds) have failed (Figure 8.2), resulting in large volumes of sediment entering nearby streams [carried by surface water runoff]. A number of the incidents have been reported in the Porirua Harbour catchment, where there has been a particularly large amount of earthworks associated with urban subdivision or roading projects in recent years."

[63] http://www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/River-and-Stream-Water-Quality-and-Ecology-SoE-report.pdf Accessed 4 January 2014

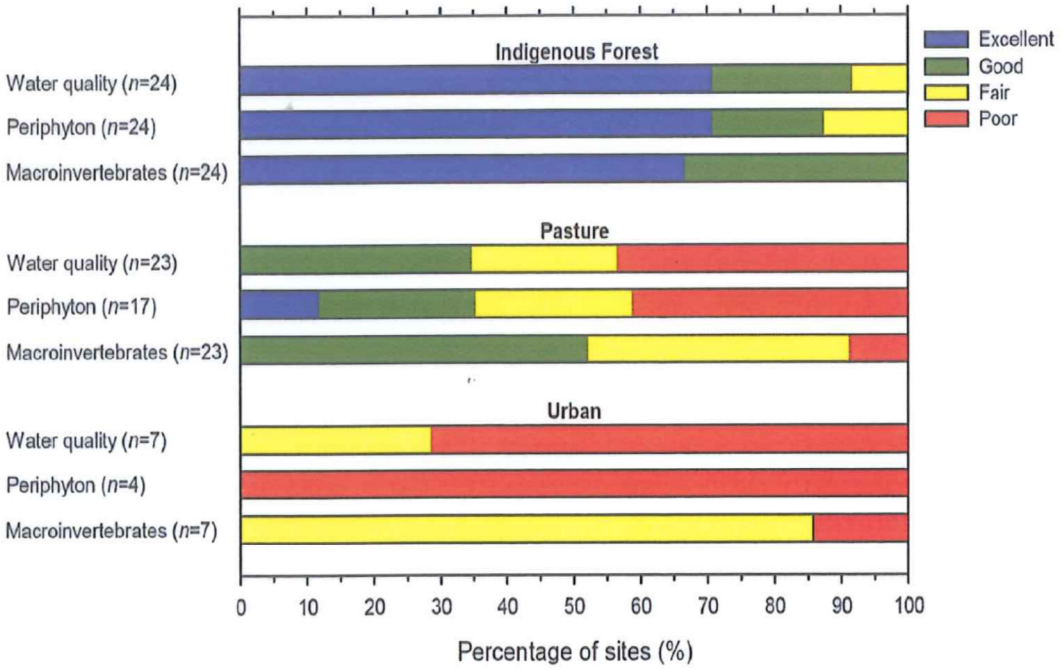


Figure 8.1: Breakdown of water quality, periphyton and macroinvertebrate health grades (classes) for 54 of the 55 RSoE sites, grouped according to their REC landcover class. Note that one site (RS44) belonging to the exotic forestry landcover class is not included in this summary

Porirua Harbour and Catchment, Strategy and Action Plan, March 2012, Porirua City Council[64]

"Abandoned, neglected and misused, the harbour and its tributaries deteriorated throughout this time. Pollutants from roads, stormwater and sewerage systems fouled the harbour, particularly the Onepoto Arm. Sediment run-off increased with urban development and associated earthworks.

Modifications to the harbour edge and streams resulted in the loss of important intertidal spawning, nursery and feeding grounds for marine life. Many remaining shellfish beds became contaminated and unsuitable for eating. In the late 1970's public health warning signs started to appear at key locations in both arms of the harbour."

[64] http://www.pcc.govt.nz/DownloadFile/Publications/Harbour-Management/Porirua-Harbour-and-Catchment-Strategy-and-Action-Plan-March-2012 Accessed 4 January 2014

Auckland Council Long Term Plan 2012-2022 (2012)[65]

Wastewater projects "*will address the current problems in central Auckland when heavy rain results in sewerage overflow onto city beaches."*

The volume of sewerage waste is not affected by rainfall. The principle reason for sewerage overflows during wet weather is from storm water entering the sewerage system during storm events and exceeding its capacity.

"*Stormwater has the potential to be a major problem in a city such as Auckland that receives a lot of rain. Untreated, it causes water pollution in receiving environments, such as the coastline, harbours and marinas. It can damage natural and rural environments, including streams, ground aquifers and overland flow paths."*

The Long Term Plan identifies a commitment of approximately of:

- $604 million to delivering network planning and stormwater catchment to manage the detrimental effects of stormwater;
- $164 million to reduce the incidence of flooding or erosion by water.
- $205.8 million as part of the Flood Alleviation programme.

This high cost raises the question, would it of have been financial cheaper to have prevented/minimised this harm in the first place? Could some these costs have been avoided, if more proactive solutions were put in place, when the problem was first diagnosed almost 20 years ago?

'*A Decade of Public Perceptions of the New Zealand Environment: A Focus on Water and its Management*' by K. Hughey, R. Cullen & G. Kerr (2011)[66]

Identifies that in 2010 the general public saw sewerage and stormwater as the second main cause of damage to water quality (down from the main cited cause in 2002).

'Future Face of Urban Water Services in New Zealand: A Discussion Document by Water New Zealand (2011)[67]

"The performance of reticulated waste water systems is less well known [than water supply systems]. It is difficult to obtain information on the performance of wastewater services because it is not aggregated and published. The majority are complying with the conditions on their consents granted under the Resource Management Act.

Anecdotal information suggests substandard performance and non-compliance with conditions on consents on the part of many smaller plants. Technical reports and papers produced by Regional

[65] http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/Long_term_plan/Pages/documents.aspx Accessed 4 January 2014

[66] http://nzae.org.nz/wp-content/uploads/2011/08/Hughey_et_al__A_Decade_of_Public_Perceptions.pdf Accessed 4 January 2014

[67] Water New Zealand is a not-for-profit organisation that promotes and represents organisations within the water industry in New Zealand. http://www.waternz.org.nz/Folder?Action=View%20File&Folder_id=83&File=future_face_of_urban_water_services.pdf Accessed 4 January 2014

Councils indicate some breaches of environmental standards as a result of discharges from wastewater treatment plants….A significant number of smaller communities lack adequate wastewater services."

It quotes the findings of a 2008 Otago Regional Council Report that:

"Many local authority sewerage discharges are still of third world quality discharge quality and many consented discharges to water still require lengthy mixing zones.

…It has been more than 16 years since the RMA had been enacted. Despite the high progress made to date, there are still many municipal and several industrial effluent discharges that are of poor quality. The effluent treatment of these discharges is substandard and often does not match the scale and environmental risks of the discharges. In many cases regional councils are reluctant to impose stringent consent requirements due to financial constraints."

In addition to review commissioned by the Ministry of Health in 2006 which:

"identified 139 communities from which potential applications for sanitary works subsidy scheme assistance could be made from communities with high deprivation indices, including 106 from District Councils.

The report made it clear that current sanitary arrangements in these communities were unsatisfactory, posing human and environmental risks…."

Land and Water Forum (2010) *Report of the Land and Water Forum: A Fresh Start for Fresh Water*[68]

"Many urban waterways remain highly polluted from the effects of:

a) *sewage leaking from broken or overflowing sewer pipes, or being discharged into stormwater systems through faulty connections;*
b) *stormwater run-off from surfaces such as roads; and*
c) *discharges from processing facilities, for example wastewater treatment and industrial plants, either within, or in breach of, consent conditions".*

"…in some areas there are issues with the management of wastewater and stormwater".

NIWA (2010) *'Waikato River Independent Scoping Study: Appendix 18 Urban Stormwater'* published by the Ministry for the Environment[69]

"This stormwater can cause adverse effects when it enters the streams and rivers flowing through an urban area, as has been described for Hamilton streams (Williamson, 2001; Collier et al.,2009) and comprehensively studied in Auckland streams (as reviewed in Mills and Williamson, 2009)….

The severity of the effect that stormwater run-off has is usually proportional to the area of urban land use directly connected to the receiving water. This can be measured as the percentage of the catchment with impervious cover (%IC) and this has been shown to be a useful predictor of potential impacts of urbanisation on stream health (ARC, 2004). It has been found, both overseas and in New

[68] http://www.landandwater.org.nz/Site/Resources.aspx#H126743-7 Accessed 4 January 2014
[69] *http://www.mfe.govt.nz/publications/treaty/waikato-river-scoping-study/appendix-18-urbanstormwater.pdf*

Zealand, that catchments with less than 10 %IC can support aquatic communities that are largely unmodified (Stark, 2006). This can vary from site to site depending on local differences in instream habitat and riparian quality. When %IC increases beyond 10 –15 percent it is common for stream health to be affected. Beyond 25 percent, streams can become highly modified. This is consistent with the findings of a recent study of Hamilton City streams (Collier et al., 2009)."

"Drainage systems need to be designed to reduce the amount of impervious surface area causing stormwater to flow directly into urban streams through stormwater pipes by maximising run-off detention, infiltration and off-channel retention of water (Taylor et al., 2004; Walsh 2004; Walsh et al., 2005), but at the same time still serving their primary function of flood control."

Cabinet Paper for a *'New Start for Fresh Water'* 2009[70]

"The limits to water resources are reflected in the following issues:

a) *Water quality is declining in many areas, particularly in lowland rivers, streams, lakes and groundwaters, which threatens biodiversity, community and cultural values, the coastal environment, and freshwater and onshore fisheries.*

(b) *Poor or declining water quality has already created direct costs, such as the nearly $450 million allocated over the next 10 to 20 years to the cleanup of Lake Taupo, Rotorua Lakes and the Waikato River, and can constrain economic opportunities (e.g. tourism, fishing or aquaculture)…."*

"*One of the most significant challenges to be faced is the strong link between some forms of land use intensification, water use and water quality decline. The effects of land use on water quality can take decades to become apparent. The actions needed to improve water quality and maintain long-term economic potential may have short- to medium-term costs, through restrictions on land use…"*

"*…Much urban water infrastructure is ageing, increasing risks for water quality and efficiency."*

"Even maintaining the status quo in water quality in some catchments may require changes in land use, not just the application of current best practice to existing uses. This implies the need for difficult adjustments and/or potentially significant short-term costs – both for individuals and regional (or even national) economies – to gain long-term net benefits."

G.N. Mills, R. B. Williamson (2008) *'The Impacts of Urban Stormwater in Auckland's Aquatic Receiving Environment: A Review of Information 1995 to 2005'*. Prepared by Diffuse Sources Ltd and Geosyntec Consultants for Auckland Regional Council. Auckland Regional Council Technical Report 2008/029[71]

"The information reviewed to date clearly shows that urban stormwater discharges can have serious long-term impacts on the health of receiving waters. Continued efforts are therefore required to prevent or minimise on-going effects and, where possible, restore impacted environments."

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[70] http://www.mfe.govt.nz/issues/water/freshwater/new-start-for-fresh-water-paper.html Accessed 4 January 2014

[71] http://www.aucklandcity.govt.nz/council/documents/technicalpublications/TR2008_029%20-%20The%20impact%20of%20urban%20stormwater%20in%20Aucklands%20aquatic%20receiving%20environment%20contaminants.pdf Accessed 20 December 2013

"Stormwater is a major hazard affecting the quality of acquatic receiving environments in Auckland's urban areas."

Figure 19
The effects of urbanisation on the freshwater environment (reproduced from Suren & Elliot 2004).

Key impacts of urban development on stream water quality are:

- Decreased water clarity (and increased suspended solids concentrations and turbidity) associated with discharge of fine particulates (eg gutter dust, soil, vegetative debris) and increased stream channel erosion.

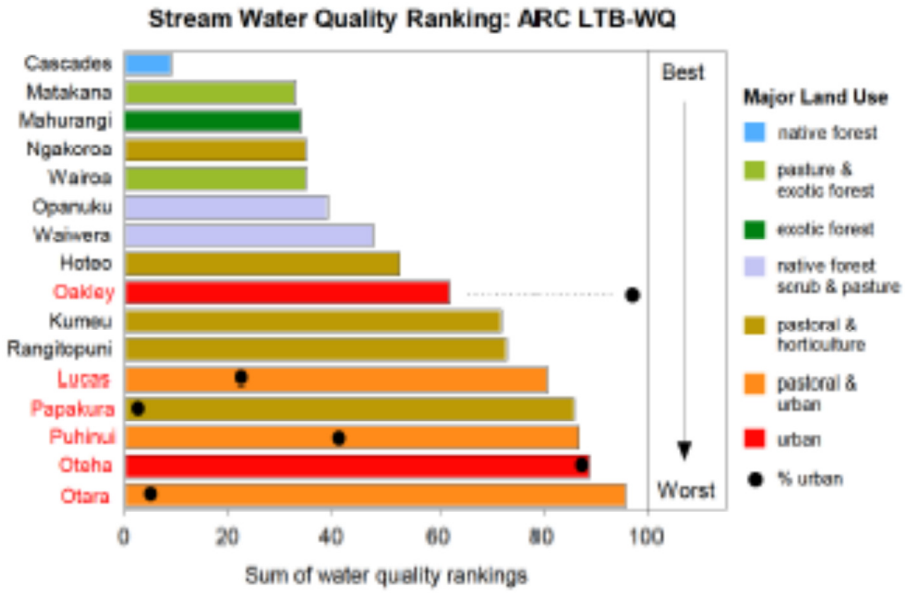
- Elevated maximum water temperatures, resulting from reduced summer lowflows and loss of stream shading.
- Changes in dissolved oxygen dynamics, with higher maximum and lower minimum concentrations, which result from greater primary productivity (during the day) and microbial respiration (at night) in nutrient-enriched, poorly shaded streams, especially during summer low flows. Organic enrichment from WWOFs [waste water overflows], intermittent spills of organic wastes, and introduced soil and vegetation contribute to this problem at times.
- Contamination by pathogenic microorganisms, as a result of WWOFs, leaking sewers, and animal wastes in stormwater run-off.
- Nutrient enrichment, from fertiliser run-off, sewage overflows, and soil loss. Plant nutrients, including nitrate-nitrogen (NO3-N) and phosphorus (P), are present in moderate amounts in stormwater. Concentrations are much higher in sewage, and therefore stormwaters contaminated by WWOFs have considerably higher nutrient concentrations.
- Increased concentrations of toxic substances (NH4-N, heavy metals, PAH), from wastewater overflows (NH4-N), vehicular use and road run-off (heavy metals, PAH), fuel spills (hydrocarbons and PAH), and greater amounts of exposed metallic surfaces (particularly roofs) in urban areas (Zn, Cu).

Aesthetic impacts can also result from litter, which is common in many urban stream reaches, and the occasional presence of oily films, discolouration, and unsavoury odours.

Change in stream flow regime is another major impact of urbanisation. Higher peak flows, increased total volumes of stream discharge during storms, and reduced summer base flows are well documented consequences of increased catchment imperviousness and channel modifications that often accompany urbanisation.

Figure 20

Ranking of long-term median water quality (for 1992–2000) in Auckland streams monitored in the ARC LTB-WQ programme. Streams that are significantly influenced by urban run-off are labelled in "red". Ranking data are from ARC (2000b), and land use (excluding "urban open space") from ARC (2003f).



"Since 1995, a very large body of work has been conducted on improving our understanding of the impacts of urbanisation on Auckland's streams. The work has…

Clearly demonstrated that urban streams have the poorest water quality, sediment quality, and biological quality of all the streams in the Auckland region. However, in many places, upstream rural land use contributes to the degraded state of urban waterways, at least for water quality and ecology."

Statement of Evidence of Thomas Schueler[72] in the Environment Court Case of Long Bay-Okura Great Park Society Incorporated, Auckland Regional Council, Landco Limited, S.B. & L.A. Singleton and North Shore City Council (2007)[73]

"Perhaps the single most important alteration associated with land development is the effect of impervious cover on increasing the runoff coefficient of a site or catchment. The runoff coefficient (Rv) represents the fraction of each rainfall event that is converted into stormwater runoff… The sharp increase in stormwater runoff volumes is the primary causal agent for the decline in most urban stream indicators…"

"I first proposed the Impervious Cover Model that projects that hydrological, habitat, water quality and biotic indicators of stream health begin to decline sharply at around 10% total impervious cover in smaller catchments in a 1994 paper (Schueler, 1994). The ICM has since been extensively tested in ecoregions around the US, Canada, New Zealand and Australia…The Auckland Regional Council (2004) has taken a similar approach to the basic ICM model as part of its urban stream classification framework, based on monitoring studies that have documented a similar decline in aquatic indicators in a range of Auckland streams."

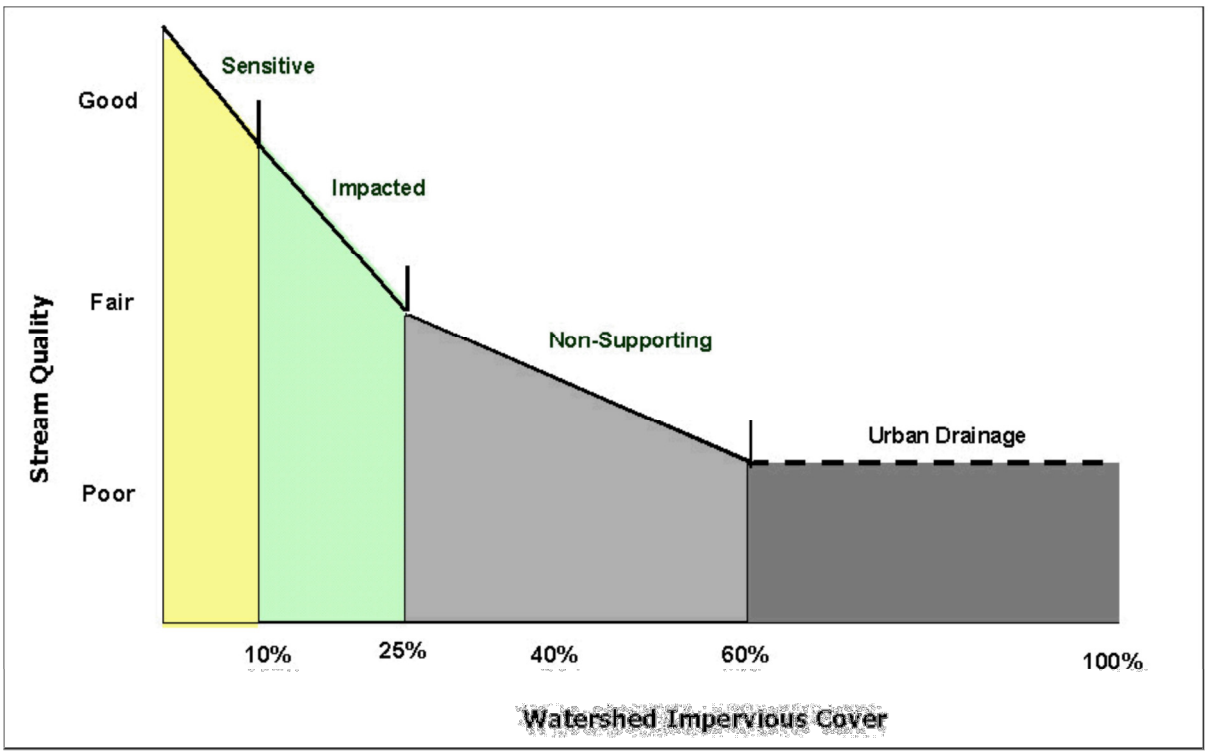
"The effect of earthworks and soil compaction nearly doubles the runoff coefficient…the compacted pervious areas…equivalent to 45 to 50% impervious cover (e.g., One acre of turf = 0.5 acres of impervious cover)."

An overview of the Impervious Cover Model and its predictions is described on the following page. Further information on the relationship between imperviousness and water quality is described in an interview with the author on the American Water Laws website: http://www.waterlaws.com/commentary/interviews/schueler_interview.html.

[72] Author identified as the Director of Practice at the Centre for Watershed Protection (America), with involvement in the development of the 'Impervious Cover Model' (ICM) and U.S. National Stormwater Quality Database. Author was engaged by North Shore City Council.

[73] http://www.mfe.govt.nz/rma/central/nps/consultation/hearing-procedings/24-1northshorecitycouncil.pdf Accessed 4 January 2014

Figure 1: Impervious Cover Model



Predictions According to the Impervious Cover Model				
Criteria	Stream Classification			
	High Quality (0-10%)	Impacted (10% to 25%)	Non-Supporting (25% to 60%)	Urban Drainage (60% to 100%)
Stormwater runoff as a Fraction of Annual Rainfall	2 to 7%	10 to 30%	25 to 60%	60 to 90%
Ration of Post to Pre Discharge 100 Year Storm	1.0 to 1.05	1.1 to 1.5	1.5 to 2	2 to 3
Frequency of Bankfull Flood Events	1.0 to 1.2 per year	1.5 to 3 per year	3 to 7 per year	7 to 10 per year
Ultimate Channel Enlargement Ratio	1.0 to 1.2 times larger	1.5 to 2.5 times larger	2.5 to 6 times larger	6 to 12 times larger
Sediment Yield	Rural background	2 to 5 times greater	5 to 10 times greater	Possibly lower
Typical stream habitat score	Good to excellent	Fair but variable	Consistently poor	Poor, often absent
Increased summer stream temperatures	0 to 2 degrees F	2 to 4 degrees F	4 to 8 degrees F	8+ degrees F
Annual Nutrient Load	Same as rural background loads	1 to 2 times higher than rural background	2 to 4 times higher than rural background	4 to 6 times higher than rural background
Violations of Bacteria	Infrequent	Frequent	Continuous	Continuous

Standards	violations only during wet weather	violations during wet weather	violations, during wet weather, Episodic violations during dry weather	violations during wet weather, frequent violations during dry weather
Aquatic Life Toxicity	No toxicity	Acute toxicity rare	Moderate potential for acute toxicity during some storms and spills	High potential for acute toxicity during dry and wet weather
Contaminated Sediments	Clean sediments	Sediments enriched but not contaminated	Sediment contamination likely, potential risk of bioaccumulation	Contamination should be presumed
Fish Advisories	None	Rate	Potential risk of bioaccumulation	Should be presumed
Trash and debris	Less than 1 ton	1 to 2 tons per square mile	2 to 5 tons per square mile	5 to 10 tons per square mile
Aquatic Insect Diversity	Good to excellent	Fair to good	Poor	Very poor
EPT Taxa	70 to 90%	40 to 70%	20 to 50%	0 to 20%
Fish Diversity	Good to excellent	Fair to good	Poor	Very poor
Riparian plant diversity	Fair to good depending on grazing	Stressed, with reduced native plant diversity	Simplified community with many exotic species	Isolated remnants, dominated by exotics

URS (2007) '*Final Report - Literature Review: Urban River Contaminants'* Environment Canterbury[74]

"The Avon/Ōtakaro and Heathcote/Opawaho Rivers run through heavily urbanised parts of Christchurch city and receive stormwater drainage from many different sources. Stormwater from the catchments contain many different contaminants including sediment, heavy metals, nutrients, organic compounds and pathogens.

The main source of sediment into urban waterways comes from the erosion of soils during urban construction (Williamson, 1993; Pitt, 1995). Stripping of the vegetation and topsoils and recontouring the land greatly increases the chances that large quantities of soils and sub soils will be eroded. The amount of this erosion will depend on the volume and intensity of any rain that falls while the soil is exposed, the catchment slope and size, and the proportion of the catchment undergoing development (Williamson, 1993). Rates of erosion at construction sites can be between 10 and 100 times greater than those in rural areas (Yorke & Davis, 1971;Chen, 1974 in Rhoads, 1995). Increased sediment contamination will continue until construction is finished at which point sediment

[74] http://ecan.govt.nz/get-involved/local-projects-community-groups/documents/literaturereviewurbanrivercontaminants.pdf Accessed 4 January 2014

concentrations will gradually decrease (over 20-30 years) to sediment loads more common in mature urban areas (Williamson, 1993)."

"A study carried out by Pattle Delamore Partners Ltd (2007a) looked at stormwater quality from Kirkwood subdivision located in Halswell. Part of the study looked at comparing levels of suspended sediment from the Kirkwood subdivision with that of the existing Halswell township. This found that average levels of sediment were much higher from the recently constructed Kirkwood subdivision (67 g/m3) than from the existing Halswell Township (11 g/m3). The higher levels found in the new subdivision are likely to be influenced by the presence of less established vegetation compared to that found in the existing Halswell township.

Construction sites, especially those that run year round were found to be by far the greatest contributor of sediment contamination"

"Urbanisation can affect stream morphology, physical conditions and biological and chemical characteristics. Increased concentrations and loads of several chemical pollutants in stream water appear universal in urban streams, often occurring even at low levels of catchment urbanisation (Hatt et al. 2004 in Walsh et al. 2005). This can have detrimental effects on stormwater runoff which in turn has a great impact on receiving waters. It has been shown that during urbanisation certain contaminants will have a much greater impact on the receiving water than pre and post urbanisation".

New Zealand Water Environment Research Foundation (NZWERF) (2004) *'On-Site Stormwater management Guideline'* NZWERF, Wellington, New Zealand[75]

"The impact of stormwater on the environment is becoming an increasingly important issue. Impacts include both quantity effects such as flooding, erosion and effects on the water table and also quality effects such as sedimentation, litter, suspended solids and dissolved contaminants. Stormwater in our urban, semi-urban and rural environments needs to be managed differently[76]….

Office of the Parliamentary Commissioner for the Environment (2000) *'Ageing Pipes and Murky Waters, Urban Water system issues for the 21st century'*[77]

Refers to '*The State of New Zealand's Environment 1997*' produced by the Ministry for the Environment, which identifies:

"The natural character and habitat quality of many fresh and estuarine waters has been lost or degraded by urban development, drainage, construction of flood control channels and stopbanks, removal of riparian vegetation, waste disposal, and urban stormwater."

"Urban stormwater quality is often similar to that of secondary-treated sewage. Urban stormwater causes serious problems in some areas (eg Auckland) polluting estuaries and harbours with sediment and toxic substances (eg heavy metals and hydrocarbons derived from motor vehicles) and, in some cases, infiltrating and flooding sewerage systems."

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[75] http://www.nzwwa.org.nz/Folder?Action=View%20File&Folder_id=101&File=section1.pdf Accessed 20 December 2013

[76] Extract of forward written by the Hon. Marian L Hobbs, Minister for the Environment 2004

[77] http://www.pce.parliament.nz/publications/all-publications/ageing-pipes-and-murky-waters-urban-water-system-issues-for-the-21st-century-2 Accessed 4 January 2014

Greater Wellington Regional Council (1999) *'Regional Freshwater Plan for the Wellington Region'*[78]

Issue 2.5.2 identified that point source stormwater discharges can have adverse effects on water quality. However, there is little information on the effects of these discharges.

"Traditionally, they are discharges that have not been addressed in New Zealand. The technology which is available and used in other parts of the world has generally not yet been adopted or applied to New Zealand conditions."

Office of the Parliamentary Commissioner for the Environment (1998) '*The Cities and Their People: New Zealand's urban environment'* [79]

"Urban stormwater flows need urgent attention if there is to be significant improvement in the quality of urban streams and coastal marine areas. The separation of combined sewage/stormwater pipes is progressing slowly in Auckland but on the basis of overseas experience, there will eventually be a need to treat all stormwater discharges, particularly that from roads. In 1995 an Auckland Regional Council commissioned report from NIWA on the effects of Auckland's urban stormwater runoff found widespread contamination of estuarine sediments sufficient to cause abnormal growth in shellfish."

Office of the Parliamentary Commissioner for the Environment (1997) '*The Management of Suburban Amenity Values: Administration by Auckland, Christchurch and Waitakere City Councils'* [80]

"Overflows from combined stormwater and sewage systems in parts of Auckland during heavy rain have the potential to create major health and environmental problems including adverse effects on local amenity values. Polluted stormwater and sediment also detract from the amenity values of maritime recreational areas like the Orakei Basin."

[78] http://www.gw.govt.nz/assets/Plans--Publications/Regional-Freshwater-Plan/Regional-Freshwater-Plan-incorporating-plan-changes-1234-and-5.pdf Accessed 4 January 2014
[79] http://www.pce.parliament.nz/publications/all-publications/the-cities-and-their-people-new-zealand-s-urban-environment Accessed 4 January 2014
[80] http://www.pce.parliament.nz/assets/Uploads/Reports/pdf/sub_amenity_full.pdf Accessed 4 January 2014

Quotes regarding Urban Stormwater using Overseas Sources

Amercian Rivers, Conservation Law Foundation, Natural Resources Defence Council and California Coastkeeper Alliance (2013) '*Petition for a Determination that Stormwater Discharges from Commercial, Industrial and Institutional Sites Contribute to Water Quality Standards Violations and Require Clean Water Act Permits'*, United States of America[81]

"Stormwater runoff from impervious areas has significant negative impacts on water quality throughout this region and nationwide. As the EPA Office of Water has found, 'Stormwater runoff in urban and developing areas is one of the leading sources of water pollution in the United States.' The National Research Council (NRC) agrees: 'Stormwater runoff has a deleterious impact on nearly all of the nation's waters' – as does the Ninth Circuit Court of Appeals: 'Stormwater runoff is one of the most significant sources of water pollution in the nation.'

In its preamble to the Phase II stormwater regulations in 1999, EPA explained the impacts of stormwater runoff in detail:

Storm water runoff from lands modified by human activities can harm surface water resources and, in turn, cause or contribute to an exceedance of water quality standards by changing natural hydrologic patterns, accelerating stream flows, destroying aquatic habitat, and elevating pollutant concentrations and loadings. Such runoff may contain or mobilize high levels of contaminants, such as sediment, suspended solids, nutrients (phosphorous and nitrogen), heavy metals and other toxic pollutants, pathogens, toxins, oxygen-demanding substances (organic material), and floatables…Individually and combined, these pollutants impair water quality, threatening designated beneficial uses and causing habitat alteration or destruction."

"In particular, over 250 studies have shown that increases in impervious area associated with urban development are a 'collection site for pollutants,' and generate greater quantities (and additional types) of contaminants. Urban development creates new pollution sources as population density increases and brings with it 'proportionately higher levels of car emissions, maintenance wastes, pet waste, litter, pesticides, and household hazardous wastes, which may be washed into receiving waters by storm water.' These increases in pollutant loadings can result in immediate and long-term effects on the health of the water body and the organisms that live in it. The U.S. Geological Survey has found that, in areas of increased urban development, local rivers and streams exhibited increased concentrations of contaminants such as nitrogen, chloride, insecticides, and polycyclic aromatic hydrocarbons (PAHs).

The deleterious effects of urbanization on water quality are evident from a review of the lists of impaired waters states must compile in compliance with the Clean Water Act. Thousands of water bodies nationwide are currently listed as impaired for stormwater-source pollutants."

"Urban stormwater is listed as the "primary" source of impairment for 13 percent of all rivers, 18 percent of all lakes, and 32 percent of all estuaries, despite the fact that urban areas cover just 3 percent of U.S. land mass."

"EPA has recognized the now-well-understood connection between high percentages of impervious cover in watersheds and pollutant loading-driven impairments (among many other deleterious

[81] http://switchboard.nrdc.org/blogs/rhammer/RDA%20Petition%20-%20WQS%20Violations%20-%20REGION%20IX%20-%20FINAL%20-%207-10-13.pdf Accessed 17 December 2013

effects)…Numerous peer reviewed scientific articles and publications have documented the connection between impervious cover and declines in water quality and stream health.

As stated by EPA, it is now understood that 'There is a direct relationship between the amount of impervious cover and the biological and physical condition of downstream receiving waters.'"

Susdrain[82] website United Kingdom[83]

"Traditional drainage systems cannot easily control poor runoff quality and may contribute to the problem. The amenity aspects of drainage systems, such as water resources management, community facilities, landscaping potential and provision of varied wildlife habitats have largely been ignored. Traditional drainage systems are not designed with these wider considerations in mind."

"Continuing our current approach to managing surface water in our existing urban areas, through the building and upsizing of traditional systems such as sewers and underground storage, is perpetuating unsustainable solutions…Many examples from around the world also show that reducing surface water from entering an existing drainage system, through retrofitting, can be more cost effective than increasing drainage capacity…"

Engineering Nature's Way website United Kingdom[84]

"Water quality control has to start from the primary source where the rain falls. Whether the rainwater is stored by natural or man-made techniques, or flows directly into drains or streams, if the surface water quality is poor at the start, it will be far more difficult to rectify downstream.

While pollution at point sources, by specific incidents, is relatively easily identifiable for action, it is increasing recognised that diffuse pollution of surface water is as large a problem. Diffuse pollution is also closely allied to uncontrolled surface water flow, including flooding.

Causes of diffuse pollution, however, can be more difficult to identify and isolate, and often demand a more holistic approach to prevention than point sources…"

A. Stephenson '*The Three Crucial Building Blocks to SuDS Progress in the UK*' (2013)[85]

"Legislation has already made SuDS [sustainable urban drainage solutions] compulsory for new development in Scotland and England and Wales will follow suit".

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[82] Susdrain was created by CIRCA (construction industry research and information association) and is an independent and authoritative platform for those involved in delivering sustainable drainage.

[83] http://www.susdrain.org/delivering-suds/using-suds/background/urban-drainage.html Accessed 18 December 2013

[84] http://www.engineeringnaturesway.co.uk/policybriefing/eu-water-framework-directive/ Accessed 18 December 2013

[85] http://www.engineeringnaturesway.co.uk/2013/the-three-crucial-building-blocks-to-suds-progress-in-the-uk/ Accessed 18 December 2013
Alex Stephenson is the Director of the UK Stormwater Division of Hydro International

Ofwat website[86] United Kingdom

"In the future, particularly as climate change increases the intensity of rainstorms, the capacity of many parts of our current drainage systems will be insufficient to meet needs. Building bigger sewers to cope with higher flows is unlikely to be a sustainable solution. It would be very expensive and in extreme weather conditions the sewers and downstream rivers would still be overwhelmed."

Environment Agency *'An assessment of evidence on Sustainable Drainage Systems and Thames Tideway Standards: A report by the Environment Agency for the Department for Environment, Food and Rural Affairs'*, Final October 2013, United Kingdom[87]

"London's sewer network uses both separated and combined systems. The combined sewer network 'service area' is approximately 550km^2. It was designed to handle waste water and run-off rainwater through a largely combined collecting system. Combined Sewer Overflows (CSOs) were incorporated into the sewer system as relief structures to prevent flooding caused by sewer overloading during periods of heavy rainfall. Currently, it is estimated that 39 million cubic metres of storm sewerage enters the tidal reaches of the River Thames in a typical year from these structures. This volume will reduce to 18 million cubic metres by 2015 on completion of the sewerage treatment works upgrades at five locations…

Even with these improvements to the sewerage system, there is little spare capacity in the sewerage network to avoid spills from the CSOs. This is largely due to the increases in population, water usage, natural infiltration and increases in impermeable areas served."

"*The Thames Tunnel Construction report placed the cost of the tunnel solution [waste water collection, storage and transfer tunnel] at £3.8billion in 2008 prices."*

Halcrow Group Limited (2013) '*Drainage Strategy Framework for Water and Sewerage Companies to Prepare Drainage Strategies. Good practice guidance commissioned by the UK Environment Agency and Ofwat*'[88]

"The [Water] Act also makes provision for the compulsory drainage of new developments through sustainable drainage systems (SuDS) and the 'right to connect' being conditional on SuDS being approved by the SuDS Approval Body of the Lead Local Flood Authority".

"The [national water] framework promotes the full evaluation of alternatives to traditionally engineered sewerage solutions to test whether these offer lower whole life cost options or better responses to uncertainty…

These should include (at least at a high level) real time control or active management, storm water retrofit techniques, education to enable customers to change behaviour, enhancing incentives for customers to reduce surface water flowing to sewers, and innovative permitting arrangements across drainage networks and wastewater treatment works. Water and sewerage companies should continue to review and develop other innovative solutions."

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[86] http://www.ofwat.gov.uk/future/sustainable/drainage Accessed 4 January 2014. Ofwat is the economic regulator of the privatised water industry in England and Wales. Ofwat stands for 'Office of Water Authority'.

[87] http://www.environment-agency.gov.uk/static/documents/Research/SuDS_and_the_Thames_Tunnel_Assessment_Final_Report_Oct_2013.pdf Accessed 18 December 2013

[88] http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT_8210_5081b1.PDF Accessed 4 January 2014

"New York has 422 CSOs [combined sewer overflows] and an agreed Long Term Control Strategy to significantly reduce the impact wet weather discharges have on aquatic systems throughout the city. Annual discharges are currently (2010) estimated to be 30 billion gallons (114 million cubic meters) per year. Building on existing and committed new sewer plans, an agreed grey [traditional drainage network approach] infrastructure based strategy to this problem is set to reduce these discharges to 19.8 billion gallons per year (a 34% reduction) by the 2030s. An alternative green infrastructure approach based around intercepting the first inch (25mm) of rainfall across 10% of the impermeable city area by 2030 is predicted to reduce CSO spills to 17.9 billion gallons per year.

Planners have calculated that the whole life costs after 20 years of the grey infrastructure solution will be $6.8 billion (2010 prices) compared to the green infrastructure whole life costs of $5.3 billion. The green infrastructure strategy reduces CSO spills by more than the grey alternative for $1.5 billion less in terms of whole life cost. Further, planners have calculated that New Yorkers will benefit by up to $41844 million (accumulated over 20 years) in additional benefits associated with lower energy bills from control of urban heating, increased property values and improved health.

Based on this analysis, New York City has committed itself to an aggressive green infrastructure based runoff control strategy to provide long term reductions in CSO spills. The plan is to achieve interception of 1.5% of impermeable area by 2015, 4% by 2020, 7% by 2025 and 10% by 2030."

Montgomery County, Maryland, America website page on Watershed Restoration and 'Rainscape' Program[89]

"The [Montgomery] County's stream system has suffered damage because of a historic lack of adequate stormwater control. In an effort to prevent future stormwater-generated problems, the County has embarked on a three-part watershed restoration effort to rehabilitate the stream system, introduce better management, and control runoff from additional urban surfaces in the County. This effort is the cornerstone of the County's MS4 stormwater permit."

Melbourne Water website[90]

"Stormwater needs to be managed as it can have an impact on our urban waterways. For new developments it is essential that the right controls are put in place to manage stormwater, prevent flooding and improve water quality."

"*Some of the effects may be to:*

- *change the structure, variety and suitability of habitat for aquatic life such as fish and macro invertebrates*
- *disturb animals and plants that live in the waterway, and affect animal breeding habits*
- *erode stream banks*
- *alter natural flooding regimes*
- *increase turbidity and pollution, affecting water quality; and*

[89] http://www6.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/watershedRestoration.asp Accessed 4 January 2014

[90] http://www.melbournewater.com.au/Planning-and-building/Stormwater-management/Pages/Why-manage-stormwater.aspx Accessed 23 December 2013

- *increase volumes of litter and oils".*

Victorian Department of Environment and Primary Industries (2013) *'Melbourne's Water Future: A Fresh approach to urban water'* State Government of Victoria[91]

"We now know, for example that once hard surfaces exceed 2 per cent of the area of a catchment, the health of downstream waterways begins to be adversely affected."

"One of the most significant challenges in our wastewater management is wet weather sewage overflows. In high rainfall events – such as the floods of 2005 and 2011 – stormwater runoff enters the sewerage mains (through manholes, cracks and joins in terracotta pipes, connection points, cross-connections with drainage pipes, and illegal connections). When the capacity of sewerage infrastructure is exceeded, sewage overflows into metropolitan creeks and waterways through many overflow points throughout Melbourne…

Moreover, as urbanisation increases and there are more hard surfaces channelling stormwater into our drains, these floods will become more regular and increasingly severe unless mitigating action is taken."

English Department for Environment, Food and Rural Affairs (2012) '*Tackling water pollution from the urban environment: Consultation on a strategy to address diffuse water pollution from the built environment'*[92]

"…Diffuse pollution in rivers and waterways is a typical characteristic of urban areas where road runoff, poorly plumbed drainage systems, old deposits of polluted sediment and runoff from industrial areas damage ecosystems in rivers, streams and ponds. The impacts may be individually small but when added together can be damaging, resulting in dirty and polluted water which makes our urban areas less pleasant places to live and work in.

…Currently, 27% of water bodies in England meet the standards necessary to support viable ecosystems… many failures are due to urban and other non-agricultural diffuse pollution…At least 1000 water bodies have a significant urban diffuse pollution problem."

"…we are considering the following principles...Encourage no regrets solutions, highlighting future risks to take possible preventative actions, and where possible seek to encourage actions which deliver multiple benefits e.g. surface water management actions for flood control which also improve water quality."

The Summary of Responses to the above consultation document published June 2013 showed that submitters considered that urban runoff should have top priority as a source of pollution to be tackled.

[91] http://www.livingvictoria.vic.gov.au/PDFs/MWF/MWF_complete.pdf Accessed 23 December 2013
[92] https://www.gov.uk/government/consultations/tackling-water-pollution-from-the-urban-environment Accessed 4 January 2014

English Department for Environment, Food and Rural Affairs (2012) '*National Policy Statement for Waste Water: A framework document for planning decisions on nationally significant waste water infrastructure*'[93]

"The Government is taking measures to reduce the demand for new waste water infrastructure in England, for example by requiring the use of sustainable drainage systems (SuDS) to reduce run-off in the built environment and exploring land management approaches that use natural systems to slow the flow of surface water in rural areas."

"Increased urbanisation (the development of green areas in and around towns and cities) will also have impacts on the capacity of the existing sewerage system. This is when permeable areas within existing development, such as gardens or driveways, are resurfaced with impermeable materials. There is consequently an increase in runoff to sewerage systems and a reduction in their capacity for carrying sewage. Increased urbanisation could intensify the impact of climate change on sewers."

"When commenced Schedule 3 to the Act [Flood and Water Management Act 2010] will establish a SuDS [sustainable urban drainage] Approving Body (SAB) in county and unitary local authorities. It will give them responsibility for approving drainage systems in new developments and redevelopments in England and Wales and for adopting and maintaining those SuDS which serve more than one property. The automatic right to connect surface runoff from these developments to a public sewer has been removed and will be contingent on approval from the SAB. Proposed drainage systems must comply with National Standards prior to approval."

"On 5 and 6 June 2011 after heavy rainfall over 900,000 tonnes of storm sewage was released into the River Thames from the tidal combined sewer overflows. These discharges, combined with warm dry weather and low river flows, resulted in the low oxygen levels and approximately 26,000 fish deaths along a kilometre stretch of the River Thames.

It is essential to reduce the likelihood of such incidents, which also have a reputational impact on the UK, as they take place in the capital city's river. The above impacts impose an economic cost on the capital, country and society. These costs include direct financial costs such as the costs of measures to mitigate against low oxygen, fish re-stocking, costs on the health service and the wider economy due to people falling ill and costs of cleaning up debris. The pollution also imposes wider 'external' social and environmental costs on society."

"The highly impermeable nature of the London urban area generates massive volumes of rainfall run-off which must be collected and disposed of quickly and efficiently to prevent flooding of properties. The existing mechanism is via drains and gullies into the sewerage system."

Urban Water Security Research Alliance (2012) '5 years of Urban Water Research in South East Queensland 2007-2012', CSIRO, Australia[94]

"Urbanisation increases the mean flow, the frequency of high flow events and the total number of days at high flow in local waterways. Higher impervious areas also result in decreasing frequency of low flow spells, but increases in the total duration of those spells.

[93] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69505/pb13709-waste-water-nps.pdf Accessed 18 December 2018

[94] http://www.urbanwateralliance.org.au/publications/UWSRA-final-synthesis-report.pdf Accessed 4 January 2014

While flow itself may be partially responsible by directly dislodging macroinvertebrates, its impact on sediment delivery to the stream through increased erosion may also change habitat quality and therefore availability…

Preliminary findings from stormwater analysis showed E. coli and enterococci were found at levels that exceeded the recreational water quality guidelines. Human contaminants in stormwater are high, with evidence of sewer leakage and overflows during storm events, particularly in older suburbs."

"Health risk assessments indicate that captured stormwater should undergo some degree of treatment prior to use for non-potable purposes".

MWH, *'Comparing the Arrangements for the Management of Surface Water in England and Wales to Arrangements in Other Countries' Final Report* (2011)[95] A report prepared for Ofwat

"England and Wales were two of the first countries to benefit from piped sewerage systems that convey both wastewater and surface water away from urban areas to a suitable point for treatment and/or disposal. They have secured a high level of public health for the populations they serve. However, they have also led to widespread pollution from combined sewer overflows, treatment works overflows and storm tanks discharges. In more sensitive waters, discharges from surface water outfalls are also becoming a problem. These systems also have a limited conveyance capacity such that in extreme storm events significant surface flooding can occur when that capacity is exceeded. As the events in 2007 demonstrated, this can lead to severe disruption to other infrastructure, business and property, and lead to substantial damage and loss".

"We found that more novel surface water management measures had initially been devised as a more cost effective way of managing increased rates and volume of run-off from developed areas. When regulations were introduced to control pollution from surface water, the use of these new methods accelerated. Nowadays, source control measures are required for all new development in most of the other countries studied. Indeed changes in planning regulations have been an important driver for delivering new methods".

"The primary driver for the introduction of SUDs in Scotland was an investigation carried out by the Forth River Purification Board (now the Scottish Environment Protection Agency -SEPA) which quantified the impact surface water drainage was having on the watercourses in their area.

…Surface water has been found to transport significant pollutant loads of heavy metals, oils, sediments and nitrogen. In the past 10 to 15 years government efforts have begun to address this issue in Australia. This has led to the more active uptake of surface water management measures, and they are now widely used across Australia.

…There are no national standards for stormwater, flood risk or surface water management in New Zealand. There are however, various design guidelines and codes of practice documents available [from District and Regional Councils] that provide guidance on appropriate design, operation, maintenance and monitoring requirements of various treatment and attenuation measures."

[95] http://www.ofwat.gov.uk/future/sustainable/drainage/rpt_com_201102mwhswd.pdf Accessed 18 December 2014

Mott MacDonald (2011) '*Future Impacts on Sewer Systems in England and Wales. Summary of Hydraulic Modelling Exercise Reviewing the Impact of Climate Change, Population and Growth in Impermeable Areas up to around 2040. A report prepared for Ofwat.*'[96]

"The models predict a significant increase in flood volumes and the number of flooded locations, with a median increase in [1 in 10 year] flood volumes of about 51% and a mean (average) increase of about 92%...If nothing is done, it is reasonable to expect a significant increase in the number of flooded properties across England and Wales, as well as an increasing frequency of flooding for those already at risk"

"Housing and industrial development adds new flow and reduces the capacity for draining rainwater. If not properly accommodated, housing growth will lead to an increase in sewer flooding. The median increase in 1:10 year flooding across 97 catchments was 4.8%, compared with current predicted flooding.

Urban creep results in more rainwater entering the network in every storm event. It will lead to an increase in sewer flooding. The median increase in 1:10 year flooding across 97 catchments was 11.5%, compared with current predicted flooding…"

Philadelphia Water Department, '*Amended Green City Clean Waters, The City of Philadelphia's Program for Combined Sewer Overflow Control, Program Summary'* (2011)[97]

"Unfortunately, for the urban waterways of the Philadelphia area, streams have fallen victim to years of the effects of urbanization. As population and development have increased within and surrounding Philadelphia, so has impervious cover. This has resulted in a significant increase in stormwater runoff to be managed by existing infrastructure, ultimately making its way to these urban streams. This increase has created a "flashy" flow regime in these urban streams, meaning that they go from very low streamflows during dry weather to extremely high flows during rain events. This effect has devastated the stream systems, causing erosion and scouring of streambanks such that habitat has been all but destroyed for benthic invertebrate and fish populations."

English Department for Environment, Food and Rural Affairs (2010) *'Surface Water Management Plan Technical Guidance'*[98]

"*It is recognised that, faced with the challenges of climate change and housing growth, and the need for sustainable development, strategic and integrated approaches to surface water drainage are essential to maximise the benefits of drainage investment for society."*

[96] http://www.ofwat.gov.uk/sustainability/climatechange/rpt_com201106mottmacsewer.pdf Accessed 4 January 2014

[97] http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf Accessed 20 December 2013

[98] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69342/pb13546-swmp-guidance-100319.pdf Accessed 18 December 2013

'Queensland Department of Environment and Heritage Protection, *'Urban Stormwater Quality Planning Guidelines'* (2010)[99]

"Poor urban stormwater quality contributes to significant water quality decline within our waterways. Sustained high urban population growth rates in Queensland have led to increasing impacts from urban stormwater. Without improved management, urban development is likely to lead to increased stormwater pollutant loads of sediment, nitrogen and phosphorus. In South East Queensland total loads from urban stormwater are projected to increase by more than 50 per cent by 2026….

With urbanisation, the area of impervious surfaces within a catchment increases dramatically…

The increased flood volumes, peak discharges and velocities in urban waterways cause a significant increase in the amount of material (contaminant loads) carried by the flow and can cause physical damage to stream channels. Activities such as land development expose soils to water and wind erosion and are major sources of sediment and nutrients. Transportation and industrial activities are sources of many other contaminants…Run-off carries these pollutants into waterways, and although concentrations may be diluted during a run-off event, the total loads can affect the environmental quality of downstream aquatic habitats.

Protecting the environmental values and uses of urban waterways requires an integrated or waterway health based adaptive approach directed at managing the volume and rate of catchment run-off, the quality of the run-off, and protecting the riparian vegetation and the habitats necessary for supporting aquatic ecosystem health. In contrast there is evidence that solely managing stormwater quality using a best practice approach is insufficient to adequately mitigate all the impacts of urbanisation (e.g. Sunshine Coast Regional Council 2008; Maxted and Shaver 1996)."

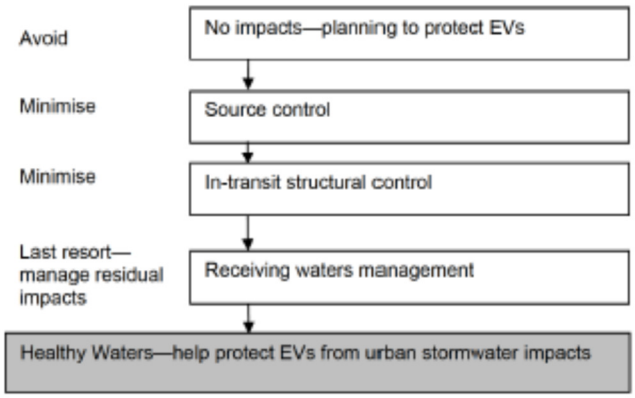

Figure 2.3 Hierarchy of stormwater management control

Queensland Government (2010) *'State Environment Planning Policy 4/10 Healthy Waters'*, published by the Department of Environment and Resource Management[100]

"Urban stormwater run-off contributes to poor water quality in waterways, which can harm aquatic ecosystems and limit human water use. Sustained high population growth in Queensland's catchments is increasing the threat to water environmental values. Unless well managed, urban stormwater causes contaminants such as nutrients, sediment and rubbish to enter waterways. Waterway erosion can also be caused by the concentration of stormwater flows and such flows can

[99] http://www.ehp.qld.gov.au/water/policy/pdf/urban-water-web.pdf. Accessed 4 December 2013
[100] http://www.ehp.qld.gov.au/water/policy/pdf/spp-healthy-waters-web.pdf Accessed 17 December 2013

disrupt ecosystem health. Similarly, development that discharges waste water to waterways can mobilise contaminants that affect water environmental values."

The above policy requires the following plans to be prepared for development proposals that comprise six or more lots or dwellings:

- stormwater quality management plan;
- waste water management plan; and
- sediment and erosion control plan.

City of Port Phillip (2010) *'Water Plan- Toward a Water Sensitive City. Take Local Action: Be part of the Solution'*, Port Phillip City Council, Victoria, Australia

"*5,100 ML/yr of stormwater is generated across the municipality. Most of this stormwater carries significant pollutant loads, including:*

- *778,000 kg/yr of Total Suspended Solids*
- *1,600 kg/yr of Total Phosphorous*
- *11,400 kg/yr of Total Nitrogen*
- *litter, heavy metals, hydrocarbons and other pollutants.*

… This stormwater drains directly into Port Phillip Bay, adversely impacting on its ecology and on the tourism and amenity values of Port Phillip's beaches".

UK Environment Agency (2007) *'The Unseen Threat to Water Quality: Diffuse Water Pollution in England and Wales report – May 2007'* Environment Agency[101]

Diffuse water pollution are pollutants from many small-scale sources carried into water bodies by rainwater run-off from urban and rural land.

"Diffuse pollution is one reason why improvements in river quality are levelling off. One in seven urban rivers is still of poor quality...

The Water Framework Directive, which is new legislation, has put diffuse pollution in the spotlight. Diffuse sources must be tackled if we are to achieve the objectives set. Some of the problems are complex and will take decades to resolve, but many of the solutions are known and could be put into practice now. Failure to do so will allow the problems to get worse and increase the future costs"[102].

"…diffuse pollution…is now [thought to be] a bigger threat to river water quality than point source pollution".

[101] http://www.environment-agency.gov.uk/static/documents/Research/geho0207bzlvee_1773088.pdf Accessed 4 January 2014

[102] Extract from forward written by Director of Environment Protection.

South East Queensland Healthy Waterways Partnership (2007) *'South East Queensland Healthy Waterways Strategy 2007-2012. Final Document – Water Sensitive Urban Design Action Plan'*[103]

"Many decades of urban development in South East Queensland (SEQ) have had a measurable adverse impact on the health of the region's waterways. SEQ is the fastest growing region in Australia, with an expected increase in population from 2.66 million in 2006 to around 4 million by 2026 (OUM, 2006). To accommodate this population growth, an estimated 575,000 new dwellings will be required (OUM, 2005). If traditional urban development practices are continued, the increase in urban land use will lead to further deterioration of already stressed waterways, water resources, and environmental values."

"Due to the predominantly coastal location of urban centres in SEQ, urban land uses tend to impact coastal freshwater and estuarine systems more than any other land use. Freshwater coastal streams with the poorest water quality in SEQ, such as Norman Creek in the Lower Brisbane River catchment (EHMP Report Card grade 'D'-), Little Eprapah Creek in the Redlands area (EHMP Report Card grade 'F'), and Slacks Creek in the Logan River catchment (EHMP Report Card grade 'D'), are all located downstream from areas of existing dense urban development or are adjacent to areas recently cleared for urban development (MBWCP, 2005).

Common pollutants identified from stormwater samples collected from different residential, commercial, and non-rural industrial land uses in SEQ include:

- *sediment;*
- *nutrients (particularly nitrogen and phosphorus);*
- *heavy metals;*
- *petroleum hydrocarbons;*
- *litter; and*
- *synthetic organic contaminants, such as pesticides and herbicides (BCC, 2004)."*

"The construction phase of urban development has the potential to generate large sediment loads if appropriate control measures are not implemented. Modelling of construction phase impacts up to 2026 from land under development, without erosion and sediment control measures in place, indicates that total sediment loads could increase by 9 percent over 2004 levels. The scale of this construction phase impact is comparable to the impact of all established development areas, which, by 2026, wouldi ncrease total sediment load by 16 percent (WBM Oceanics, 2007)….

Total-sustainable-load modelling studies indicate that the if water quality in Moreton Bay is not to deteriorate significantly by 2026 the package of management interventions to be applied in SEQ needs to include application of best practice WSUD to all urban development and retrofitting of WSUD measures to the existing urban landscape."

The economic drivers for WSUD in SEQ include:

- *increased understanding of the economic values associated with healthy waterways;*
- *increased expectations among commercial users of waterway services (e.g. tourism operators) of the maintenance of healthy waterways despite rapid increases in the catchment's population;*
- *increased understanding that it costs much more to rehabilitate degraded waterways than to protect waterways from degradation, and that often only rehabilitation is possible, not restoration;…and*

[103] http://www.healthywaterways.org/TheStrategy/ActionPlanLinks.aspx Accessed 4 January 2014

- i*ncreased recognition that the liveability of SEQ needs to be maintained to ensure that it continues to be a growing population centre with a healthy economy".*

Victorian Department of Sustainability and Environment *'Using the integrated water management provisions of Clause 56 – Residential Subdivision'*. VPP Practice Note (2006)[104]

"As the density of urban development in an area intensifies, so does the proportion of impervious areas, which in turn increases the volume of surface run-off from a rainfall event. Run-off rates become much higher and concentrated over shorter periods of time. These peak flows may be evident even after small, frequent rainfalls and have the potential to cause flooding and significant erosion in downstream waterways.

Urban development is also a significant generator of stormwater pollutants such as sediments, hydrocarbons, heavy metals, nutrients, pathogens and litter. Stormwater pollutants and peak flows can threaten the health of waterways by degrading aquatic habitats, disturbing riparian vegetation or modifying their physical form.

Urban run-off needs to be managed to minimise the risk of flooding and protect receiving waters and the environment. The receiving waters can be either surface water (creeks, rivers, bays) or groundwater."

NSW Department of Environment and Conservation (2006) 'Managing Urban Stormwater, Harvesting and Reuse'[105]

"Urbanisation changes the way water flows through a catchment, and this can have a range of adverse impacts on the water environment, including:

- *poor water quality and degraded aquatic ecosystem health within rivers and creeks from the disposal of stormwater and wastewater*
- *changes to the pattern of flow in streams and rivers*
- *increased frequency and magnitude of flooding*
- *demand for potable water exceeding the sustainable supply, and impacting on the availability of water for users."*

"Urban development typically has major impacts on the volume, frequency and quality ofrun-off, and has associated ecosystem impacts. For example, it can:

- *double annual run-off volumes*
- *reduce infiltration*
- *increase peak flows by up to ten-fold*
- *significantly increase the frequency of run-off.*

Urbanisation of a catchment commonly results in up to a four-fold increase in stormwater pollutant loads to local waterways."

[104] http://www.dpcd.vic.gov.au/__data/assets/pdf_file/0020/41717/VPP_Clause_56_4-Intwaterman.pdf Accessed 23 December 2013

[105] http://www.environment.nsw.gov.au/resources/stormwater/managestormwatera06137.pdf Accessed 23 December 2013

'National Water Quality Management Strategy: Australian Guidelines for Urban Stormwater Management (2000) published in Australia for the Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council[106]

"Urban drainage systems have often been developed to minimise the risk of flooding, without due consideration of other important values such as resource conservation, environmental quality, public safety, and amenity.

It is now clear that a new approach to stormwater management is needed - an approach that addresses issues of storm water quality and aquatic ecosystem health, as well as stormwater quantity. We need an approach that recognises the environmental impacts of urbanisation, the linkages between land and water management, and the importance of community values and involvement.

Urban stormwater presents a management challenge in terms of quantity (flood and drainage management, stormwater reuse), quality (litter,nutrients, chemicals, sediments) and aquatic ecosystem health (aquatic habitats, riparian vegetation, stream stability and environmental flows).

It is difficult to make generalisations about what impacts urbanisation will have on aquatic ecosystem health. Generally, reduced water quality and a lower diversity of aquatic flora and fauna can be expected. The composition of ecological communities may also be altered, or the relative abundance of species tolerant to the altered conditions may increase. Left unmanaged, these impacts may not only be detrimental to the environmental values of urban waterways, but may also pose a risk to public health and restrict potential opportunities for the community to benefit from the waterway.

Growth of urban areas, increased urban density, industrial development, and failure of ageing sewers have commonly led to increased urban stormwater pollution of local and downstream ecosystems. Inadequate provision for stormwater drainage has led to flooding problems from increased peak flows, greater flow volumes and altered flow patterns."

Pollutant	Dry weather concentrations			Wet weather event mean concentrations		
	Forest	Rural	Urban	Forest	Rural	Urban
Suspended Soils (mg/L)	1 to 20	3 to 270	1 to 350	1 to 140	4 to 200	20 to 1,000
Total phosphorous (mg/L)	0.006 to 0.24	0.0008 to 0.81	0.001 to 2.2	0.01 to 0.42	0.03 to 1.3	0.12 to 1.6
Total nitgrogen (mg/L)	0.04 to 1.2	0.12 to 4.2	0.1 to 11.6	0.27 to 0.66	0.23 to 5.1	0.6 to 8.6
Faecal coliforms (cfu/100mL)	0 to 200	10 to 100	40 to 40,000	260 to 4,000	700 to 3,000	4,0000 to 200,000
Increased water temperature (°C)	n/a		5	n/a		

[106] http://www.environment.gov.au/system/files/resources/30f22565-8ec8-4308-80a2-a6e4554a55cd/files/urban-stormwater-management-paper10.pdf Accessed 4 December 2013

Natural Resources Defence Council (1999), Stormwater Strategies, Community Responses to Runoff Pollution, United States[107]

"The United States Environment Protection Agency (EPA) now considers pollution from all diffuse sources, including urban stormwater pollution, to be the most important source of contamination in our nation's waters. While polluted runoff from agricultural sources may be an even more important source of water pollution than urban runoff, urban runoff is still a critical source of contamination, particularly for waters near cities - and thus near most people. EPA ranks urban runoff and storm-sewer discharges as the second most prevalent source of water quality impairment in our nation's estuaries, and the fourth most prevalent source of impairment of our lakes. Most of the U.S. population lives in urban and coastal areas where the water resources are highly vulnerable to and are often severely degraded by urban runoff…

The main reason why urban stormwater remains such an important contributor to water pollution is the fact that in most areas, stormwater receives no treatment before entering waterbodies. The storm-sewer system merely collects the urban runoff and discharges it directly to the nearest river, lake, or bay."

"…much stormwater pollution can be prevented with proper planning in growing or redevelopment areas….strategies that deal with stormwater specifically must be implemented if the quality of America's waterbodies is to improve."

"The stormwater pollution problem has two main components: the increased volume and velocity of surface runoff and the concentration of pollutants in the runoff. Both components are directly related to development in urban and urbanizing areas. Together, these components cause changes in hydrology and water quality that result in a variety of problems including habitat loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion, as well as affects on our health, economy, and social well-being.

Research has shown that when impervious cover reaches between 10 and 20 percent of the area of a watershed, ecological stress becomes clearly apparent. After this point, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases…typical total imperviousness in medium density, single-family home residential areas ranges from 25 percent to nearly 60 percent.

Construction activity is the largest direct source of human-made sediment loads…Studies indicate that poorly managed construction sites can release 7 to 1,000 tons of sediment per acre during a year, compared to 1 ton or less from undeveloped forest or prairie land. Construction activity can also result in soil compaction and increased runoff…

Two hundred years of unregulated, unmanaged urban stormwater have contributed to many severe public health problems and expensive natural resource losses in the United States. Left unregulated and uncontrolled, urban stormwater:

- *pollutes drinking water sources, filling in reservoirs with clogging silt and oxygen-robbing nutrients and contributing to drinking water emergencies;*
- *fills in navigable waterways with contaminated sediment, leaving us with increased dredging and spoil disposal costs;*

[107] http://www.nrdc.org/water/pollution/storm/stoinx.asp
Accessed 3 December 2013

- *closes or shrinks lucrative rockfish, shad, flounder, crab, oyster, and other commercial fisheries due to chemical contamination, oxygen starvation, and the resulting loss of habitat;*
- *fouls beaches and other recreational waters, causing losses in revenues from declines in boating, fishing, duck hunting and coastal tourism;*
- *scours smaller stream channels and dumps huge gravel and silt loads, ruining fish and amphibian habitat;*
- *obliterates small streams, springs and wetlands during development (these natural waterbodies are sources of clean ground and surface water and serve as habitat for aquatic life); and*
- *damages homes and businesses during the flash floods common where stormwater is left uncontrolled*

Each of these problems carries heavy costs: increased spending on health care, higher insurance and drinking water rates, declining stocks of commercial fish, and loss of coastal tourism revenues. Americans are spending millions on these symptoms of stormwater pollution instead of trying to control the root cause.

Most of the U.S. population lives in urban and coastal areas where the water resources are highly vulnerable to and are often severely degraded by urban runoff. Even a partial accounting shows that hundreds of millions of dollars are lost each year through added government expenditures, illness, or loss in economic output due to urban stormwater pollution. The ecological damage is at least as significant."

CSIRO (1999) 'Urban Stormwater: Best practice Environmental Management Guidelines'[108] CSIRO Publishing 2006 Australia[109]

"Urbanisation leads to changes in both the quantity and quality of the water that is delivered to urban receiving waters. Unmanaged, these changes can result in considerable damage to the environment.

…The increased flood volumes, peak discharges and velocities in urban waterways cause a significant increase in the amounts of material (loads of pollutants) carried by the flow. Activities such as transportation and construction provide abundant sources of pollutants that are readily available for wash-off on the relatively smooth urban surfaces—Table 1.1 lists common pollutant types and their sources. Run-off carries these pollutants into waterways, and although concentrations may be diluted during a run-off event, the total loads can affect the environmental quality of downstream aquatic habitats."

[108] http://www.publish.csiro.au/nid/220/issue/3822.htm Accessed 23 December 2013
[109] CSIRO stands for Commonwealth Scientific and Industrial Research Organisation

Note About Author

Allison Tindale is currently employed in the Local Government Sector. She has worked for a variety of Councils in England, Wales and New Zealand. She has practiced as a town planner since 1997 in the countries of Australia, England, Wales and New Zealand. Previous employment includes the private sector as both a town and social planner and the central government sector (as a consultant engaged by the former NSW Office of the Commissioners for Inquiry for Environment and Planning). She holds a Masters of Urban and Regional Planning (with Honours), as well as a Bachelor of Economics (triple major) from the University of Sydney, Australia.

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