Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 2.4.3: Climate Change Guidance Material for Urban Stormwater Management

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Contents

1. Introduction

This report provides a stocktake of guidance material available to urban stormwater managers in the Auckland region. A summary of the regulatory framework relevant to stormwater management is given in Section 2 noting where climate change is addressed in relation to stormwater. Section 3 is a review of national and Auckland regional technical guidance material that can be used by practitioners to plan for possible adaption to the impacts of climate change on stormwater management. How the technical guidance has been interpreted and used by local councils is addressed in Tool 2.4.2.

2. Regulatory framework and strategic planning documents

Resource management in New Zealand operates under a three-tier system of governance (national, regional and local/district). The regulatory framework under this system is summarised in Figure 2.1 for stormwater management in the Auckland Region. The framework consists of statutory and non-statutory planning documents, summarised in this section, which are backed by technical guidance material overviewed in Section 3. The documents identify stormwater management as an activity which is sensitive to climate change that may require future adaptation.

During the writing of this report, the Auckland Regional Council and seven Territorial Authorities (TAs) were amalgamated to form the Auckland Council (November, 2010) and a number of new planning documents are currently being developed. The proposed Auckland Plan will be released for public consultation in September 2011, this sets out the Council's high level strategic vision for Auckland. This plan will be followed by Unitary Plan which will replace existing district and regional plans in order to implement the vision of the Spatial Plan. Although the regulatory framework in Auckland is currently in a state of flux, the review provided here remains of relevance because stormwater management will continue to be subject to the statutes, types of planning documents and guidance material described below.

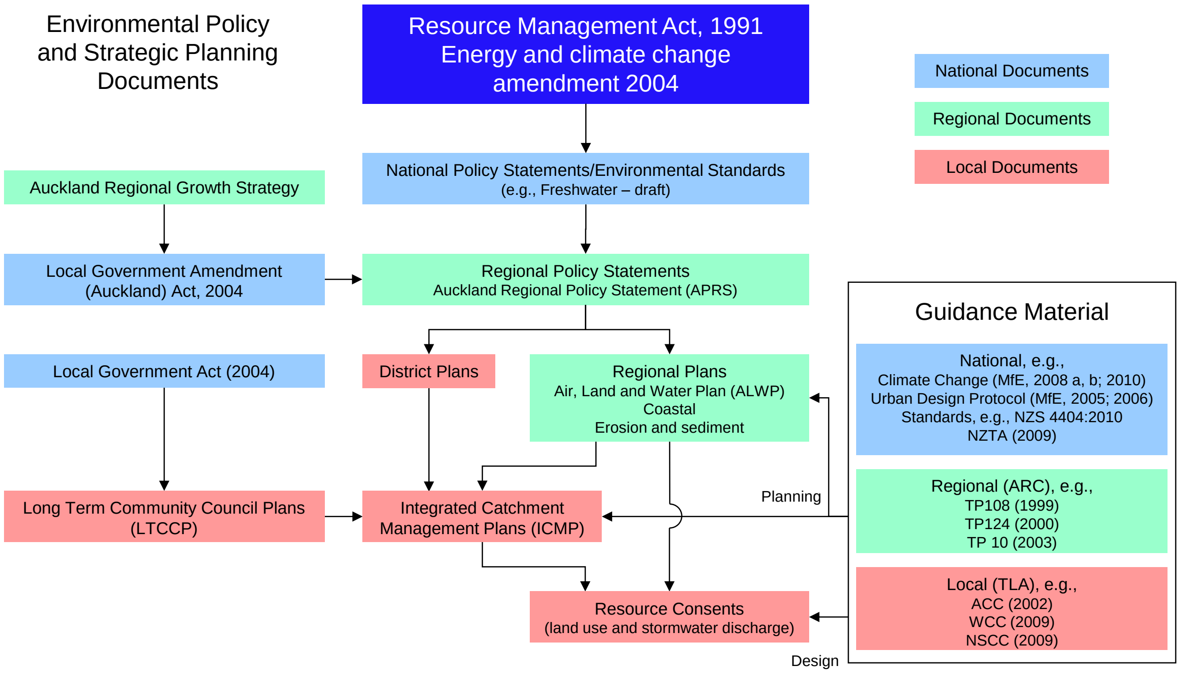

Figure 2.1: Regulatory framework and guidance material for stormwater management in the Auckland Region

2.1 Resource Management Act (1991)

The Resource Management Act (RMA; 1991) is the principal statute under which the effects of stormwater discharges to the environment are managed. The Act has the purpose of promoting the sustainable management of natural of and physical resources (Section 5):

"(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.

(2) In this Act 'sustainable management' means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while:

(a) sustaining the potential of the natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment."

2.2 Resource Management (Energy and Climate Change) Amendment Act (2004)

The need to account for the effects of climate change in resource management was introduced to the RMA by the Resource Management (Energy and Climate Change) Amendment Act (2004). Climate change is addressed in Section 7 (Other matters):

In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall have particular regard to— (i) the effects of climate change:

The implications of the amendment for local and regional government decision making are discussed in a summary document (MfE, 2007) available for download from the MfE Climate Change website[1]. This document lists stormwater management as a sensitive activity that could be affected by climate change, particularly in areas on flood plains or near the coast.

2.3 National Policy Statements and National Environmental Standards

National Policy Statements allow central government to give regional and district authorities direction with respect to environmental issues. They guide decision making under the RMA. National Environmental Standards are intended to promote consistent standards at the regional and local levels. There are currently no National Policy Statements or Environmental Standards which pertain specifically to stormwater management. However, the National Policy Statement on Freshwater Management[2] which came into effect in July 2011 addresses the key issues of water quality, allocation, ongoing engagement, and effective implementation of the RMA. These include policies in relation to the setting of water quality limits and imposing requirements on discharge consents (including the discharge of contaminants in stormwater) in order to ensure these limits are met. The policies require councils to have regard to the reasonably foreseeable impacts of climate change when making or changing regional plans.

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[1] http://www.mfe.govt.nz/publications/climate/making-good-decisions-climate-change-effects-dec07/index.html (date of last access, 3 March 2011)

[2] http://www.mfe.govt.nz/rma/central/nps/freshwater-management.html (date of last access, 2 September 2011)

2.4 Regional Policy Statements

Regional Policy Statements (RPSs) provide a framework for sustainable and integrated resource management which takes into account the main issues relating to the use, development and protection of the natural and physical resources in the region. An RPS has duration of 10 years, but can be reviewed at any time. An RPS also provides the framework for strategic integration of land use and infrastructure by co-ordinating and influencing the urban form across multiple TAs.

The Local Government Amendment (Auckland) Act (2004) aligns the Auckland RPS (ARPS; ARC, 1999 a) to the objectives of the Auckland Regional Growth Strategy (1999 b). Stormwater management is discussed in Chapter 8 (Water Quality) of the ARPS. The main objectives are to protect and enhance the quality and quantity to freshwater and marine habitats and to reduce the adverse effects of point and non-point source contamination. While the challenge of climate change on regional environment management is noted, the main policy focus is in relation to mitigating greenhouse gas emissions from transport and industry. Stormwater management issues associated with climate change are not addressed *per se* although the impacts on natural hazards (e.g., flood risk) and sea level rise are noted. The ARPS states that planning and engineering controls for climate change impacts can be exercised through district plans and resource consents.

2.5 Regional Plans

Regional Plans provide the rules for those aspects of resource management which are a function of regional councils. Regional plans have duration of 10 years, but can be reviewed at any time. Standards and non-statutory requirements, such as design criteria, can be incorporated into the plans. The purpose of Regional Plans is to achieve integrated management of natural and physical resources across the region.

The ARC prepared three plans which concern stormwater management: Coastal, Sediment Control and Air, Land and Water. These plans remain in effect and may or may not be superceded by provisions in the new *unitary plan*[3] . Climate change is addressed in relation to sea level rise in the Coastal Regional Plan, which could affect some aspects of stormwater management; however, the other plans make no mention of climate change.

[3] At the time of writing the Auckland Council has not made a decision on whether all existing regional plans will be incorporated into the unitary plan (Auckland Council Stormwater Seminar, 19 August, 2011)

2.6 District Plans

The purpose of District Plans are to achieve integrated management of the effects of use, development and protection of a district's natural and physical resources and control of land in relation to natural hazards. District Plans contain rules and other provisions relating to the subdivision and development of land.

Under the Auckland Council, the existing district plans for the region will continue to apply to their former districts until a new unitary plan is adopted. The district plans were evaluated with respect to stormwater management in the Boston Group Report (ARC, 2004 a) and to Low Impact Design (LID), by Bennet and Megaughin (2008). Climate change impacts noted in the district plans which may affect stormwater management include increased flood risk, sea level rise (i.e., location of coastal outfalls), land stability / slippage, and uncontrolled overflows from sanitary sewers.

2.7 Long Term Council Community Plans (LTCCP)

In addition to the District Plan, TAs must prepare a Long-Term Council Community Plan (LTCCP) under the Local Government Act (2002). The LTCCP must, amongst other provisions, describe the way in which stormwater is to be managed within the council. The LTCCP sets out the council's function with respect to stormwater management (e.g., flood protection, stormwater quality management, maintenance of stormwater drainage infrastructure) and describes how these functions are to be implemented and funded over the life of the plan.

Provisions for climate change are only a minor part of the LTCCPs prepared by Councils in the Auckland Region. All the LTCCPs note that expected increases in the frequency of high intensity rainfalls could lead to increased flood risk and land instability.

2.8 Other plans relevant to stormwater management

2.8.1 Stormwater Action Plan

The Stormwater Action Plan (SWAP. ARC, 2004 b) was prepared following the findings of the Boston Consulting Group Report (ARC, 2004 a). It sets the scene for organisational co-operation to address regional stormwater problems and meet community expectations for water quality and the environment as set out in the RMA, the ARPS, the Proposed ALWP, the region's District Plans and LTCCP documents.

SWAP is largely concerned with setting funding allocations to meet the stormwater management objectives across the region. Climate change is not discussed in the plan.

2.8.2 Integrated Catchment Management Plans

Integrated Catchment Management Plans (ICMPs) are non-statutory documents intended to manage stormwater and wastewater discharges, diversions and associated activities within the catchment or district. ICMPs may address climate change issues depending on land use and the scale and nature of future development, however, whether and how this is done differs between the TAs. Tool 2.4.2 includes a summary of the ICMP for Lucas Creek, North Shore City, which has addressed climate change.

2.8.3 Stormwater Asset Management Plans

Stormwater Asset Management Plans, prepared by the TAs, are concerned with specifying in detail the measures and costs associated with maintaining the level of service required to meet stormwater management objectives for current and future demands as set out in the LTCCP. Like the LTCCPs, where included, climate change is only a minor part of these plans.

3. Technical Guidance Material

Supporting the planning documents summarised above are a range of guidance documents of relevance for the design and maintenance of stormwater management systems. Like the planning documents, this material can have a national, regional or local focus. Note that while the recommendations given in the MfE guidance manuals described below are not prescriptive, these recommendations have been or are being incorporated into other documents such as standards and design criteria, some of which do require compliance.

3.1 Climate Change Effects and Impacts Assessment Guidance Manual (MfE 2008 a)

The *Climate Change Effects and Impacts Assessment* guidance manual (MfE, 2008 a, first edition 2004) has been prepared specifically for local government in order for them to assess and manage risks to infrastructure and assets associated with climate change. The manual is the primary guidance document for climate change adaptation and is widely cited in other national, regional and local strategic planning and technical documents. A summary document (Preparing for Climate Change, MfE, 2008 b) has been prepared by MfE and is commonly referred to as the "red-book".

Both documents are available for download from the MfE Guidance on Climate Change website[4].

The manual:

- *provides projections of future climate change around New Zealand (Chapter 2);*
- *compares these projections with present climate extremes and variations (Chapter 3);*
- *identifies potential effects on local government functions and services (Chapter 4);*
- *describes the development of climate change scenarios from future climate projections for use in risk assessment (Chapter 5);*
- *outlines methods for assessing the likely magnitude of such effects and explains how this information can be applied to assess the risk associated with various climate change impacts (Chapter 6); and*
- *provides guidance on incorporating climate risk assessment into local government regulatory, assessment and planning processes (Chapter 7).*

The risk assessment process detailed in Chapters 4-6 of the manual is broken into three broad stages in the red-book:

1. Qualitative analysis to identify those functions and services that could be affected by climate change.
2. Preliminary quantitative assessment or screening using a mid-range climate projection and relevant socio-economic scenarios to test whether existing planning and infrastructure will be able to accommodate any increase in risk or resource availability. For sensitive functions and services, assessment may also include a high-end climate change projection. Where the potential impact is significant, detailed assessment should follow.
3. Detailed scientific and technical risk assessment using a range of climate change projections for those functions or services which appear unlikely to cope with the impacts of climate change followed by analysis of response options to manage the risk.

[4] http://www.mfe.govt.nz/issues/climate/resources/local-govt/index.html

Qualitative Analysis

Qualitative analysis is discussed in Chapter 4 of the manual. The purpose is to gain an understanding of the links between climate influences and possible impacts in order to determine the role of climate, and climate change, for council functions and services.

The guidelines provide two tables to aid qualitative analysis (Tables 4.1 and 4.2 of MfE, 2008 a), the parts of which are of relevance for stormwater management are reproduced below (Table 3.1 and Table 3.2). Possible climate change outcomes with respect to stormwater management, including combined sewers, are reproduced in Table 3.1. There are links between other functions and stormwater management, for example land use management resulting in urban expansion and intensifications could lead to increased imperviousness leading to stress on the drainage network. However, these links are not made explicitly in the MfE guidelines.

Natural resources sensitive to climate change that are linked to stormwater discharges are presented in Table 3.2. While the effects of changes in stormwater quantity on natural resources are identified in the manual, the effects of changes in stormwater quality are lacking. Stormwater impacts on land stability in urban areas are also not noted, though landslides are mentioned with respect to erosion which is linked to stormwater in Table 3.1 (but not in Table 3.2).

Once a council function or service has been identified as being sensitive to climate change, a screening assessment should be undertaken to determine whether climate change is likely to have a significant effect that may require a response. The key factors to consider are:

1. Duration. What is the time-horizon of the activity with respect to climate change? Climate change should be considered for long-term decisions.

2. Current and future drivers. Is there an existing or foreseeable problem that is either exacerbated or caused by climate change? Investment decisions for climate-sensitive infrastructure should be preceded by a risk assessment which includes the response to climate change and a cost benefit analysis. Infrastructure designs which incorporate climate change adaptation should be considered in cases where the resulting asset 'life-cycle' costs are less than the costs of future replacement or up-grades.

Table 3.1: Local government functions (stormwater, wastewater in combined sewers) and possible climate change outcomes (extracted from MfE, 2008 a, Table 4.1)

Function	Affected assets or activities	Key climate influences	Possible effects	Section in Table 3.2 giving type/explanation of effects
Wastewater	Infrastructure	Increased rainfall	More intense rainfall (extreme events) will cause more inflow and infiltration into the wastewater network. Wet weather overflow events will increase in frequency and volume. Longer dry spells will increase the likelihood of blockages and related dry weather overflows	See Drainage
Stormwater	Reticulation Stop banks	Increased rainfall Sea-level rise	Increased frequency and/or flooding. Changing flood plains and damage to property. Increased stream erosion. Changes in groundwater levels. Salt water intrusion in coastal zones.	See Rivers, Drainage and Coastal areas

Table 3.2: Sensitivity of natural resources, linked to stormwater, to present climate and climate change (extracted from MfE, 2008 a, Table 4.2)

Natural resource	Key climate influence	Impact of climate change	Present sensitivity
Rivers	Rainfall	River flows likely to increase in the west and decrease in the east of New Zealand. More intense rainfall causing increased flooding. Less water for irrigation in north and east. Increased problems	Strong seasonal inter-annual and Inter-decadal fluctuations.
Drainage	Rainfall	Increased frequency of intense rainfall events could lead to increased surface flooding and stormwater flows and increased frequency of ground water level changes.	Natural year-to-year variation in the location and size of heavy rainfall events.
Coastal areas*	Sea-level rise, storm frequency and intensity, wave climate, sediment supply	Effects of sea-level rise and other changes will vary regionally and locally. Coastal erosion is likely to be accelerated where it is already occurring and erosion may become a problem over time in coastal areas that are presently either stable or are advancing	Short- and medium-term fluctuations in sea levels (i.e., up to about 30 years) are dominated by ENSO and IPO variations
Water quality*	Temperature and rainfall	Reduced rainfall and increased temperatures could have significant impacts on the quality of surface water resources in northern and eastern New Zealand. Lower stream flows or lake levels would increase nutrient loading and lead to increased eutrophication.	Most sensitive during summer months and drier years.

* not linked to stormwater in the MfE tables

3. Location with respect to hazards. Is the activity in a location that could be affected by climate change such as coasts, bed-rock hill slopes or flood plains? Decisions on these activities should take the associated hazards of these locations into account.

4. Extent of activity. What are the wider implications of the decision? For stormwater management, decisions involving a single piece of drainage infrastructure or will generally have a lesser consequence than those affecting an entire network. The exception is where the decision sets a precedent for future applications.

5. Complexity. What is the nature of the decision? Is it affected by a single climate change parameter or an array of parameters with multiple effects over time? Complex decisions should be met at the policy level. The example is given of location a new suburb as opposed to a single house.

Practitioner interviews (summarised in Tool 2.4.2) showed that as a result of qualitative analysis, stormwater is considered a function that is sensitive to climate change by the local authorities.

Preliminary quantitative assessment

If the effect of climate change on a function or service is likely to require a response, a preliminary quantitative assessment should be carried out to determine whether a formal risk assessment is necessary.

Preliminary screening is essentially a climate sensitivity analysis. The focus is on the impacts of mid-range climate projections. Where the impact is significant, detailed assessment using a range of climate scenarios may be warranted. If the impact is not significant, the manual recommends that the impacts resulting from a higher-end climate change projection should also be examined. The assessment should also take into account socio-economic change (e.g., demographics, land-use change).

The method recommended for assessing functions or services affected by heavy rainfalls is based on an adjustment of extreme rainfalls on the basis of projected changes in mean annual temperature (Table 3.3). The extreme rainfalls are then used to force event based models of the function being assessed. Extreme rainfalls are defined according to their intensity-duration-frequency (IDF) such that the rainfall intensity of the extreme rainfall can be derived from IDF curves for a given and event duration and frequency expressed as either the Annual Recurrence Interval (ARI) or Annual Exceedance Probability (AEP). IDF curves give the distribution of extreme rainfalls over time. Following the MfE method, a 10-year ARI / 10% AEP rainfall with a 24-hour duration would have an increase in intensity of 6.3% for every 1ºC increase in annual temperature.

Table 3.3: Factors for use in deriving extreme rainfall information for preliminary assessments (Source: MfE, 2008 a)

Duration	Average Recurrence Interval (Years)						
	2	5	10	20	30	50	100
< 10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30 minutes	7.2	7.4	7.6	7.8	8.0	8.0	8.0
1 hour	6.7	7.1	7.4	7.7	8.0	8.0	8.0
2 hours	6.2	6.7	7.2	7.6	8.0	8.0	8.0
3 hours	5.9	6.5	7.0	7.5	8.0	8.0	8.0
6 hours	5.3	6.1	6.8	7.4	8.0	8.0	8.0
12 hours	4.8	5.8	6.5	7.3	8.0	8.0	8.0
24 hours	4.3	5.4	6.3	7.2	8.0	8.0	8.0
48 hours	3.8	5.0	6.1	7.1	7.8	8.0	8.0
72 hours	3.5	4.8	5.9	7.0	7.7	8.0	8.0

Note: This table recommends *percentage* adjustments to apply to extreme rainfall *per 1°C of warming*, for a range of average recurrence intervals (ARIs.). The percentage changes are mid-range estimates per 1°C and should only be used in a screening assessment. The entries in this table for a duration of 24 hours are based on results from a regional climate model driven for the A2 SRES emissions scenario. The entries for 10-minute duration are based on the theoretical increase in the amount of water held in the atmosphere for a 1°C increase in temperature (8%). Entries for other durations are based on logarithmic (in time) interpolation between the 10-minute and 24-hour rates.

If there are no IDF curves locally, they can be constructed from historical records or derived from the High Intensity Rainfall Design System (HIRDS) available online from NIWA (http://hirds.niwa.co.nz). The HIRDS application will automatically adjust rainfall intensity given a user defined temperature increase.

The IDF concept is very familiar to stormwater engineers and is used for event-based modelling to determining system capacity and flood risk assessments. It is central to design as can be seen in the incorporation of MfE guidance into design criteria discussed below. Tool 2.4.2 summarises a number of climate change impact assessments from the Auckland region which have been based on MfE adjusted extreme rainfalls. More information on the use of extreme rainfalls for system modelling in general can be found in Tool 2.4.1 along with a discussion of modelling issues such as choice, parameterisation and spatial representation. Tool 4.7 explores the implications of the MfE adjustments on the design of stormwater management devices.

Detailed risk assessment

Risk assessment is required if the preliminary quantitative assessment indicates that the climate change effects pose a significant risk to the function or service. The method follows the New Zealand Standard for Risk Management, AS/NZS4360, which recommends a scenario-based approach. There are three risk assessment methods which can be used: modelling using synthetic or climate change-adjusted historical climate data; expert opinion, which may be necessary if there is a lack of data or modelling capability; and monitoring (wait and see).

The modelling approach is of most interest to stormwater management – examples can be seen in Tools 2.4.2 and 2.4.4. The chosen model is calibrated to current climate and is then run using a range of scenarios covering the spectrum of climate change projections. The climate scenarios can be extreme rainfalls (event-based modelling – e.g., flood risk assessment), or long-term rainfall series (continuous modelling – e.g., network capacity assessment). The model can also be adjusted for changes in the system including changed land use or urban form, water demand, population increase. The steps are:

1. Run the model for different time-slices over the lifetime of the asset or service (e.g., 25, 50, 75, 100 years).

2. Use the model results to evaluate the risk or likelihood, the level of risk and the consequences. This step requires the risks associated with climate change to be compared to other risks both separately and together.

3. Assess responses based on risk within the context of statutory and other responsibilities, including responsibilities to consult and plan ahead.

4. Communication, consultation, monitoring and evaluation. Communicate and consult with stakeholders. Monitor climate change, associated risks and the effectiveness of responses over time. Review the risk in light of climate change projections to ensure that response remains relevant.

The modelling approach as set out in the first edition (MfE, 2004) was demonstrated by Shaw et al. (2005) for the Wairau Valley, North Shore City, and was used as an exemplar in the manual and is summarised in Tool 2.4.2. Modelling issues such as choice, parameterisation and spatial representation are overviewed in Tool 2.4.1.

3.2 Coastal Hazards and Climate Change guidance manual (MfE, 2008 c)

The *Coastal Hazards and Climate Change* guidance manual (MfE, 2008 c) is intended to aid coastal communities plan for the impacts of sea level rise and associated coastal hazards (tides, storm surge, waves, coastal erosion and coastal inundation). A summary document (*Preparing for Coastal Change*, MfE, 2009) has been prepared by MfE and is commonly referred to as the "blue-book". Both documents are available for download from the MfE Guidance on Climate Change website.

The potential impacts of sea level rise on urban areas is explored more fully in Bin 2.2, hence only a brief summary of the guidance material is provided here.

The coastal hazards guidance manual makes few references to stormwater management. The main issue discussed is inundation of coastal infrastructure with the note that the location of new constructions such as pump houses should take sea level rise into account. It is also noted that coastal pipe networks are at risk of back flow if outfalls become inundated or are subject to storm surge. Outfalls may experience increased levels of erosion. Finally, it is noted that coastal hazards, particularly high tides and storm surges, can exacerbate other climate change related impacts such as coastal flooding including urban flooding due to inadequate stormwater drainage capacity. Not mentioned in the material is that possibility that gravity systems with coastal outlets may have a reduced energy grade line (total hydraulic head) which could affect flow in pipes.

For planning and decision making, the manual recommends that:

For timeframes out to the 2090s (2090–2099):

a. *a base value sea-level rise of 0.5 m relative to the 1980–1999 average should be used, along with*

b. *an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980–1999 average.*

For timeframes beyond 2100 where, as a result of the particular decision, future adaptation options will be limited, an allowance for sea-level rise of 10 mm per year beyond 2100 is recommended (in addition to the above recommendation).

3.3 Tools for Estimating the Effects of Climate Change on Flood Flow guidance manual (MfE, 2010 a)

The *Tools for Estimating the Effects of Climate Change on Flood Flow* guidance manual (MfE, 2010 a) is intended to aid local authorities manage increased flood risk due to climate change. It provides guidance on how to incorporate the impacts of climate change into river flow estimation. A summary document (*Preparing for Future Flooding*, MfE, 2010 b) has been prepared by MfE and is commonly referred to as the "green-book". Both documents are available for download from the MfE Guidance on Climate Change website.

The potential impacts of river flooding on urban areas are explored more fully in Bin 2.1, hence only a brief summary of the guidance material is provided here.

The manual is primarily concerned with catchment-scale flood events and methods of assessing and managing flood risk. The potential impacts of projected increases the intensity and frequency of extreme rainfall events are addressed along with changes in seasonal rainfalls, snow coverage and melt. While the prospect of coastal inundation due to sea level rise is noted, readers are referred to the Coastal Hazards manual (MfE, 2008 c) for detailed guidance.

A distinction should be drawn here between catchment-scale flooding of river systems, including urban rivers, and localised flooding due to a failure of the stormwater system which is largely outside the manual's scope. Hence, while it is noted that in urban areas river flooding may be exacerbated by stormwater flows, there is little guidance specific to stormwater management. The general advice to engineers is ensure that infrastructure, including urban drainage, is either located outside flood prone areas, is designed to withstand flooding or is protected from flooding, preferably using soft engineering approaches.

The manual follows the risk assessment methodology given in the Climate Change Effects and Impacts Assessment guidance manual (MfE, 2008 a). Much of the guidance is on the choice and use of catchment models to estimate river flow volumes and depths and flood extent (i.e., level of inundation). As well as the adjustment to extreme rainfalls recommended by MfE (2008 a) for preliminary screening, the manual advocates continuous modelling for detailed analysis to capture the effect of antecedent catchment conditions. Methods of deriving synthetic daily rainfall series suitable for catchment modelling are discussed in the manual (Tool 2.4.1 gives an overview).

The models cited in the manual are not generally applicable to simulation of stormwater and the daily time-step advocated is to coarse for urban drainage models. However, the DHI Mike 11 and Mike 21 models are noted in the manual as hydrodynamic models that can be used to assess inundation in urban catchments. An example of their use is for the ARC Rapid Flood Hazard Mapping project (van Kalken, 2009; Roberts and van Kalken, 2010; see summary in Tool 2.4.2), albeit with simplifying assumptions for stormwater drainage.

The green-book summarises the modelling recommendations given in the manual and further provides general guidance on evaluating flood risk in the context of the social, cultural, economic and environmental consequences. There is also advice on how to manage flood risk including adaptation of existing infrastructure and flexible design of infrastructure in new developments. The possibility of increased need for future flood protection measures is also noted.

3.4 New Zealand Standard NZS4404: 2010 Land Development and Subdivision Infrastructure

NZS4404:2010 (Land Development and Subdivision Infrastructure) supersedes the earlier NZS440:2004 (Land Subdivision and Engineering) and provides a set of guidelines for the design and construction of various types of urban infrastructure including stormwater drainage systems. The new standard includes consideration of climate change in the design phase in response to the 2004 amendment of the RMA. Section 1.4 (Climate Change) states that climate change is likely to increase the magnitude of some hazards and therefore risk management should be incorporated into the design of infrastructure to maintain the level of service throughout the design life.

Stormwater drainage infrastructure is addressed in Section 4 of the standard. Road drainage is addressed in Section 3 with reference to Section 4. Section 4 states that all stormwater systems are to be designed with an asset life of at least 100 years which has obvious implications with respect to climate change. It is noted that some devices, such as raingardens, may need renovation or replacement to maintain system function into the future. Section 4.2.9 (Climate Change) states that design storms must be adjusted for climate change and that the performance of coastal stormwater systems should take into account the effects of down stream sea level rise. Section 4.3.5.1 (Design storms) reiterates that design storms must be adjusted for climate change. Design storms should be taken from local sources where available or derived from HIRDS. Section 4.3.5.3 (Tidal areas) states storm surge, tsunami, climate change and sea level rise need to be taken into account in system design. Further, Section 4.3.6 (Stormwater Pumping) states that sea level rise may necessitate pumping of low land gravity systems in the future and this should be taken into account. No guidance on how to make adjustments to design storms or which climate projection to use is given. Instead readers are referred to the MfE guidance material summarised above for further information.

The standard also places increased emphasis on sustainability in urban design including a commitment to LID (Sections 1.4 and 4.3.7) and recommends using stormwater management devices for stormwater drainage. However, the link between adoption of stormwater management devices and climate change adaptation is not made.

3.5 New Zealand Transport Agency Stormwater Treatment Standard (NZTA, 2010)

The New Zealand Transport Agency (NZTA) has recently published the Stormwater Treatment Standard for State Highway Infrastructure (NZTA, 2010). The standard is intended to assist roading engineers select and design stormwater drainage systems to control the volume and quality of road runoff. The standard cites TP10 (ARC, 2003) amongst other criteria from New Zealand and overseas to size and design stormwater infrastructure including a variety of LID devices.

Climate change is addressed in Chapter 6 (Stormwater Hydrologic Design Criteria Recommendations) of the standard. The guidance has been prepared with reference to the RMA 2004 amendment and reproduces the MfE extreme rainfall adjustment factors (MfE, 2008 a) stating that for device components with a design life of more than 25 years, the design storm should be adjusted to account for climate change. Design storms should be taken from local sources where available or from HIRDS. The standard recommends a temperature projection of 2.1ºC for Auckland – which is the 2090 mean annual average temperature increase cited by MfE (2008 a) for the region. Flood protection infrastructure should be designed for the 100-year ARI. Storm-peak discharge control infrastructure (e.g., erosion control) should be designed for medium storms (2- to 10-year ARI). Water quality infrastructure should be designed for the 90% AEP rainfall event, which equates to around 1/3 of the 2-year ARI design storm.

While the impact of sea level rise on coastal roads is noted, there are no recommendations for its inclusion in design.

3.6 Auckland Regional Council Guidance

Much of the technical guidance for stormwater management in the Auckland region has been prepared by the ARC. The documents most relevant to stormwater management are TP 108 (ARC, 1999 c) and TP 10 (ARC, 2003) which guide system design – both are currently being updated with new versions expected in 2011 or 2012.

TP 108 gives guidance on the calculation of surface runoff for use in engineering design. The document has two sections: the synthesis of design-storms; and runoff calculation methods. Maps showing isohyets for 24-hour design rainfall depths (2, 5, 10, 20, 50 and 100-year ARIs) across the region are provided in the appendices. The design rainfalls are disaggregated over the course of the event duration according to a modification of the Chicago hyetograph. The U.S. Department of Agriculture, Soil Conservation Service (1986) curve method to derive unit hydrographs is recommended for runoff calculation. TP 108 pre-dates the RMA 2004 amendment and consequently does not address climate change, however, it is understood that the updated document will make reference to the MfE (2008 a) adjustments of extreme rainfalls to account for climate change (B. Hellberg, project manager, personal communication, 2010).

TP 10 is the design manual for stormwater management devices and is widely used or cited around the country by other authorities. The design criteria make use of the design storms derived for TP 108. The criteria state that water treatment devices be sized to accommodate the volume of runoff generated by 1/3 of the 2-year 24-hour rainfall. Devices for peak runoff control are generally sized to store and release the runoff generated by the 2- and 10-year 24-hour rainfalls at the pre-development discharge rate. Where there is an existing flood risk downstream, the 100-year 24-hour design storm is also used. There is also a provision for extended detention for erosion control to detain the first 34.5 mm of rainfall which is independent of design storms. While TP 10 does not address climate change *per se*, the planned inclusion of climate change adjusted design storms in TP 108 will affect the sizing of stormwater management devices.

Tool 4.7 investigates the effects of design storm adjustments for climate change on the size of ponds and raingardens designed according to TP 10 criteria.

4. Concluding remarks

This tool has overviewed the regulatory framework and existing technical guidance material available for urban stormwater management in the Auckland region to help stormwater managers plan for adaptation.

Many of the planning documents in the Auckland region pre-date the RMA 2004 amendment which requires the impacts of climate change to be taken into account as part of resource management. Hence, there are relatively few mentions of climate change in relation to stormwater management. The newly amalgamated Auckland Council is preparing new plans which are likely to have provisions for climate change.

The technical guidance material can be split into two groups. In the first group are the documents prepared by MfE which have a strong emphasis on natural hazard risk identification and management including evaluation of adaptation strategies. These documents follow a risk assessment process to help plan for adaptation where needed to reduce the identified risks associated with climate change. While there is little specific mention of stormwater in the guidance, both the coastal hazards (MfE, 2008 c; 2009) and flooding (MfE, 2010 a and b) guidance manuals note that the way in which stormwater is managed could have an impact on the risks of natural hazards in urban areas and their receiving environments. For instance, failure of stormwater systems during peak flows could exacerbate the risks of river and coastal flooding. While the links are not explicitly addressed in the guidance, they are assumed to be part of the tacit knowledge of stormwater practitioners.

The second group of guidance documents consists of national and regional design criteria for drainage infrastructure including stormwater management devices. The main focus is on stormwater design for green and brown-fields developments rather than adaptation of existing systems. These documents incorporate the guidance from MfE into the design process, largely by adjusting design-storms for a mid-to-high range temperature projection according to the MfE method of adjusting extreme rainfalls. It should be noted that the MfE method was intended to provide input data for a preliminary analysis as part of a risk assessment rather than for design purposes. More sophisticated methods for accounting for climate change may supersede the current MfE guidance in the future, such as the use of a Regional Climate Model (see Tool 2.4.4).

5. References

ARC, Auckland Regional Council (1999 a) Auckland Regional Policy Statement.

ARC, Auckland Regional Council (1999 b) A Vision for Managing Growth in the Auckland Region, Auckland Regional Growth Strategy 2050, Auckland Regional Growth Forum, Auckland.

ARC, Auckland Regional Council (1999 c). Guidelines for stormwater runoff modelling in the Auckland Region. Auckland Regional Council Technical Publication No. 108. (ARC TP108). Auckland Regional Council.

ARC, Auckland Regional Council (2004 a) Auckland Regional Stormwater Project: An Action Plan To Deliver Improved Stormwater Outcomes. Prepared by the Boston Consulting Group for ARC.

ARC, Auckland Regional Council (2004 b) Auckland Regional Stormwater Action Plan: a co-ordinated approach to regional stormwater management and the delivery of improved stormwater quality outcomes.

ARC, Auckland Regional Council, ARC (2003) Stormwater management devices: design guidelines manual. Second Edition, TP 10

Auckland City Council (2009) Stormwater Asset Management Plan 2009. Prepared by Auckland City Council in association with Metrowater and Maunsell Limited.

Bennett, J. and Megaughin, M. (2008) Model Codes of Practice for Enhanced Stormwater Management and Improved Uptake of Low Impact Design. Prepared by URS for Auckland Regional Council. ARC TR2008-045

Kinley, P.; Sharman, B. and Davis, M. (2007) A pragmatic assessment of climate change impacts on drainage infrastructure and resulting management practices in Auckland City. 5th South Pacific Stormwater Conference

LTCCP (WCC, 2006-20016), vol 2, part 15: Waste Management, Stormwater, Wastewater, Water Supply, Support and Planning)

MfE, Ministry for the Environment (2004) Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand. Prepared by D. Wratt, B. Mullan and J. Salinger (NIWA), S. Allen and T. Morgan (MWH

New Zealand Ltd), and G. Kenny (Earthwise Consulting). Ministry for the Environment Report ME 513, Wellington. p153.

MfE, Ministry for the Environment (2007) Making Good Decisions – Climate Change Effects. Publication number: INFO 242

MfE, Ministry for the Environment (2008 a) Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand. 2nd Edition. Mullan B; Wratt D; Dean S; Hollis M; Allan S; Williams T, Kenny G and MfE. Ministry for the Environment, Wellington. p149

MfE, Ministry for the Environment (2008 b) Preparing for climate change: A guide for local government in New Zealand. Publication number: ME 891

MfE, Ministry for the Environment (2008 c) Coastal Hazards and Climate Change. A Guidance Manual for Local Government in New Zealand. 2nd edition. Revised by Ramsay, D, and Bell, R. (NIWA). Prepared for Ministry for the Environment. viii+127 p.

MfE, Ministry for the Environment (2009) Preparing for coastal change: A guide for local government in New Zealand. Publication number: ME 907

MfE, Ministry for the Environment (2010 a) Tools for estimating the effects of climate change on flood flow: A guidance manual for local government in New Zealand. Woods R, Mullan AB, Smart G, Rouse H, Hollis M, McKerchar A, Ibbitt R, Dean S, and Collins D (NIWA). Prepared for Ministry for the Environment. ME 1013 Wellington

MfE, Ministry for the Environment (2010 b) Preparing for future flooding: A guide for local government in New Zealand. Publication number: ME 1012

New Zealand Government Resource Management Act (1991) Public Act 1991 No 69, Date of assent 22 July 1991

New Zealand Government, Local Government (Auckland) Amendment Act (Earlier Vesting of Public Transport Service Assets and Liabilities) Order 2004 (SR 2004/400) (as at 19 November 2004)

New Zealand Government, Local Government Act 2002 No 84 (as at 27 November 2010), Public Act

New Zealand Government, Resource Management (Energy and Climate Change) Amendment Act 2004 No 2, Public Act 2004 No 2, Date of assent 1 March 2004

New Zealand Standards (2004) Land development and subdivision engineering, NZS 4404:2004

New Zealand Standards (2010) Land development and subdivision infrastructure. NZS 4404:2010

New Zealand Transport Agency, NZTA (2010) Stormwater Treatment Standard for State Highway Infrastructure.
(available for download from http://www.nzta.govt.nz/resources/stormwater-management/stormwater-management.html)

NSCC, North Shore City Council (2009) Stormwater Asset Management Plan. Prepared by Nina Sardareva – Asset Management Team Leader Water

Roberts, C. and van Kalken, T. (2010) Regional and local flood hazard mapping. Presentation to the Auckland Regional Council Stormwater Seminar, 21 July, 2010

Shaw, H.; Reisinger, A.; Larsen, H. and Stumbles C. (2005) Incorporating climate change into stormwater design – why and how? 4th South Pacific Stormwater Conference, Auckland, 2005.

U.S. Department of Agriculture, Soil Conservation Service (1986) Urban hydrology for small watersheds. Tech. Rep. 55, Engineering Division, Soil Conservation Service, US Department of Agriculture.

van Kalken, T.; Taylor, A.; Davis, M. and Hellberg, B. (2009) rapid two dimensional flood hazard mapping in the Auckland Region. *Water NZ South Pacific Stormwater Conference, 2009*