Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 1.6: Sensitivity Matrix Tool for Assessing Vulnerability of Urban Environments to Climate Change

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1. Introduction

This document gives details of one of a number of Tools developed to assist Councils, and others, in taking account of long-term climate change effects in their on-going management of the urban environment, with the aim of making the built environment more resilient to climate change effects.

The Tool described here [Tool 1.6] is included within a Toolbox Framework of various reference and guidance documents and software tools. These are designed to assist in assessing risks and development responses in a way that will reduce risks and lead to more resilient urban areas in the face of climate changes which include increasingly extreme weather events.

This and other documents within the Toolbox are specifically concerned with the risks that will arise from climate change effects and uncertainties, and not with the risks and uncertainties associated with the drivers of climate change.

The Sensitivity Matrix Tool described here [Tool 1.6] will assist councils to determine the priorities for their areas in facing climate change, and adapting to its consequences.

1.1 Background

The reality of climate change creates additional challenges for Councils and others charged with the responsibility of shaping and maintaining our urban areas. The effects of climate change will threaten existing infrastructure and buildings and create additional challenges in the decisions that have to be made in planning. These relate both to maintaining and/or retro-fitting existing urban areas, and in planning for future "greenfield" developments.

These challenges arise principally because of uncertainty in the following, both at a global and local scale:

a) The long-term trends (rates of change) in environmental stressors (either positive or negative);

b) The frequency and severity of climate extremes;

c) The impact that (a) and (b) above will have on the vulnerability and durability of urban infrastructure and buildings;

d) The medium- and longer-term socio-economic and behavioural responses to (a) to (c) above.

More particularly, the adverse effects of climate change can cause the following (other things being equal):

- A reduction in design life of public assets

- Increased chance of premature failure of assets
- Higher demands on resources
- Greater exposure to adverse effects and their consequences in both the public and private sector.

The Sensitivity Matrix Tool described here is used at the start of an overall process of decision-making. It aims to help local authorities understand the aspects of greatest vulnerability for their urban communities in a relatively straight-forward and rapid manner, and thus to identify priorities and target resources into adaptive responses.

1.2 Purpose of Tool

The Sensitivity Matrix Tool enables a council to understand and summarise their current understanding of the sensitivity[1] of a region's urban infrastructure and buildings to the full range of potential climate change effects. The Tool also allows the relevant issues to be scoped and investigated in a preliminary way, and provides a basis for identifying priorities for a particular area.

2. Overview of the Sensitivity Matrix Tool

The Sensitivity Matrix Tool involves both a matrix and a methodology for eventually populating the matrix. The basis of the Tool is that the community of people working in areas of the urban environment are knowledgeable about these areas, whether they specialise in single-purpose asset planning and management, or whether they are involved in integrated landuse or strategic planning. This knowledge can be shared and drawn together in a way that assists in prioritising actions for an urban (or other) community.

2.1 The Basic Matrix

A Sensitivity Matrix (see example in Figure 2.1) comprises a two-dimensional matrix (spreadsheet) with climate change effects listed down the left hand side, and urban infrastructure and buildings potentially vulnerable to these effects across the column headings.

Key sensitivities are noted in each cell of the matrix for each combination of climate change effect and infrastructure/buildings element. The climate change effect(s) that have the greatest impact, or multiple significant impacts, on urban infrastructure and buildings are then prioritised for assessment using other tools.

[1] The word *sensitivity* is used, recognising that priorities should be based on more than just the physical vulnerability of assets to climate change effects.

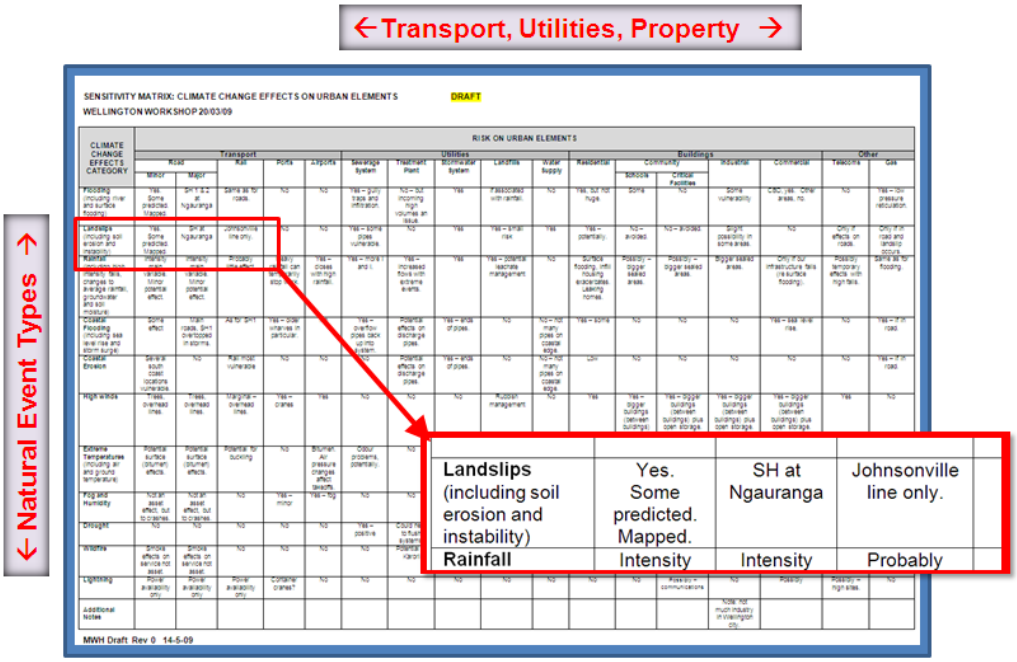

Figure 2.1: Illustrative Example of a Sensitivity Matrix

While the Sensitivity Matrix concept is simple, there are challenges to be met in generating a true picture of the importance of climate effects on urban components. Most particularly, the difficulty stems in assimilating what is likely to be a large amount of possibly highly speculative information, both written and perceived, about the possible impacts of climate change.

2.2 The Decision Conferencing Method

The most effective way of rapidly assimilating large amounts of conflicting and uncertain information, both written and perceived, is through the process of group discussion using a workshop approach. Formally known as 'decision conferencing', it relies on the ability of a group of people to sift through large amounts of information and reach conclusions as to which are the most important elements. Decision conferencing usually involves a face-to-face facilitated workshop process, bringing together key informants.

A decision conferencing workshop seeks to explore and, where possible, reach a consensus view about the importance of magnitude of some effect or topic which is not amenable to direct measurement (O'Hagan et al., 2006), as shown diagrammatically in Figure 2.2.

The effectiveness of a workshop is always greatly enhanced by good preparation and the selection of the right mix of participants. For this reason it is essential that the workshop has a clear agenda. This will include one or more sessions explaining and

discussing climate change risks generally, and then each of the elements in the matrix. From this basis, discussions can focus quickly on the salient matters. The method also rapidly exposes areas of high uncertainty that may warrant additional investigation before a reliable assessment can be formed.

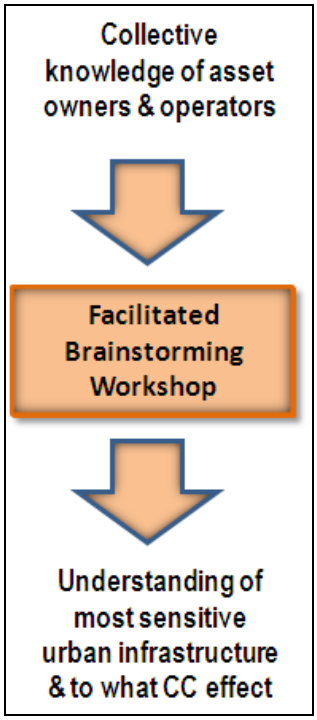

Figure 2.2: Schematic of Decision Conferencing Workshop Process

To be effective, a workshop should be well structured and facilitated by an individual with some knowledge of the topics being discussed, but not necessarily an expert in any one facet of the discussions. The facilitator's role is to provide structure to the discussion, ensure they are open, unbiased and non-confrontational. The facilitator should endeavour to allow for free and inclusive debate but direct the proceeding towards its intended outcome, avoiding lengthy discussion of extraneous information and topics, and keeping the group focussed on the task at hand.

2.3 Data Needs

Basic information is needed as to the elements of the urban area, and/or infrastructure and buildings which are being examined. For example, where is the infrastructure located; what is its capacity; what is the current policy framework relating to its expansion, maintenance and replacement? For urban areas more generally, where are they located; are they already vulnerable to weather events; what is the existing planning regime?

An understanding of the likely climate changes over the next 50 to 100 years is also necessary, drawing on existing guidance (e.g. see [Tool 1.2] or MfE, 2008a,b and MfE, 2010). This should be identified, as far as possible, in terms of the area of interest. In addition, it will be necessary to take into account non-climate related aspects such as topography, elevation in relation to sea level, vegetation cover, density or intensity of urban development.

While there may be numerous limitations in the data at the time of undertaking the sensitivity assessment, this is not a reason to delay or defer consideration and prioritisation. There will be future opportunities to revisit this stage, ideally approximately every five years or so, as part of overall long-term council community planning under the Local Government Act, and/or as part of reviews of resource management planning in terms of the Resource Management Act.

2.4 Tool Outputs

The output of the Sensitivity Matrix Tool is a completed matrix which captures the range of elements which make up the urban area (transport, utilities and buildings) and the range of climate change effects they are potentially exposed to.

Along with the matrix is a preliminary risk assessment (based on a red-yellow-green colour-based hierarchy to add clarity), and a set of notes that provide an estimate of extent and limitations – for example if only some areas are vulnerable to a type of effect, this should be noted.

The completed matrix should form a basic resource for other decisions, providing context and continuity across the multitude of council activities and responsibilities, and community interests.

2.5 Assumptions and Limitations

The use of the Tool will only be as good as the knowledge of those who are involved in developing the matrix. For that reason it is important that the decision conferencing workshop is inclusive. For example, it should include representatives of regional and district local government and representatives of different infrastructure components, as well as those responsible for planning the area's urban future. It should also involve people reasonably knowledgeable about climate change effects and how these may affect the area of interest.

In building up the matrix it is anticipated that the attendees will bring information about community views and broad planning and policy information. Legacy issues can also be important, for example, issues around closed landfills or remediated contaminated sites.

As Sensitivity Matrix development should be regularly repeated over time, lack of detailed information is not a critical issue. The first matrix can be improved upon at a future iteration.

3. Examples of Application of the Sensitivity Matrix Tool

This tool was used early in the overall Impacts of Climate Change on Urban Infrastructure and the Built Environment Project, working with people from the four geographic areas from which case study examples were expected to be drawn, to help identify suitable examples for further study.

The decision conferencing workshops were held between November 2008 and April 2009 with local government agencies in Christchurch, Wellington, Auckland and Westport. The areas were selected as being representative of a range of potential climate change issues in terms of built environments, but also were all areas with significant existing capability and interest in managing the effects of future changes in climate variables.

This section outlines the methodology and summarises the findings from this series of workshops. The four Sensitivity Matrices so derived are given in Appendix A.

3.1 Organisation and Conduct of Workshops

In advance of each workshop, background information was provided about their purpose, and the involvement and input of appropriate local authority representatives was sought. Representatives of the project research team also attended.

All workshops involved representatives of both territorial and regional councils in the area. Elected representatives were present at two of the workshops. Other agencies, including consultants and agencies with related statutory responsibilities, attended workshops on the invitation of the local authorities initially contacted.

Several of the local authorities involved had key staff allocated to a co-ordinating and facilitating climate change policy and practice role, and these people were particularly helpful in identifying who should attend the workshops and ensuring distribution of material.

While the scope of the workshops was broader than just developing a Sensitivity Matrix, workshop time was spent directly on discussion and populating the matrices of potential effects of climate change on the built environment.

The Sensitivity Matrix component proceeded along the lines of short presentations by key council representatives on their agency's approach to climate change with reference to the relevant policies and current priorities, followed by a more general discussion on the potential effects of climate change.

All councils involved in the workshops are engaged in climate change responses at policy and practice level. They use the currently available guidance material on climate change and seek more refined information on variability and improved decision tools. Most consider that their communities are not yet fully aware of climate change or are not convinced of climate change as an issue.

The Sensitivity Matrices developed at the workshops were intended to be very much a 'first cut' of potential issues, and a tool that would highlight possible case studies. There was no attempt to capture the extent or scale of risk elements or to define them geographically beyond a broad level or area of interest.

Basically, the process was to be a "brain dump" of knowledge that the councils have about their own community and private assets, and their potential vulnerability to different potential aspects of climate change. The timeframe applied was in relation to the "life" of urban assets – thus some assets would not be at risk now, but may be in 50 to 100 years.

3.2 Populating the Sensitivity Matrix

At each workshop, the items on the vertical (potential climate change effects) and horizontal (elements of the urban environment) axes were discussed, comments noted and subsequent changes made if needed. It was acknowledged that all items on the vertical axis were not mutually exclusive, but most were. Councils variously expanded the horizontal axis to include further elements of importance to their communities.

In practice, the collective knowledge enabled each matrix to be populated to a reasonable extent with the people involved, as can be seen in the completed matrices provided in Appendix A.

The following approach to the notes assembled from each workshop was applied in filling out the matrix for each area:

- Where there was expected to be a potential issue, its existence and any comments that the workshop wished to record was noted;
- Where there was expected not to be an issue, this was recorded as a "no", or "unlikely";

- Where the participants felt that there was insufficient information available to them, but nevertheless an effect was unlikely (as most councils had identified aspects of vulnerability through civil defence or lifeline-related responsibilities), a question-mark was used to indicate this.

As a second stage, the project team colour-coded the matrix as follows:

- red: high impacts possible;
- orange: medium impacts, localised impacts, or uncertain impacts possible
- green: no or low impacts most probable.

While a simplification, this method has the benefit of clearly highlighting the most obvious issues for each urban area, and assisting in identifying the most appropriate subjects for case studies that could be used from each area. The ensuing colour-coded matrix was checked back with the local authority involved after the workshop, for their agreement on the colours used for each component of the matrix.

3.3 Overall Findings from Application of Sensitivity Matrix

The four urban areas considered in the case studies yielded results which were quite varied. There were some similarities, but more marked differences.

It is also noted that participants were generally aware of the current expectations of physical effects of climate change for their urban areas under consideration and these were therefore built into their assessment of vulnerability. For example, Christchurch workshop participants acknowledged the likelihood of increasing drought in the future, but also the likelihood of increasing rainfall intensities in the catchments which serve the large Canterbury Rivers.

The scale of the urban areas considered varied greatly, and this was also reflected in the vulnerability. For example, flood risks facing communities in Auckland or Wellington urban areas would be experienced by only small parts of the overall community, whereas virtually the whole of the Westport urban area is potentially at risk from flooding.

Some general comments have been made below in relation to each of the four urban areas, reflecting the collective thoughts of participants at each of the council workshops:

a. Christchurch

Christchurch identified rainfall and flooding effects along with coastal flooding and erosion as issues of greatest concern. Impacts are expected upon major utilities and roading systems as well as some residential and some industrial areas. Potential effects of extreme temperatures and drought on the urban/built environment are recognised. The relatively recent addition of Banks Peninsula to Christchurch City has brought additional issues with uncertain implications.

b. Wellington

Wellington City and Greater Wellington Regional Council identified a greater range of vulnerabilities than other areas, largely due to its geographic diversity and the potential range of climate change effects. The area was seen as vulnerable to rainfall events, surface flooding, coastal flooding and some erosion, high winds and extreme temperatures.

c. Auckland

As a large and complex urban area, Auckland also identified a wide range of vulnerabilities although most were relatively localised in terms of the extent of potential effects. Flooding, landslips, coastal flooding and rainfall events were seen as having the greatest potential effects on parts or all of the urban area. However, all potential climate change elements were seen as having some impact on the urban fabric – either public or private – with transport and utility systems most vulnerable. Vulnerabilities were noted throughout all types of urban built development. Change in landuse and intensification of urban development in future are seen as having the potential to increase problems relating to stormwater and coastal management.

d. Westport

As a smaller urban area strongly influenced by a major river and in close proximity to the coast, rainfall changes and sea level rise were the biggest concerns, with potential for river flooding of residential areas and overloading of stormwater systems. Effects on main roads accessing the town were also noted, with river flooding, landslips, and coastal flooding all being relevant, along with potential effects of fog on the port and airport.

Overall, despite their simplicity, the Sensitivity Matrices were found to be useful in providing a collective and current informed view of the issues facing the different areas. They thus provide a basic indicator of likely vulnerabilities of urban infrastructure and buildings to climate change.

4. Conclusion

As a useful tool in climate change impacts investigations, the Sensitivity Matrix seeks to establish preliminary priorities for councils considering impacts of climate change on their urban infrastructure and built environment. For example, the Tool may be used to distinguish whether higher projected flood levels rather than increasing numbers of landslides are of greater concern for a particular asset or infrastructure type.

In reaching conclusions about these concerns, workshop participants take account of not just the physical effects, but also community views, legacy and planning issues, as well as the amenability of the issues to affordable and acceptable resolution. As a consequence, a populated Sensitivity Matrix provides useful ongoing guidance. The exercise of developing such a matrix should be repeated every five to 10 years for most urban environments.

Overall, the application of climate change related Sensitivity Matrices to urban areas identified by councils demonstrates an appropriate way of bringing together and analysing current information at an early stage and at a preliminary level, thus helping begin the process of assessing the vulnerability of infrastructure and buildings to climate change. The use of this Tool enables identification of priorities for further investigation and possible emphasis in future planning documents.

References

MfE, 2008a, Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand (2nd Edition), Ministry for the Environment, Wellington, May 2008.

MfE 2008b, Coastal Hazards and Climate Change – A Guidance Manual for Local Government in New Zealand, Ministry for the Environment, Wellington, July 2008.

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O'Hagan A, Buck C.E, Daneshkhah A, Eiser J.R, Garthwaite P.H, Jenkinson D.J, Oakley J.E and Rakow T, 2006, Uncertain Judgements - Eliciting Experts' Probabilities, John Wiley & Sons Ltd., London.

Appendix A

SENSITIVITY MATRIX: CLIMATE CHANGE EFFECTS ON URBAN ELEMENTS
CHRISTCHURCH WORKSHOP – 10/11/08

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS																
	Transport					Utilities					Buildings					Other	
	Road		Rail	Ports	Airports	Sewerage System	Treatment Plant	Stormwater System	Landfills	Water Supply	Residential	Community		Industrial	Commercial		
	Minor Roads	Major - State Highways & Arterials										Community Buildings	Critical Facilities				
Flooding (including river and surface flooding)	Yes. Several localities.	Yes. SH1 north – loss of lanes with old Waimakariri Bridge.	Rail bridges N and S.	No	No	Some areas affected	Unlikely	Some areas subject to ponding.	No – not sure about old landfills (location dependent).	No	Some areas exposed	Certain locations	?	Some – near estuary	No		
Landslips (including soil erosion and instability)	Some suburbs – Lyttelton, Port Hills, Sumner, and Banks Peninsula roads	SH75	No	No	No	Not expected unless roads affected	No	No	No	No	Some hill suburbs & in Banks Peninsula	?	?	Probably not	No		
Rainfall (including high intensity falls, surface flooding, changes to average rainfall, groundwater and soil moisture)	Yes – several suburbs	?	No	No	Only if major flood (500+ year event)	Infiltration and inflow in lower-lying areas	Some effects from greater inflow	Some areas subject to ponding.	Not sure about old landfills (closed)	No generally. Yes for Banks P.	Yes – some parts of city	?	?	Some localities only	Possibly in localised areas		
Coastal Flooding (including sea level rise and storm surge)	Some roads	Possibly access to Sumner, settlements to Banks Peninsula etc	No	Minor effects only	No	Possibly some localised areas	In the longer term (80-100 years) expected to be at high risk	At outfalls In 80-100 years, most outfalls at high risk	No	No	Christchurch has many low-lying areas and many settlements on Banks Peninsula are low-lying	Christchurch and Banks Peninsula have many coastal communities	?	Certain locations – eg, industries on riversides and near the coast	No		
Coastal Erosion	Few roads	No	No	No	No	Possibly but localised	Uncertain (new pipeline)	At outfalls	No	No	Some potential	?	?	Uncertain	No		
High winds	?	?	No	Safety at berths	Possibly	No	No	No	No	No	Not known	?	?	?	No		
Extreme Temperatures (including air and ground temperature)	No	No	Not expected	No	No	No	Uncertain	No	No	No	No – adequacy of cooling systems in summer uncertain.	?	?	?	No		
Fog and Humidity	No – driver safety	No – driver safety	No	No	No (assume adequate radar)	No	No	No	No	No	No	No	No	No	No		
Drought	No	No	No	No	No	Uncertain as water is needed to flush the pipes.	Uncertain – impact of any water restrictions on process	No	No	Concern about aquifer in prolonged drought, and generally over next 80-100 years	No	No	No	No	No		
Wildfire	No	No	No	No	No	No	No	No	No	No	Lifestyle areas only	No	No	No	No		
Lightning	No	No	No	No	?	No	No	No	No	No	No	No	No	No	No		

Note: Drought, wildfire and lightning may be serious issues in terms of urban communities on Banks Peninsula. Implications are yet to be assessed.

SENSITIVITY MATRIX: CLIMATE CHANGE EFFECTS ON URBAN ELEMENTS
WELLINGTON WORKSHOP – 20/03/09

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS																	
	Transport						Utilities						Buildings					Other	
	Road		Rail	Ports	Airports	Sewerage System	Treatment Plant	Stormwater System	Landfills	Bulk water supply	Water Supply	Residential	Community		Industrial	Commercial	Telecoms	Gas
	Minor Roads	Major - State Highways & Arterials											Schools	Critical Facilities				
Flooding (including river and surface flooding)	Yes. Some predicted. Mapped.	SH 1 & 2 at Ngauranga	Same as for roads.	No	No	Yes – gully traps and infiltration.	No – but incoming high volumes an issue.	Yes	If associated with rainfall.	Could be – pipelines across rivers.	No	Yes, but not huge.	Some	No	Some vulnerability	CBD, yes. Other areas, no.	No	Yes – low pressure reticulation.
Landslips (including soil erosion and instability)	Yes. Some predicted. Mapped.	SH at Ngauranga	Johnsonville line only.	No	No	Yes – some pipes vulnerable.	No	Yes	Yes – small risk	Some – not an issue.	Yes	Yes – potentially.	No – avoided.	No – avoided.	Slight possibility in some areas.	No	Only if effects on roads.	Only if in road and landslip occurs.
Rainfall (including high intensity falls, changes to average rainfall, groundwater and soil moisture)	Intensity main variable. Minor potential effect.	Intensity main variable. Minor potential effect.	Probably little effect.	Heavy rainfall can temporarily stop work.	Yes – closes with high rainfall.	Yes – more I and I.	Yes – increased flows with extreme events.	Yes	Yes – potential leachate mgmt	Yes – potential groundwater effects.	No	Surface flooding, infill housing exacerbates. Leaking homes.	Possibly – bigger sealed areas.	Possibly – bigger sealed areas.	Bigger sealed areas.	Only if our infrastructure fails (re surface flooding).	Possibly temporary effects with high falls.	Same as for flooding.
Coastal Flooding (including sea level rise and storm surge)	Some effect – south coast roads potentially high risk from sea level rise and storm surge	Main roads, SH1 overtopped in storms.	As for SH1	Yes – older wharves in particular.	No	Yes – overflow pipes back up into system.	Potential effects on discharge pipes.	Yes – ends of pipes.	No	No	No – not many pipes on coastal edge.	Yes – especially south coast suburbs including Kilbirnie subject to sea level rise and storm surge.	No	No	No	Yes – sea level rise.	No	Yes – if in road.
Coastal Erosion	Several south coast locations vulnerable.	No	Rail most vulnerable	No	No	No	Potential effects on discharge pipes.	Yes – ends of pipes.	No	Small effect possible.	No – not many pipes on coastal edge.		No	No	No	No	No	Yes – if in road.
High winds	Trees, overhead lines.	Trees, overhead lines.	Marginal – overhead lines.	Yes – cranes	Yes	No	No	No	Rubbish mgmt	Control systems	No	Yes	Yes – bigger buildings (between buildings) plus open storage.	Yes – bigger buildings (between buildings) plus open storage.	Yes – bigger buildings (between buildings) plus open storage.	Yes – bigger buildings (between buildings) plus open storage.	Yes	No
Extreme Temperatures (including air and ground temperature)	Potential surface (bitumen) effects.	Potential surface (bitumen) effects.	Potential for buckling	No	Bitumen. Air pressure changes affect takeoffs.	Odour problems, potentially.	No	No	Odour possible	Increased demand	No	No	No	No	No	No	Need to cool roadside cabinets.	No
Fog and Humidity	Not an asset effect, but possibly crashes.	Not an asset effect, but possibly crashes.	No	Yes – minor	Yes – fog	No	No	No	No	No	No	No	No	No	No	No	No	No
Drought	No	No	No	No	No	Yes – positive	Could need to flush systems.	No	No	Yes – increased supply needed.	No	No	No	No	No	No	No	No

WELLINGTON WORKSHOP CONTINUED – 20/03/09

Wildfire	Smoke effects on service not asset.	Smoke effects on service not asset.	No	No	No	No	Potential at Karori	No	No	Potential quality problems.	No	Yes – some areas	No	No	No	No	Some locations	No
Lightning	Power availability only	Power availability only	Power availability only	Container cranes?	No	No	No	No	No	Control systems	No	No	No	Possibly – communications	No	Possibly	Possibly – high sites.	No
Additional Notes															Note: not much industry in Wellington City.			

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS (ADDITIONAL)															
	Electricity	**Buses (electric)**														
Flooding (including river and surface flooding)	If underground	Yes														
Landslips (including soil erosion and instability)	Yes – in some areas	No														
Rainfall (including high intensity falls, changes to average rainfall, groundwater and soil moisture)	If underground	No														
Coastal Flooding (including sea level rise and storm surge)	No	No														
Coastal Erosion	No	No														
High winds	Yes	Yes														
Extreme Temperatures (including air and ground temperature)	Possibly	No														
Fog and Humidity	No	No														
Drought	Possibly – rain needed to keep lines clean.	No														
Wildfire	Possibly – some areas.	No														
Lightning	Possibly	Possibly														

SENSITIVITY MATRIX: CLIMATE CHANGE EFFECTS ON URBAN ELEMENTS

AUCKLAND WORKSHOP – 24/03/09

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS															
	Transport				Utilities					Buildings				Other		
	Road		Rail	Ports	Airport	Sewerage System	Treatment Plant	Stormwater System	Landfills	Water Supply (Bulk)	Residential	Community		Industrial	Commercial	Tele-communications	
	Minor Roads	Major - State Highways, Motorways, Major Arterials										Schools	Essential Services (eg, hospitals)				
Flooding (including river and surface flooding)	Yes. Vulnerable to local drainage inadequacies.	Parts of SH1, 16, 20 under water at times of surface flooding. (SH1 already affected at 1% flood)	Britomart Station potentially affected by less than 10 year event. Onehunga line on reclaimed land and subject to surface flooding.	Yes	Yes	Yes	Increased inflow and infiltration (ie, I&I), so potentially. Possible Mangere overflow (untreated?).	Yes. May cause erosion of pipes and other system components.	Several closed landfills (Oakley, Motions, Meola) next to streams New ones are more secure.	Pipe bridges vulnerable. Dam safety. Quality could be reduced, but possible to cope.	Yes. But info hard to get. Probably a small percentage in whole region, but a lot of people. Accesses also vulnerable.	As for residential. Some risk.	Potential	Yes. Some areas, eg, Wairau Valley, Onehunga. Typical problem.	Yes. Some areas, eg, Wairau Valley, Onehunga. Typical problem.	Yes. Road cabinets.	
Landslips (including soil erosion and instability)	Yes. Local roads in many places.	Not for motorway, but yes for some arterials.	No	No	No	Yes	No	Yes – can affect structures (and vice versa).	One closed (Newmarket) could be exacerbated	As with stormwater for pipe systems. Potential for total failure of eg, Hunua, Waitakere dams.	Some. As above.	Yes – some potential.	Yes – some potential.	Potential for some to be at risk.	Potential for some to be at risk.	?	?
Rainfall (including high intensity falls, surface flooding, changes to average rainfall, groundwater and soil moisture)	All minor roads vulnerable.	?	Britomart Station. Water can't get out.	Yes	Yes	Yes. More I&I leakage, pipeline collapse, some small pumps at risk. Potential public health issues.	Yes. Increased flow so more overflows.	Overland flow paths add to resilience, but some areas already at risk.	Infiltration issues, leachate.	Droughts, average changes a problem. Spillway performance – 100 year flood passage.	Surface flooding a patchy issue.	Some but less than residential.	Some potential but less than residential. Greater awareness	Same as for flooding. Possibly worse for some pockets in flood prone areas.	Same as for flooding. Possibly worse for some pockets in flood prone areas.	Yes, for above ground services.	
Coastal Flooding (including sea level rise and salt water intrusion effects, storm surge)	Yes, plus salt water intrusion effects on surfaces.	Parts of SH1, 16, 20, plus Tamaki Drive.	No. Britomart below sea level, but safe.	Onehunga Wharf potentially subject to 100 year event.	Yes	Yes. Sea level intrusion – pipeline delay plus odour. Pipe bridges more at risk. Hobson Tunnel may have odour problems. Possible pipeline corrosion (but short underground system).	Potentially	May cause erosion of systems.	Yes. Some closed landfills at coastal fringe (Meola, Motions).	No	Some areas at 1/100 surge.	Yes – some	Yes - some	Yes – some	Yes - some	Sea water intrusion	
Coastal Erosion	Minor but some potential cliff issues.	Potential SH16. Armoured but a bad storm event could affect it.	No, except possibly Onehunga Wharf.	No, except possibly Onehunga Wharf.	Possibly	Yes	No (Mangere balancing tank).	Yes – coastal and stream outfalls.	Yes. Some closed landfills at coastal fringe (Meola, Motions).	No – but system does cross bridges.	Some areas	Yes – some	Yes - some	Yes – some	Yes - some	?	

AUCKLAND WORKSHOP CONTINUED – 24/03/09

High winds	Yes. Exposed.	SH1 Harbour Bridge lanes close at 80km/hr. Expect more closures.	Only electrified services vulnerable.	Yes	Yes	No	No	Causes storm surge. Effects as above.	Blown rubbish at transfer stations.	No	Standard of construction - risk increased with high winds.	Adequate design standard	?	More so than other categories because of building size.	?	Yes	
Extreme Temps (including air and ground temperature)	Yes. Expect more maintenance needed.	Yes. Expect more maintenance needed.	Yes. Potential buckling.	No	No	No	System works better at slightly warmer levels (standard 16-18^{o})	Water quality effects. Higher temperatures, less movement can exacerbate poor quality. A treatment issue.	Could crack capping and lead to infiltration.	Algal blooms. Increased demands.	Increased energy demand. Some materials may not be robust with increased occurrence of high temperatures.	As for residential	As for residential	Potential	Potential	Yes. Cooling needed for cabinets.	
Fog and Humidity	Potential minor effects (affects drivers).	Potential minor effects (affects drivers).	?	?	No, because of adequate technology	No	No	No	No	No	No	No	No	?	?	Corrosion susceptibility	
Drought	No	No	No	No	No	Probably not. But clay shrinkage could break lines in some areas.	No (domestic water supply would be last to go).	No	Longer droughts could lead to more infiltration.	Yes. Vulnerable to 1/200 year drought.	Soils, gardens.	No	No	?	?	No	
Wildfire	No	No	?	No	No	No	No	No	No	Hunua dams Waitakeres?	Waitakeres	No	No	?	?	?	
Lightning	No	No	?	No	No, because of protection and warning systems	No	No	No	No	No	?	No	No	?	?	Yes, re overhead system.	
Additional Notes						Current pumps designed for 15-20 years. Pipes for 80 years plus.		Some areas already have inadequate soakage for current rainfall. Subject to specific on-site Council requirements.		Note: Onehunga has a local aquifer supply (possibility of salt water intrusion). The islands have their own tank supply.							

AUCKLAND WORKSHOP CONTINUED – 24/03/09

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS (ADDITIONAL)															
	Gas Supply	**Fuel Pipelines**	**Water Supply Reticulation**	**Electricity supply**												
Flooding (including river and surface flooding)	Potential	?	Pipe bridges - erosion	Yes. Some potential. Lines and substations												
Landslips (including soil erosion and instability)	Potential	Yes (not in Auckland city)	Some areas already susceptible	Possibly. Some poles/pylons.												
Rainfall (including high intensity falls, changes to average rainfall, groundwater and soil moisture)	Potential	?	No	Yes, for above ground services.												
Coastal Flooding (including sea level rise and storm surge)	Potential	?	No	Especially in CBD												
Coastal Erosion	Potential	No	No	No												
High winds	No	?	No	Yes												
Extreme Temperatures (including air and ground temperature)	?	?	Demand increase adds risk	Yes. Affect systems.												
Fog and Humidity	No	?	No	No												
Drought	No	?	Shrinkage of soils may lead to problems.	No												
Wildfire	No	?	No	?												
Lightning	No	?	No	Yes, re overhead system.												
Additional Notes	Underground supply. Vulnerabilities similar to water supply reticulation	Risk issues around current supply related to limits getting into port at present. Expect greater diversity of sources in future. Loss of power to pumps is a risk.		Note: external effects on hydro lakes. Waikato river temperature re Huntly discharge.												

SENSITIVITY MATRIX: CLIMATE CHANGE EFFECTS ON URBAN ELEMENTS
WESTPORT WORKSHOP – 2/04/09

CLIMATE CHANGE EFFECTS CATEGORY	RISK ON URBAN ELEMENTS																	
	Transport					Utilities						Buildings					Other	
	Road		Rail	Ports	Airport	Sewerage System	Treatment Plant	Stormwater System	Landfills	Water Supply		Residential	Community		Industrial	Commercial	Power supply	Tele-communications
	Minor Local Roads	Major - State Highways								Reticulated	Bulk		Support Services	Emergency Services				
Flooding (river flooding)	Yes – some areas (isolated).	50 year event on Buller will close SH connection, but not SH6 to Greymouth.	Yes	During a flood, boats can't get in. However, floods clear the bar, so are also beneficial.	No historic record of flooding of airport or access road.	Flooding potential	No	Yes	No	No	No	Yes	Potentially in future	Potentially in future	Potentially in future	Potentially in future	Slight risk to pylons	Underground lines
Landslips (including soil erosion and instability)	Not in Westport	Yes (arterial routes but not SHs)	Yes	No	No	No	No	No	No	Trunk main cross significant hillside	Yes because of river supply (quality, intake treatment and potential loss of supply)	No	No	No	No	No	Possibly regarding main supply	Remote lines (not in Westport)
Rainfall (including high intensity falls, surface flooding, changes to average rainfall, groundwater and soil moisture)	Yes. Adequacy of stormwater system (eg, event of 17/03/07).	Flooding only (safety of roads) – minor impact.	No – except where flooding and/or washouts.	No (but see drought below)	Yes – high intensity surface flooding	Yes	No – but may have to treat more wastewater (infiltration and inflow)	Yes	Yes	No	No	Yes	Yes - potentially	Yes - potentially	Yes - potentially	Yes - potentially	Substation possible flooding (river or heavy rainfall)	Yes, if surface flooding
Coastal Flooding (including sea level rise and storm surge)	No	Yes – coastal road north	No	Same as flooding	Only if a lot of change	No	No	No	No	No	No	Some potentially	No buildings likely to be affected	No buildings likely to be affected	No buildings likely to be affected	No buildings likely to be affected	No	No
Coastal Erosion	No – except Carters Beach. No houses affected.	Yes – coast road north. Minor effect.	No	No	Yes	No	No	No	No	No	No	No – but long-term potential issue	No	No	No	No	No	No
High winds	Yes (trees and debris)	Yes (trees and debris)	Trees on line	Yes	Yes	No	No	No	Blowing rubbish	No	No	Yes – but not high risk	?	?	?	?	Yes	Possibly
Extreme Temps (including air and ground temperature)	Minimal	Minimal	Yes – potential to buckle.	No	Possibility of icing, or tarmac heating at extremes	No	No	No	No	Possibly high demand but not thought to be an issue.	High demand periods plus evaporation rates	No	?	?	?	?	Snow/ice accretion possible effects (but not really known)	No
Fog and Humidity	No	No	No	Navigational safety	Yes	No	No	No	No	No	No	No	No	Air ambulance	No	No	No	No
Drought	No	No	No	Yes. Bar shoals and boats can't get in. Port can be closed at periods of low rainfall.	No	No	No	No	No	Yes	Fire fighting demand?	No	No	?	?	?	No	No

WESTPORT WORKSHOP CONTINUED – 2/04/09

Wildfire	No	Very low	No	No	Minimal	No	No	No	Yes	No	Plant small risk – quality issue	No	No	No	No	No	Possibly for remote mains	Possibly for remote mains
Lightning	No	Very low	No	No	No (unless power out – would affect communication)	No. Pump station risk if electricity supply affected.	No	No	No	No	Plant small risk – quality issue	No	No	If power supply affected.	No	No	Possibly for remote mains	Possibly for remote mains
Additional Notes	River flooding is main issue. Landslips contribute to bed load. More floods equal more sediment movement. This could affect the bar and bed level of river. Sea level rise would have a big effect on sediment transport to sea and subsequent flooding potential which could exacerbate other effects.												Note: small community, so buildings tend to be mixed in with other buildings. Undulating topography means complex potential effects.					