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CLIMATE CHANGE ADAPTATION

Guidance on adapting New Zealand's built environment
for the impacts of climate change

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Preface

This guidance manual is intended to provide information on the impacts of climate change on the built environment, and provide introductory building-related adaptation advice for two key urban stakeholders:

- Central, regional and local government agencies (policy/advocacy focus)
- The building and construction industry (building focus)

It is not intended to provide a detailed analysis of policy options, or a 'step-by-step' builder's guide for specific building types.

Acknowledgments

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EXECUTIVE SUMMARY

This guidance manual provides information on the adaptation of the New Zealand built environment to the impacts of climate change. It is designed to help government agencies and the building and construction industry to first understand the key impacts that climate change will have on the built environment, and second, to begin planning and implementing integrated adaptation strategies to future-proof New Zealand's built assets and protect the communities of which they are a part.

Recently promulgated ice-core data from Antarctica going back 800,000 years, indicates that the atmospheric concentration of carbon dioxide has never previously exceeded the pre-industrial age concentration of 270 parts per million (ppm). In the industrial age, mankind learned to harness the power of fossil fuels to increase productivity and quality of life. Simultaneously (it has been argued), the decline of mankind's ability (at least in lands where Europeans migrated to, including New Zealand) to construct buildings appropriately for the local climate began: a legacy this country continues to live with today.

Currently, the concentration of carbon dioxide has risen close to 380 ppm, which is approximately 5% above 1990 levels. Scientific evidence indicates that even if global emissions of greenhouse gases were to be kept constant at 1990 levels, atmospheric concentrations would still continue to rise – meaning that temperatures would continue to increase for several decades, with sea-level rises predicted to continue for several centuries – due the lag in the climate system.

Other evidence firmly indicates the physical reality of climate change. Climate records show that the global mean surface average temperature has increased by close to 1°C in the past century. Projections from scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) include a further increase in globally averaged surface temperature of 1.4°C to 5.8°C between 1990 and 2100 (NZCCO, 2004a)[1]. This rate of warming is probably without precedent during at least the past 10,000 years.

Although New Zealand's temperature change range will be moderated by the effect of the seas surrounding it, there is no room for complacency with a built environment predicted to be impacted by an increased frequency and intensity of overheating, flooding and tropical cyclone events. While there is not conclusive evidence for the flooding events of 2004 in the North Island to be a direct consequence of climate change[2], the scale of devastation caused by the flooding should serve as wake-up call for government that hitherto reliance on historical data to predict the return of major weather events should now be discarded and replaced by adaptive action plans that target future-proofing of our built assets.

In the context described, mitigation of emissions and measures to stabilise atmospheric concentrations of greenhouse gases to prevent dangerous human interference to the climate system[3] is only part of the answer. Adaptation to a warming climate is also vital – and the sooner adaptive measures are taken, the better prepared the population (and the built environment) will be to any number of more dramatic weather events and worsening climatic trends.

Why adapt the built environment? It would be fair to say that in general, buildings have not been considered at the forefront of the debate on climate change assessment and decision-making. Houses especially play a fundamental role in our lives – 'every man's home is his castle' is an oft-heard

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[1] Some experts argue that the upper end of this range could be higher, as a result of 'abrupt' climate change – e.g. the relatively sudden breakdown of the Ocean Conveyor and the release of trapped methane, a greenhouse gas with 20 times the global warming potential of carbon dioxide, from permafrost and other sources.

[2] Other macro scale phenomena such as el Niño and sunspot cycles can also upset normal weather patterns.

[3] The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 with its ultimate aim being "*stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*".

expression – but any strong connection to the environment impacts beyond the home is rarely made. This disconnection is still apparent: buildings are, and continue to be, great consumers of resources and generators of waste. And crucially, the fact that people spend 95% of their time in, or moving around, the built environment as a whole, would suggest that buildings are indeed a key part of this debate.

Taking adaptive measures now against climate change is therefore essential. It is neither prudent nor desirable, and indeed economically unwise in many cases (for individual properties), to wait until problems caused by climate change occur before taking remedial action. In a nation where the average life of a house is about 80 years (some houses will last 150 years or more) it is a fact that most of the houses standing now – and not forgetting those currently being built – will be around until 2070 and beyond.

In other words, if buildings are not built or retrofitted now to deal with both the present *and* future climate, an unsustainable situation will get progressively worse and present formidable problems for both this generation and the next.

The New Zealand Government and building and construction industry have a range of roles and responsibilities in relation to managing climate change impacts. Government and industry should be giving serious thought to developing and implementing integrated adaptation strategies that complement existing mitigation initiatives. Of particular importance are the impacts associated with building overheating, flooding (both coastal and inland) and tropical cyclones.

This guidance manual is a companion document to the following New Zealand Climate Change Office of the Ministry for the Environment's publications (downloadable from www.climatechange.govt.nz/resources/local-govt/guidance.html):

- Climate Change Effects and Impacts Assessment (May 04)
- Coastal Hazards and Climate Change (May 04)
- Local Communities: Planning for Climate Change (May 04)

It also builds on a number of BRANZ publications, in particular (downloadable from www.branz.co.nz/branzltd/publications/pdfs/sr107.pdf):

- Implications of climate change for the construction sector: adaptation and mitigation strategies and revised CCSI[4] (Camilleri 2001)

Readers are advised to study these documents in conjunction with this manual.

Guidance Manual Contents

Section One of this manual provides generic information about New Zealand's built environment, the climate change impacts likely to affect it, the concept of adaptation (and its relationship with mitigation) and provides reasons for taking action now. It also includes information about making adaptation work, such as linking adaptation with other agendas for change and taking into account regional climate variations.

Section Two provides specific adaptation strategies for the built environment in response to the predicted impacts of climate change. This information is organised into three parts: Part A is targeted toward government agencies (central, regional and local authorities as major property and infrastructure owners and managers of the built environment); Part B is targeted at the building and

[4] The CCSI (Climate Change Sustainability Index) assesses the vulnerability of houses or office buildings to key climate change impacts. This index is discussed in Section 2.4

construction industry (as the designers, developers, builders and renovators of the built environment); Part C provides international and national case studies of building-related adaptation initiatives.

Section Three provides the report's conclusions and recommendations for future work.

The Appendix guides interested readers to additional reference sources and practical guidance relating to climate and/or sustainable building(s).

1. CLIMATE CHANGE AND THE BUILT ENVIRONMENT

1.1 New Zealand's built environment sector

New Zealand's built environment sector is wide ranging and includes a variety of government agencies, building and construction-related industries, organisations and institutions. The built element of the sector comprises both residential (houses, apartments, flats, terraced housing) and non-residential assets (industrial, commercial, service provision, e.g., hotels, hospitals, schools, churches, etc). Two of the more significant types of buildings are residential houses (around 1.4 million units) and office buildings (around 67,000 units). The capital value of the built environment stock accounts for approximately 9.5% of New Zealand's GDP (Page, 2002).

The built environment and all it contains is integral to our survival on the planet: it accommodates and sustains individuals and families, economic activities, education and health services, and is a repository of the nation's cultural heritage. All of this is potentially under threat from the direct and indirect impacts of climate change.

1.2 Climate change impacts on the built environment

The direct impacts of climate change include those that precipitate physical building or infrastructure failures that would not otherwise have occurred, and indirect impacts including changes to society, behaviour and institutions as a result of efforts to future-proof various elements of the built environment. The direct and indirect impacts of climate change on the built environment are summarised in the following tables (see Tables 1 and 2).

Table 1: Summary of main direct climate change impacts[5] on buildings

Summer overheating of buildings may lead to increased thermal discomfort and heat stress for home occupants and office workers, as well as increased mould growth and the potential for other health problems. *Fact: the average predicted temperature change for New Zealand is +0.3°C to +0.9°C (by 2030) and +0.6°C to +2.7°C (by 2070)*
Flooding of poorly sited buildings in residential, commercial or industrial zones in flood-prone areas will be more common under climate change. Flooding leads to damage of building contents, possible contamination from sewage, and structural collapse. Some buildings could become uninsurable if they are in flood-prone areas. *Fact: by 2030, the chance of flooding may increase twofold; by 2070, the chance of flooding is predicted to be four times more probable than currently estimated.*
Increased rates of coastal erosion, due to sea-level rise and storm surges, can have catastrophic consequences for buildings in vulnerable locations. *Fact: projected sea-level rises for New Zealand are 4cm -24 cm (by 2030) and 10 cm-60cm (by 2070)*
Subsidence is expected to increase in buildings, due to higher temperatures, lower summer rainfall, increased evapo-transpiration, and changes to water-table levels. *Fact: seasonal changes in the pattern of soil wetting/drying means a re-evaluation of ground subsidence risk, especially for building foundations on clay soils*
Increased driving rain and severe winds will affect building facades and internal structures and

5 Impacts adapted from "Briefing note: climate change impacts on buildings", available for downloading from www.ukcip.org.uk . 'Facts' adapted from Camilleri (2000a) and Wratt (2002).

lead to more rain penetration around openings. *Fact: it is uncertain whether the incidence of storms and tropical cyclones will increase with climate change (possibly +10-20%).*
More intense rainfall events could lead to drainage systems (including roof drainage, sewer systems, carriageway drainage etc) being unable to cope. *Fact: by 2030, heavy rainfall events could increase twofold; by 2070, heavy rainfall events are predicted to be four times more likely.*
Climate change is expected to reduce summer rainfall, so that pressures on urban water resources are likely to increase. *Fact: projected intensification of westerly winds across New Zealand is expected to result in rainfall increases in western regions and decreases for Gisborne, Hawkes Bay, Wairarapa, Marlborough and Canterbury regions.*

Of these impacts, research by Camilleri (2000a) has identified three key direct risks for New Zealand's built environment: **coastal and inland flooding, building overheating and tropical cyclones.** An indicative cost-benefit analysis for adapting houses has been undertaken in Section 2.5 which examines payback (issues) for building owners when they are faced with the question of whether or not to adapt their house or not to predicted climate impacts.

- **Coastal and inland flooding**

Most of the impact due to flooding will be damage to energy/telecommunications infrastructure, goods and chattels, internal features (e.g., underfloor/wall insulation), internal plasterwork and refurbishments. Additionally, some properties may experience sewage intrusion (from sewer 'back up'), corrosiveness of sea water (e.g. masonry damage) and run-off from agricultural land (e.g. fertilisers and soil minerals). Properties in flood-prone coastal or inland regions may also be subject to complete obliteration from a combination of storms and tidal surges enhanced by rising sea-levels.

- **Building overheating**

High temperatures inside houses and offices will affect the comfort of occupants, especially those groups deemed to be vulnerable to extremes in temperature (the elderly, infirm and young children) especially when daytime work performance or night-time sleeping is affected. When high temperatures are coupled with high humidity (predicted for cities such as Auckland), the likelihood of mould proliferation, strongly linked to health problems, is also increased (Sanders and Phillipson, 2003). Positive impacts include higher night-time winter temperatures and decreased winter energy consumption.

- **Tropical cyclones (extreme winds and driving rain)**

The action of wind on buildings causes dynamic structural loading by pressure forces. Structural failure can range from removal of individual tiles or iron sheeting through to uplifting of entire roofs or walls. High wind speeds also have implications for the wind environment surrounding buildings, such as comfort and/or safety issues for pedestrians (Sanders and Phillipson, 2003).

When a building is exposed to frequent driving rain, weathering generally occurs which can lead to higher maintenance requirements to ensure weathertightness over a building's lifetime. More effective water management systems may have to be adapted for roofs, guttering and drainage to cope with predicted greater volumes of water to ensure damage to the building fabric is minimised.

Table 2: Summary of main indirect climate change impacts on buildings

Changes to building standards, codes and regulations which positively act to transform the industry from the worst potential primary impacts of climate change. *Fact: the Building Act (1991) has been repealed; the new Building Act (2004) contains significant changes to the way buildings are designed and constructed.*
Alterations to the fabric of soft systems in the built environment – social, behavioural and institutional. *Fact: systems of education and regulation, and the structures of contractual and professional relationships are often durable and long-lasting.*
Pressure brought upon 'weather event' insurance schemes and disaster relief. *Fact: insurance firms are already denying coverage or significantly increasing premiums for areas prone to natural disasters.*
Increasing salination of water supplies due to non-sustainable water abstraction and aquifer depletion. *Fact: saltwater intrusion is expected to be greatest in alluvial plains subject to drought (the eastern coasts) where there will be increasing demand on aquifers for urban or industrial water supply, or for irrigation.*
The effect of post-Kyoto policies or strategies which mitigate future climate change. *Fact: the New Zealand Government has ratified the Kyoto Protocol and has in place a policy package (DPMC, 2002) for dealing with climate change mitigation and adaptation.*
Migration of undesirable fauna and flora into regions where they have not previously been established, including species which may threaten building infrastructure (reducing lifespan of buildings) or precursor industries (notably forestry). *Fact: species such as termites, which may thrive in warmer climates, have already been detected in southern parts of England. Their impact on industry or building stock in the UK (or of such species in New Zealand) is as yet uncertain. Locally, Forest Research is undertaking modelling experiments which examine how a species' behaviour will alter should the local climatic conditions alter[6].*

Of the indirect impacts, the amendment of building-related legislation (passed 12 August 2004) is significant in that the changes are aimed at improving the standard of housing in New Zealand and specifically include clauses referring to 'sustainability' for the first time[7]. These amendments, as well as allowing for the construction of a higher standard of commercial and domestic dwelling (in terms of higher insulation, etc), should aid climate-proofing of buildings in the long-term.

It should be noted that the anticipated impacts, whether direct or indirect, are not always negative. Whether they are positive or negative depends on idiosyncrasies peculiar to geographic location and local climates, and the individual and societal capacity to take necessary adaptive measures. Determining what adaptation strategy or response is employed will therefore vary across regional and local government agencies; likewise across all elements of the building and construction industry.

It should also be noted that dealing with climate change impacts does not automatically mean that a totally new approach to risk/hazard management is required. Much of government or

6 Pers comm., Geoff Ridley, Forest Research, February 2004.

7 New sustainability principles are included for: whole-of-life building costs, energy (efficiency, conservation and renewable sources), building materials, water (efficiency and conservation), and waste.

industry policies or activities already provide for existing climate conditions, and all that is required under climate change is to ensure that the figures used are relevant to the climate that is predicted at the end of the lifetime of the built asset. In other words, adaptation measures simply involve ensuring that the agreed level of protection is achieved for the future climate, and not re-inventing the wheel for sustainable urban management.

1.3 What is meant by 'adaptation'?

Adaptation to climate is not new: humankind has adapted to its climate for thousands of years. Adaptation means making:

> '*adjustments in natural or human (built) systems that take into account altering climate conditions, to lessen potential damages, or to benefit from opportunities associated with climate change*'[8].

Adaptation can thus be justified as a way of reducing the negative impacts of climate change and of taking advantage of the opportunities (particularly business opportunities) created by it.

Adaptation can take a variety of forms. Broadly speaking, it can involve a set of proactive and planned measures consciously undertaken to meet anticipated climate changes, and it can involve unplanned adjustments in response to climate changes that have not been consciously designed for (Lisø et al, 2003).

1.4 Why adapt now?

Land-use planning and building decisions that are taken today usually have long-term horizons due to the permanency of dwellings and infrastructure (e.g., roads, network utilities): as a result, climate-change effects will eventually have major implications for those decisions. It is vital that planning for climate change impacts begins immediately, particularly where decisions are being made on issues that have planning horizons of 50 years or more.

Urgency aside, actual awareness of climate change issues is relatively high and increasing among sector stakeholders, meaning that the political feasibility (and chances of success/acceptance) of starting now is good. For example, awareness at central government level is reasonably high as it is an issue that closely relates to four priority areas (energy, sustainable cities, water quality/allocation, and child/youth development) in the government's Sustainable Development Programme of Action (DPMC, 2003). As part of this programme, infusion of 'sustainability thinking' across government departments by the Department of the Prime Minister and Cabinet is strengthening that awareness. At local government level, awareness of climate change issues is also increasing based on the amount of advice now being provided by the New Zealand Climate Change Office (NZCCO) to officials (NZCCO, 2004a, 2004b, 2004c).

Knowledge of climate change issues has in the past been low in the building and construction industry (Saville-Smith, 2000) though this knowledge is steadily increasing[9]. Although not specifically addressing climate change, the recently amended Building Act will serve to increase awareness. The implications of these amendments for both new building and building retrofitting (for the latter, adaptation will be a more important consideration than mitigation) will become manifest when the New Zealand Building Code (NZBC) is upgraded in 2005[10].

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[8] Definition based on that of McCarthy et al. (2001).

[9] Pers comm., Kevin Golding, Manager (Future), Winstone Wallboards Ltd, August 2004.

[10] The revised code will, crucially, include a definition of 'sustainable development'. In theory, climate change could be given explicit recognition in the definition process.

Public perception is also being affected by events such as the summer heatwaves experienced in Canterbury during January 2004, and the financially devastating and unseasonable storms experienced in the lower North Island during February and in the Bay of Plenty in July of 2004.

With awareness growing and climate change impacts perceivably increasing, both government and industry are advised to start planning integrated adaptation strategies for their relevant stakeholders. As mentioned, development of these strategies is not necessarily a new process requiring additional resources: adaptation thinking can be 'added into' existing planning, forecasting and business development processes for implementation now (just as other external drivers affecting a business, e.g., regulatory or fiscal changes, require an adjustment in forward planning) (see also Section 2.2.4).

1.5 Making adaptation work

Strategies for adaptation, whether current or future, do not (and should not) act in isolation. Government agencies and sector groups within the building and construction industry need to be aware that there are a number of contextual factors that need to be taken into account when planning any adaptation initiative. These factors include:

how adaptation links with other agendas for change
the synergies between adaptation and mitigation strategies
regional climate variations.

1.5.1 Linking adaptation with other agendas for change

Any adaptation measures taken should be designed to support economic and social objectives in addition to being compatible with long-term environmental objectives. Adaptation strategies will be enhanced by the removal of inconsistencies between planning and regulatory mechanisms. For instance, uptake of adaptation measures will be assisted by reform of the NZBC (to include the recently passed sustainability provisions) and by amendments to planning procedures which ensure buildings are built in, or re-located to non-sensitive areas (e.g. with regard to flooding or extreme climate variability).

Although adaptation responses by themselves are important, any adaptation measures taken by the industry will require almost simultaneous changes in other aspects of the industry. Most obviously are the impacts of far-reaching measures needed to constrain carbon dioxide emissions (O'Connell, 2003; also see section 1.5.2) and measures to control other environmental impacts (e.g. measures to reduce urban sprawl, transport dependency and waste disposal) also require consideration.

Perhaps the 'easiest' way for adaptation to be accommodated in policy formation and implemented practically is to link it with responses to mitigate adverse impacts.

1.5.2 Adaptation vs. mitigation

Programmes to reduce greenhouse gas emissions (mitigation) are well underway, both nationally and internationally. Adding adaptation requirements to this agenda is the next logical step. The IPCC's most recent Assessment Report states:

> '*Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts…together they can contribute to sustainable development objectives*' (IPCC, 2001)

Indeed, it can be argued that two must be linked because despite efforts to stabilise greenhouse gas concentrations in the atmosphere at a relatively low level[11], climate change will not be altogether prevented, nor will the impact of climate change phenomena be altogether prevented (NZCCO, 2004a).

Controlling carbon emissions is only one side of the climate change equation. New Zealand is a small emitter of GHG (in terms of total emissions per country) in comparison to the larger industrialised nations and will be able to do little in its own right to halt global emissions. Therefore the focus and efforts in this country are increasingly likely to focus on adaptation, while maximising synergies with mitigation strategies (refer to discussion below).

The relationship between mitigation and adaptation can be further described as follows: while the physical exposure component of vulnerability can be targeted through greenhouse gas mitigation strategies, vulnerability is likely to persist (for many buildings, and at-risk building occupants), if not increase, with climate change. Adaptation measures target society's sensitivity and coping capacity and if correctly adopted will effectively reduce vulnerability as a result of climate change (Lowe, 2001a) (see Figure 1).

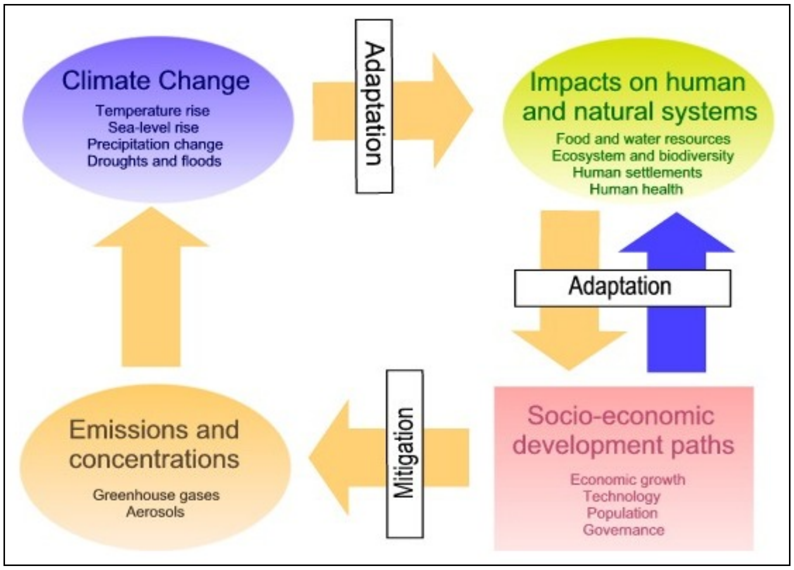

Figure 1: Climate change – an integrated framework

Lowe (2001b) also argues that effective mitigation/adaptation programmes can exist, demonstrated by the synergism that exists between mitigation and reduction of building emissions. Lowe (2001a) further states that for any given adaptation measure, the interactions with mitigation may be positive (synergistic), negative, or neutral (see Figure 2).
Examples of interactions in each quadrant include:

Box A: Conflict

- regulatory ban on air-conditioning

Box B: Positive Synergy

[11] Lowe (2000, in O'Connell 2003) argues that atmospheric stabilisation of carbon dioxide at 450ppm is the minimum (and internationally, politically acceptable) stabilisation level achievable with existing technology.

- improved thermal insulation
- thermal mass construction
- ‘living’ roof structures
- advanced glazing systems
- energy efficient appliances
- passive heating and cooling systems.

Box C: Negative Synergy

- adoption of inappropriate construction standards
- retention of minimum insulation standards
- ‘business as usual’.

Box D: Conflict

- increased use of air-conditioning.

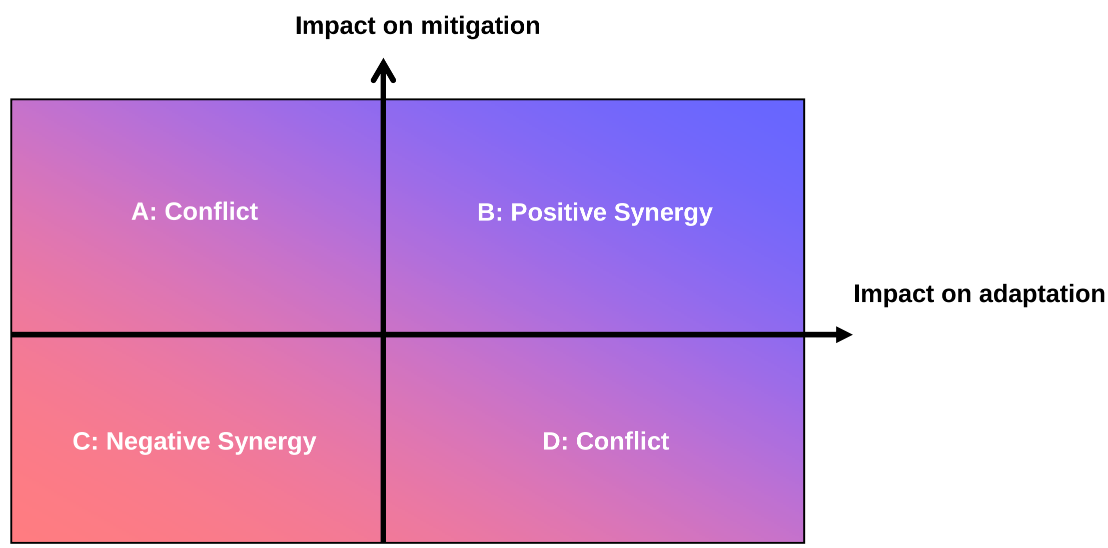

Figure 2: Classifying interactions between climate change mitigation and adaptation strategies

A positively synergistic response is clearly the ideal situation and as a result, the adaptation potential of any mitigation approach should be strongly emphasised. For example, specifying a zero or low-energy house which has also been designed for optimum solar access, has been flood-proofed, sited away from a floodplain and is strengthened for high (tropical cyclone) winds is a robust response. However, many buildings will not, in likelihood, need such rigorous adaptation.

Remember that strategies taken early in the planning or building cycle, i.e. at building planning and design stage, will better future-proof the building and be more effective in the longer term. The capital cost of taking integrated measures may (or may not) be slightly higher initially but will be much lower than having to retrofit, or deal with the consequences of an unprepared building, at a later stage (Larsson 2003, Graves and Phillipson, in Lowe, 2001b).

1.5.3 Design for regional climate variations

One barrier that is commonly cited in developing and implementing adaptation strategies are the uncertainties that still exist in climate change projections at the regional level. Auckland's climate is predicted to become hotter and more humid while in Christchurch the climate is predicted to become hotter and drier (Camilleri, 2000a). Adaptive responses are therefore going to be different across the country to cope with the needs of various regions and communities. Although there is no 'one size fits all', it is not a case of starting from scratch; core adaptation strategies can be adjusted to take regional variations into account.

Advances in predicting regional and local climate variations are underway and readers are referred to NIWA for the most up to date information: www.niwa.co.nz/ Detailed information on regional climate differences and regional projections for future climate change can also be found in the document 'Climate Change Effects and Impacts Assessment: a guidance manual for local government in New Zealand' available from the New Zealand Climate Change Office (www.climatechange.govt.nz/resources/local-govt/effects-impacts-may04/index.html) (NZCCO, 2004a).

A number of design guides for 'eco', 'green' or 'sustainable' buildings have been produced (see Appendix 1); it would be desirable that these type of publications increasingly reflect the local climate variations in New Zealand and in future begin to include climate impact relevant guidance and information (refer to Section 2.2.4 for further discussion).

2. ADAPTATION STRATEGIES

How can the built environment be adapted? This section identifies mainstream adaptation strategies for New Zealand's built environment. It is broken up into three parts: Part A provides strategies for government agencies, focusing more on policy advice and advocacy methods for affecting change (macro level adaptation techniques). Part B provides strategies for the building and construction industry and is focused mainly on the adaptation of buildings (micro level adaptation techniques). Part C provides case studies of adaptation initiatives (both macro and micro levels) from around the world.

Note: the separation of Parts A and B provides a somewhat artificial distinction: government agencies will also be interested in the adaptation of individual buildings (especially from an asset manager perspective), and the building and construction industry will be interested in employing policies to affect change. Readers are advised to study the parts relevant to them.

PART A: GOVERNMENT

Central, regional and local government are key stakeholders in managing climate change impacts because:

- they are obliged to inform and involve the public, small-medium enterprises, and large industry, e.g. education campaigns
- they have a responsibility to achieve future targets and outcomes from the 2002 climate change policy package (DPMC, 2002)
- they are extensive property/asset owners, users and managers in the built environment (e.g. government offices, hospitals, educational institutions, in addition to the bulk of roading, rail lines, airports, sea ports etc).

2.1 Action to date

As part of its portfolio of climate change work, the New Zealand Climate Change Office (NZCCO) has begun a programme to assist regional councils and territorial authorities to better understand and take into account climate change impacts when carrying out their day-to-day operations. This has been designed to provide underpinning information for the climate change public awareness programme '4 Million Careful Owners' (refer to www.4million.org.nz) and to respond to expectations that central government will provide guidance to councils on climate change effects under the provisions of the RMA (Energy and Climate Change) Amendment Act which came into effect in March 2004.

Also, the 'Communities for Climate Protection' initiative released in July 2004 by the government (and delivered by the International Council for Local Environmental Initiatives – ICLEI – refer to http://www3.iclei.org/ccp-NZ) is part of programme to help councils reduce greenhouse gas emissions at community level. Included in the initiative are milestones for developing and implementing a 'local action plan', a plan which can plausibly include a strong adaptive component and include practical design and construction guidance (see Section 2.2.4).

Most regional councils appear to provide information about climate related risks for their region. A handful of councils have also prepared climate change case studies[12]. Although they contain no specific reference to impacts on buildings and discussion of adaptation is absent, councils are examining the type of impacts which will undoubtedly have future impacts on buildings (e.g. sea-level rise, precipitation changes and coastal hazards).

Christchurch City Council has assessed the impacts of climate change for its city (Ridgen, 2002). No direct assessment is made for buildings; however, there is a discussion of 'urban impacts' with reference to impacts to dwellings and infrastructure from flooding. The council also has a policy 'to avoid higher intensity forms of built development in areas that could be subject to anticipated sea-level rise'.

2.2 Adaptation strategies for Government

Adaptation policy development and advocacy is still relatively in its infancy in New Zealand. There has been significant attention paid to built environment adaptation at the international level in at least Norway (Lisø et al, 2003); the UK (Lowe 2001a, 2001b, 2003; Sanders and Phillipson, 2003); Japan (Shimoda, 2003) and Canada (Larsson, 2003). As a result there is a range of adaptation strategies emerging that could be considered by the government and potentially accommodated into New Zealand climate change policy. These measures are categorised as:

- the identification, evaluation and removal of barriers to adaptation
- assessment of the adaptation requirements of the built environment
- improved research to assist in developmental work
- mechanisms to deliver adaptation strategies.

2.2.1 Identifying, evaluating and removing barriers

The barriers that adaptation strategies face have been identified as follows (adapted from barriers to mitigation strategies identified by O'Connell, 2003):

- consumer attitude and lifestyle choice

[12] Refer to www.climatechange.govt.nz/resources/local-govt/guidance.html for details.

- lack of awareness about climate change and the associated risks and opportunities
- lack of technical or management expertise to exploit internal efficiencies or new revenue opportunities
- financial constraints, especially in small businesses, which prevent making proposed changes or investments
- lack of awareness of, or unwillingness to embrace proposed or future changes to regulatory framework, particularly codes and standards
- the lack of 'green' builders and low awareness of sustainable construction methods (as a subset of this, where 'green' construction is occurring in New Zealand, adaptation of the building(s) to climate is not explicit in the design brief, etc)
- climate resilient features are not currently recognised/valued for onward sale of buildings
- insurance declined for vulnerable properties because of building's age or specific geographic location
- time constraints or competing priorities for management attention, especially in small or medium enterprises (SMEs)
- unreliable or unsympathetic building managers and landlords not wishing to invest in properties, e.g. if property is over a certain age
- silo thinking and lack of integration by specialists – lack of an integrated design process which involves all stakeholders (particularly for new dwellings)
- vested interests in retaining status quo by industry and lobby groups.

Although identifying barriers is relatively easy, it is evaluating and removing them that is more complex. Key questions for government agencies include how to manage the perception of risk, how to effectively communicate climate change information (cross-sector and within government), and how to raise public awareness. These are issues that are still to be adequately resolved.

Within government, the profile of climate change, given its international importance and recognition as a key driver for sustainable development, should be strengthened even further nationally by being 'piggy-backed' on the sustainability 'infusion' theme of the government's Sustainable Development Programme of Action (see Section 1.4).

Presently (and on-going), sustainability 'thinking' is being infused across government departments; and principles are being incorporated into the budgeting process for all new bids – recognition of climate change issues is also a vital aspect of this process. Another important avenue for promulgating the intent to take climate change seriously is through its incorporation in urban environmental (built environment) policy (see Section 2.2.4).

Raising public awareness is a huge, but not impossible, task. Survey data indicates nearly 60% of the population 'know a lot or a fair amount' about climate change; and 40% think it will pose a significant threat in their lifetime[13]. What is needed is to alter an apparent 'out of sight out of mind' way of thinking to 'this could affect me sooner than I think' way of thinking.

Ultimately, an integrated awareness-raising effort with other initiatives tackling other environmental issues would be appropriate so people can start 'making the connections' between issues such as the link between disposal of solid (building) waste and greenhouse gas emissions from landfills (PCE 2004). For example, the WasteMINZ initiative 'Lifeafterwaste'

[13] Pers comm., Justine Daw, NZCCO, January 2004.

(www.wasteminz.org.nz/lifeafterwaste/index.htm), which is aimed at achieving a resource efficient and sustainable society, could work closely with upcoming climate change awareness programmes.

2.2.2 Assessment of adaptation requirements

When determining the adaptation requirements of the built environment as a whole, it is important to remember that the built environment is characterised by subsystems with widely different characteristic timescales. Subsystems, such as building service systems, and the building and construction industry itself, can and do have the ability to change dramatically over periods of just a few years, a timescale significantly shorter than the rate of most aspects of climate change (Lowe, 2003). In rough descending order, the built environment aspects of greatest longevity are:

- settlement patterns – i.e. communities, villages, towns and cities
- soft systems – e.g. systems of education and regulation, the structures of contractual and professional relationships
- transport infrastructure
- building envelopes
- energy systems
- water supply and treatment systems.

As a result, not all climate impacts are equally important or urgent for different subsections – some may be major, some negligible. Some major impacts may justify immediate action, e.g. flooding or coastal inundation, justifiable by the very long timescales associated with human settlements (Lowe, 2003). Therefore, different levels of government (central, regional and local) will need to react in different ways to the impacts of climate change depending on which elements of the built environment are in their jurisdiction and what other issues must be integrated into the broader strategy. (See the Climate Change Office's guidance for local government (refer to Chapter 7 in: NZCCO, 2004a) for information on the integration of climate change risk assessment into council decisions.)

A useful action would be therefore, to undertake a rigorous stocktake of the built environment under the respective government agency's jurisdiction. Roles and responsibilities can then be assigned. Again, risk must be determined, prioritised and managed (see the Climate Change Office's guidance for local government (refer to Chapter 6 in: NZCCO, 2004a) for information on risk assessment).

Once this is ascertained, different adaptation measures can be considered. The Government of Canada lists five basic categories of adaptation response:

- prevent the loss – adopt measures to reduce vulnerability to climate change
- tolerate the loss – do nothing to reduce vulnerability and absorb losses
- spread or share the loss – do not reduce vulnerability, but rather spread the burden of losses across different systems or populations
- change the activity – stop activities that are not sustainable under the changed climate, and substitute with other activities
- change the location – move the activity or system[14].

[14] adaptation.nrcan.gc.ca/overview_e.asp accessed 30/7/04

It is important for the New Zealand government to have the information it needs to know when each option is the most desirable, both now and over time. Each council and territorial authority will have the bulk of the responsibility for supplying this information within an acceptable timeframe so that an adaptation response can be undertaken in earnest.

2.2.3 Improved research

From the previous subsections it is clear that a critical response for government is to undertake or commission further 'adaptation research'. This could be achieved by linking into the project instigated by Landcare Research on Low Impact Urban Design and Development (LIUDD – www.landcareresearch.co.nz/about/tamaki/liudd.asp) and 'mainstream sustainable housing' project established by Beacon Pathway (see www.beaconpathway.co.nz or www.nowhome.co.nz). There are opportunities emerging in the latter project, particularly in its 'Retrofit' objective[15].

The International Global Change Institute (IGCI) based at Waikato University has a programme[16] focusing on a 'vulnerability and adaptation' approach to assessment and research. This approach is characterised by a: focus on risks arising from climatic extremes; examining regions and communities where decisions concerning risk reduction are often made; and incorporation of resource managers, decision-makers and planners (the research stakeholders) into the research process.

The IGCI is working with Environment Bay of Plenty and some district councils in case studies aimed at better understanding behavioural and organisational responses to the risks of climate variability and change, including barriers to effective response and how to overcome them. This will facilitate the "mainstreaming" of climate issues into policy and planning processes and for promoting adaptation measures at the level of local authorities (also see Section 2.2.4).

Good risk management processes need to be implemented and roles and responsibilities clearly defined. Other key topics include:

- the role of technology and innovation in adaptation
- economic impacts of various adaptation choices
- adaptation decision-making tools
- how to encourage proactive action
- how to support effective adaptation at local and central levels.

These and other issues were the subject of a workshop on adaptation practices held on 11-13 October 2004 in Wellington, New Zealand[17].

2.2.4 Mechanisms to deliver adaptation strategies

A useful mechanism for delivering adaptation strategies is to link with current planning processes and initiatives (both public and private) to provide a basis for climate change decision making. These include, but are not limited to:

- **Development and implementation of built environment policy**: The Ministry for the Environment is currently undertaking an Urban Affairs work programme that could be integrated with climate change adaptation – for example, the Urban Design Protocol (as part

15 Beacon's goal is to establish a 'sustainability standard' for New Zealand houses such that 90%+ of housing stock (new and retrofit) meet a (to-be-defined) 'standard' by 2012 (timed to be the end of the First Commitment Period of the Kyoto Protocol).

16 The CLIMPACTS programme (a five year programme running to ca. 2007) - refer to www.waikato.ac.nz/igci

17 Refer to: www.climatechange.govt.nz/about/international-workshop/index.html for more details.

of the Sustainable Cities work theme of the SDPoA – refer to www.mfe.govt.nz/issues/urban/work-programme/protocol.html). There is ample scope for reference to (and action plans, etc for) design and future-proofing of buildings and infrastructure for climatic changes. For example, the UDP makes strong reference to 'Forward Planning'; and within discuses 'proactive guidance to encourage appropriate future urban development'. This guidance should explicitly include adaptation of built form to climate change. There should be a coordination process developed in which all TLAs in climatically similar regions produce consistent information.

In addition, there are any number of territorial authorities producing built environment or building information/guidance in their city or district plans which could specifically include (or be extended to include) information regarding design for climate change in their regions. For example, both Christchurch and Waitakere City Councils produce sustainable building guides (see Appendix 1).

- **Mainstream sustainable building practice**: 'Sustainable' buildings have up until recently been regarded as a luxury but recent reports have indicated that they can blend relatively easily into mainstream construction practices (Matthiessen and Morris, 2004, Kats et al, 2003). Practical examples of adaptation, linked to sustainable construction practices, are a way of assisting in its broader uptake.

  Although the recent construction of showcase (mainly commercial or educational) sustainable buildings throughout New Zealand (such as the Christchurch South Library and Landcare Research's Tamaki campus) are welcome in this regard, future construction needs to signal adaptive solutions to climate change as a core driver for the project.

- **Hazard and risk management**: The insurance industry can demand that a higher standard of building is required to withstand such events otherwise substandard properties will not be insured. Local government can inform the public (through resource and building consent processes) about hazard zones and the adaptation of buildings.

- **Home adaptation and maintenance programmes**: 'Cleaner home' schemes (such as promoted by Environment Canterbury) may widen the appeal of home adaptation. Further strategies involve educating building owners about the importance of maintenance. The risk of damage from extreme climatic events is reduced if essential maintenance is performed regularly and defects or potential problems are recognised and addressed rapidly. Some landlords (such as Housing New Zealand Corporation) and multiple building owners/managers have a great influence in this regard by carrying out planned maintenance of their stock.

- **Role of media**: Linked to education, initiatives such as the NZCCO's '4 Million Careful Owners' campaign[18] referred to in Section 2.1 could be expanded to or adapted for other media, most importantly television. Different age demographics appear to relate to or identify with their peer media 'icons' or 'stars' in order to receive the latest information on the latest products, trends, ideas, etc. This avenue to awareness-raising should be more closely investigated. WasteMINZ is proposing such an approach though its Lifeafterwaste initiative[19]. For example, catchy mnemonics such as the 'Fix, Fasten and Forget' campaign, used to raise awareness of earthquake risk, could readily be extended to an equally 'catchy' campaign for home adaptation.

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[18] The second phase of this campaign (began mid-2004) involves engaging key stakeholders to increase their awareness of climate change issues and build foundations for long-term behaviour change. The emphasis will be on voluntary actions and practical measures to reduce GHG emissions.

[19] Pers comm., Brian Richards, Brand Strategist for Lifeafterwaste, September 2004.

Importantly too, use of culturally-sensitive information to reflect New Zealand's growing number of communities, languages, values, etc will need to be considered in awareness-raising campaigns.

The information provided here highlights some of the issues that the Government needs to be aware of in developing adaptation strategies for New Zealand's built environment. The development and implementation of any strategy will involve the active involvement of all spheres of government, the private sector and the community. As indicated above, determining the most effective approach will depend on further research.

PART B: BUILDING AND CONSTRUCTION INDUSTRY

The building and construction industry also has wide-ranging roles and responsibilities in adapting the built environment as it includes a range of professionals responsible for:

- the design and planning of the built environment and buildings
- the extraction of raw resources, processing and manufacturing of building components
- on-site building construction
- building management, and occupant productivity and well-being
- appropriate end-of-life disposal and/or re-use of buildings.

2.3 Action to date

The only building specific work on adaptation has been prepared by BRANZ during a long-term research project examining the implications of climate change for the construction sector. This body of work represents the earliest efforts in this country to provide adaptation-related guidance for the building and construction industry. The reports can be downloaded free of charge from the BRANZ website:

www.branz.co.nz/branzltd/publications/pdfs/sr94.pdf (Camilleri, 2000a)
www.branz.co.nz/branzltd/publications/pdfs/sr96.pdf (Camilleri and Jaques, 2001)
www.branz.co.nz/branzltd/publications/pdfs/sr107.pdf (Camilleri, 2001)

To provide a brief overview, Camilleri (2000a) and Camilleri and Jaques (2001) identified the many ways that the built environment may be affected by climate change: the most important of these impacts were found to be increased inland and coastal flooding, overheating, and tropical cyclones. Additionally the Climate Change Sustainability Index (CCSI) was developed (Camilleri, 2000b; Camilleri and Jaques, 2001) to assess the vulnerability of houses or office buildings to these impacts.

Camilleri (2001) presents adaptation and mitigation strategies for houses and offices buildings to minimise the adverse impacts of climate change. It also includes methods for assessing whether adaptation is necessary proffers possible adaptation strategies The CCSI was also developed to include adaptation and mitigation strategies.

2.4 Adaptation strategies for the building and construction industry

Adaptation strategies for the building and construction industry are largely concerned with the adaptation of the built stock; namely buildings. An adapted building is a structure that can cope with many different future climate scenarios and applies to both new and existing buildings. Adaptation strategies for buildings involve two key steps:

1. Assess building vulnerability

2. Employ building adaptation techniques.

2.4.1 Assessing building vulnerability

As mentioned, three key climate change issues are predicted to have widespread impact on houses and office buildings: overheating, flooding (coastal and inland) and tropical cyclones. The Climate Change Sustainability Index (CCSI), developed by Camilleri (2000a, 2001) is an assessment of how vulnerable a building in New Zealand is to the impacts of these three issues[20].

The CCSI is a numerical rating which assesses each specific impact on a scale from -2 to +5; a score of ‘0’ being the reference level for normal building performance. Any rating less than -2 receives an ‘X’ rating which means the building being assessed is at extreme risk.

The first stage in the assessment is straightforward: what age is the building? Adaptation to the direct impacts of climate change is only needed for buildings that will still be standing and have a useful economic life concurrent with climate change impacts[21]. Johnstone (1995) has analysed housing mortality to derive estimates of the likelihood of houses surviving until 2030 and 2070, at which time the climate is likely to be significantly different from current norms. The decision criteria, derived from this analysis, are that on a nationwide basis:

- houses built before the 1920s in general do not need to be adapted
- houses built in the 1920s to 1940s should be adapted for the climate change impacts predicted for 2030
- houses built in the 1950s and later should be adapted for the more extreme climate change impacts predicted for 2070.

For it to be worthwhile to adapt an existing house now against overheating, flooding or tropical cyclones:

- the house should have a good chance of surviving until the ‘impact’ occurs
- the impact should be severe enough and thereafter persistent to justify the adaptation cost
- the house should have a worthwhile economic life for its occupants afterwards.

The demarcation between the ranges listed above is arbitrary and was applied so as not to leave any more than ca. 50,000 houses from any decade exposed to climate change risk (Camilleri, 2001). Based on the supposition that houses last up to 150 years from the date of construction, the economic life of houses surviving (from the nation’s existing housing stock) until 2030 ranges from 10 years for the oldest houses to 110 years for 1990s houses (Camilleri, 2001).

Houses being built now should also be built to withstand the predicted climate change impacts for 2070 though, as is discussed elsewhere in this report, (see Sections 2.2.4 and PART C) this is not explicitly occurring in New Zealand.

It is more cost effective to do this now than to wait another 20 years (see Section 2.5 for an indicative cost benefit analysis). Although it is building and context specific, it is generally more costly and difficult to retrofit as a building ages, and therefore becomes less cost effective as the building nears the end of its life. The longer it is left the costlier it becomes to retrofit. Then, if

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20 The CCSI does not at this stage include issues incorporated in international methods, e.g. an assessment of embodied energy from construction GHG emissions.

21 Unless the building has a high personal value or intrinsic value (e.g. historic buildings).

the building is ‘retired’ earlier than it could have been, costs are also borne through the loss of income/utility and in the requirement of a new building to be built earlier, etc. In other words, being reactive rather than proactive incurs expenses rather than deferring them.

The second stage involves an assessment using the overheating component of the CCSI. Prevention of overheating is recommended for houses with a CCSI rating of 0 or less. Houses with a –2 rating have an urgent need for adaptation, as they probably suffer from severe overheating already.

For office buildings, if the CCSI is 1 or less, then the building is likely to suffer from significant overheating at times during summer, and some modification is recommended to improve the current overheating performance. Lower ratings indicate worse overheating, and independent assessment for the particular building is advised.

The third stage rates the flooding vulnerability. Inland and coastal flooding are assessed separately, and then combined to give an overall flooding rating for the building. If the house scores a rating of less than 0, then some adaptation is strongly recommended. If the house scores a 0 rating, then some adaptation is recommended. If the house scores a rating from 1 to 5, then adaptation is not necessary to maintain flooding risks below the currently acceptable level, though adaptation could provide greater protection.

In terms of offices, the assessment for offices is virtually identical to that for domestic properties except that common features (e.g. floors and/or vital equipment below ground level) attract an additional negative modifier (Camilleri, 2001).

The fourth and final stage assesses vulnerability to tropical cyclones. The assessment is done by giving a credit for a defined geographic region (Camilleri 2001). For example, Northland receives a -2 rating as it is normally first landfall for any approaching tropical storm; similarly, Southland receives a +5 rating due to its relative remoteness from tropical storm influence. As there is little certainty about the likelihood of increased extra-tropical cyclones, it is not recommended that houses in general be adapted for the possible increased risk at this stage.

With reference to the devastation caused by Cyclone Bola in 1988 (and the prediction for greater occurrence of such magnitude storms), it would be prudent, in any case, to ensure that the structural strength of the house is comparable to best-practice standards especially for buildings located from Bay of Plenty northwards (refer to Section 2.5 for cost benefit analysis on this aspect). If the CCSI assessment for inland or coastal flooding in these regions is ≤ 0, then it is recommended that measures are taken to reduce the risk or damage potential.

A summary of assessing vulnerability using the CCSI is shown in Figure 3.

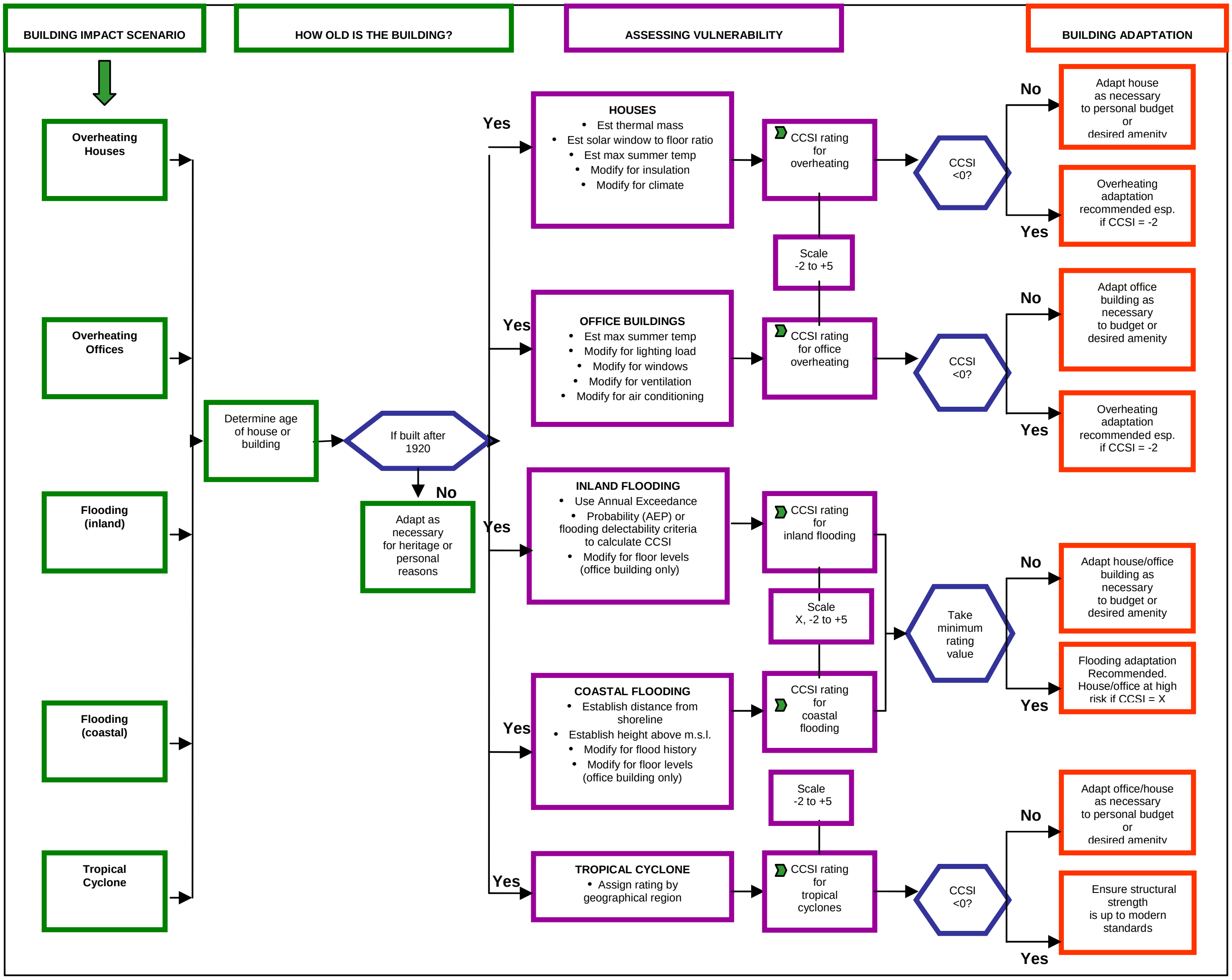


Figure 3: Summary of Climate Change Sustainability Index (CCSI) assessment

2.4.2 Building adaptation techniques

Once an assessment of vulnerability has been made, various techniques can be employed to adapt a building to the specified impact. Again, emphasis is on the three risk issues for New Zealand: overheating, flooding and tropical cyclones.

- **Overheating**

There are significant opportunities for improving the design of new buildings so that they can cope more effectively with very hot weather. This includes the use of methods to control solar gain, provide adequate ventilation, and provide thermal mass. These features are otherwise known as ‘passive solar design’. Other features can be added, such as renewable energy sources to power cooling systems, photovoltaic cladding, heat exchangers, and chillers connected to combined heat and power systems, etc. The focus of this section is on the basics of passive solar design.

For detailed information refer to the Australian Greenhouse Office Technical Manual ‘Your Home’ available at www.yourhome.gov.au under ‘Passive Design’.

Improving the solar performance of buildings is easier and less expensive if designed for at the start. For existing houses it is generally more difficult and expensive to adapt, though opportunities arise during substantial renovations. During renovations, all but the addition of thermal mass can be done readily, but careful design and planning should allow such adaptation techniques to be incorporated in new and existing houses at minimal cost.

Reduce solar gain

Reducing solar gain is a very effective method of minimising building overheating. It can be achieved by the following measures, in order of most to least effective:

- reduce window sizes
- shading by eaves or overhangs
- shading by trees, shrubs or screens
- reflective glazing
- internal reflective blinds
- double-glazing.

For north facing windows external shading is very effective if properly designed to cut out the summer sun, but allow penetration of winter sun. Based on information provided by the Cement and Concrete Association (NZCCA 2001), correct sizing of northern-facing eaves/overhangs to avoid overheating during summertime ensures that mid-day summer sun is prevented from reaching the interior. This can be done using the following simple equation, for three main centres in New Zealand. Using Figure 4, determine h, distance between the window sill and the underside of the eave. Movable or retractable awnings could also be given consideration as they provide flexibility for counteracting both periodic cool ambient summer conditions and internal overheating in the winter.

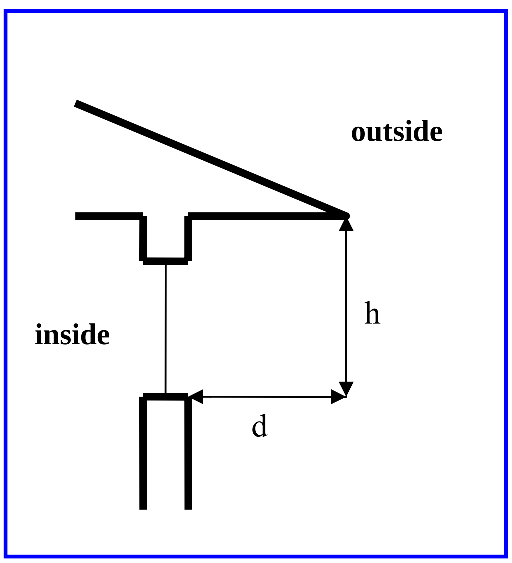


Figure 4: Sizing eaves to protect summertime overheating

The required depth of the eave is approximately **d** = **h** x **L.**
The corresponding **L** value can be determined for regional location from Table 3.

Table 3: 'L Values' for the sizing of eaves

Location	**L** value
Auckland	0.24
Wellington	0.32
Christchurch	0.35

Windows that go to floor level, such as ranch sliders or French doors, can be more problematic, but there are advanced glazing solutions available that deal with large window areas (see www.glasstech.co.nz for more information). West and east facing windows can be difficult to shade properly, as awnings or eaves are less effective for low summer sun. Side screens are better options, as are deciduous trees and shrubs. It is more important to shade west windows against afternoon sun, than east windows against morning sun.

It is important to remember that reducing overheating by reducing summer solar gain can result in an increase in space heating needs if winter solar gain is also decreased. Therefore particular attention needs to be paid to ensuring that measures to address solar design excludes summer sun, but admits winter sun, to optimise both comfort and energy use throughout the year.
Ventilate

Overheating can be reduced by increasing the amount of ventilation. This does not address the issue of excess solar gain, but does improve comfort. The higher the ventilation rate, the greater the cooling – the upper limit reached when the air movement becomes uncomfortable to the occupants, or the internal air temperature equilibrates to the external air temperature.

Good ventilation can be achieved by active (require external energy sources to operate) and passive (do not require external energy sources to operate) systems. Active systems, such as fans, can provide a range of ventilation rates that do not depend on the outside wind and weather conditions (as passive ventilation does). Extractor fans need to have sufficient capacity to be useful however, with a ventilation rate of 10 air changes per hour requiring 800 l/min for a 4m x 5m x 2.4 m room.

The advantages of fan forced ventilation are that it is operates on demand and can be controlled by a thermostat or timer. Disadvantages are the installation and operating costs, potential noise, energy requirements, and need for user control. Because active systems use energy, there are further disadvantages in that increased energy demand also leads to increased greenhouse gas emissions – which is counterproductive to greenhouse gas mitigation efforts.

Ceiling fans re-circulate air in the room, and can promote ventilation if windows are open. Comfort is also improved by increased air movement, which increases perspiration loss from the skin to assist cooling.

There are a number of passive options for achieving ventilation (listed below). Passive systems are examples of positive synergy between adaptation and mitigation, as they require no external energy sources to operate (and therefore do not release greenhouse gases).

- passive stack ventilation (e.g. through roof-lights or clerestory windows)
- passive vents in windows or walls
- windows open on security latch.

Passive stack ventilation requires the vertical movement of air. In its most basic form the combination of open low windows or vents on one side of a house, with high vents or windows on the opposite side, may be enough to achieve effective passive ventilation. The extra height in two-storey houses may make for more effective passive ventilation, especially important as the upper storey could otherwise trap rising hot air, and be much warmer than the lower storey.

Passive vents and secure open windows offer another method, albeit less controllable method of ventilation. Unless the flow-path of the air creates a passive stack, the ventilation rate depends on the wind speed. This means that on hot days with light winds, the amount of ventilation may be insufficient. Therefore, to work best, the vents should allow for the cross-flow of air through a room, or through the house. Figure 5 shows good cross-ventilation in combination with other elements of passive solar design.

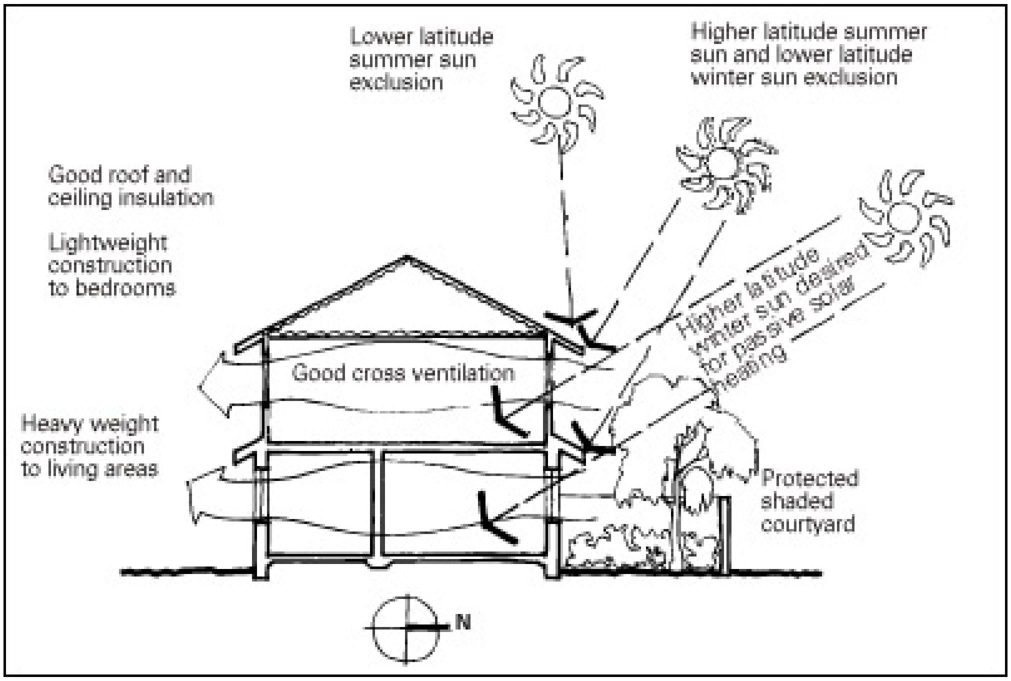


Figure 5: Elements of passive solar design

(www.yourhome.gov.au accessed 24/8/04)

Insulate

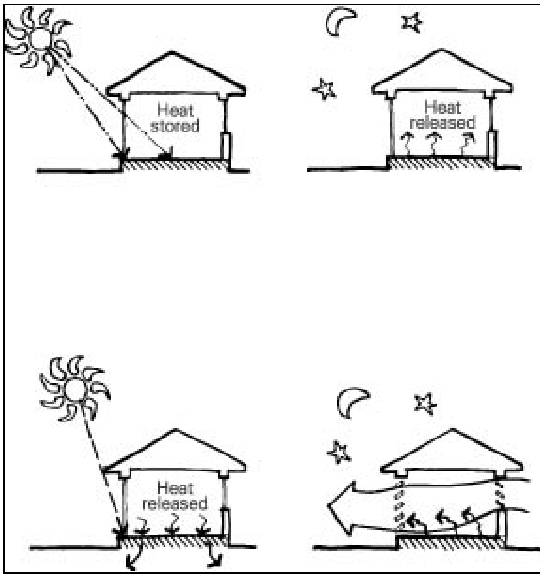
Houses insulated to the requirements of the current NZBC Clause H1 are likely to be approximately 1°C cooler/warmer than an uninsulated house of the same design. A superinsulated house (approximately double the insulation of H1) could be another 1-2°C cooler/warmer. This is because additional insulation, particularly in the roof space, reduces overheating in summer and provides significant reductions in winter heating requirements. It also reduces heating and cooling costs and provides improved year-round comfort. For new houses insulate the roof, walls, and floor over and above the requirements in the NZBC, especially in the roof. For existing houses, increase insulation in all areas (when practicable), especially the roof.

Reflective foil is a common and effective technology in Australia and reflective bright roof paint has been shown in the US to reduce air conditioning loads.

Add thermal mass

Thermal mass is the ability of a material to absorb heat energy (see Figure 6). A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. Appropriate use of thermal mass throughout a building can make a big difference to comfort and heating and cooling bills.

Thermal mass acts as a ‘thermal battery’. During summer it absorbs heat, keeping the house comfortable. In winter the same thermal mass can store the heat from the sun or heaters to release it at night, helping the home stay warm. Correct use of thermal mass can delay heat flow through the building envelope by as much as 10 to 12 hours, producing a warmer house at night in winter and a cooler house during the day in summer.



Winter Allow thermal mass to absorb heat during the day from direct sunlight or from radiant heaters. It will re-radiate this warmth back into the home throughout the night.

Summer Allow cool night breezes and/or convection currents to pass over the thermal mass, drawing out all the stored energy. During the day protect thermal mass from excess summer sun with shading and insulation if required.

Figure 6: Impact of thermal mass in winter and summer

(www.yourhome.gov.au accessed 24/8/04)

Avoid air-conditioning

Air-conditioning is currently uncommon in New Zealand houses, perhaps because in contrast to other countries, long periods of continuously uncomfortable day and night outside air temperatures are (as yet) rare. Air-conditioning can be used as a quick-fix solution to some overheating problems, though in many cases taking some of the other steps to control overheating documented here could make air-conditioning unnecessary or redundant.

Even with a properly designed and installed air-conditioning unit, overheating problems may not be alleviated, especially if the overheating is caused by excessive amounts of east or west glazing. Also, air-conditioning does not deal with direct solar radiation, which can cause discomfort and glare.

If air-conditioning is specified, a reverse-cycle heat pump air-conditioning system is a good option as it can also provide heat for space heating, at less than a third of the running costs of electric heating.

Office buildings

Although there are some similarities between domestic and commercial properties (especially businesses operating from converted domestic housing), the causes and solutions for overheating in office buildings have their own peculiarities.

Reducing lighting and equipment loads are often the easiest and most cost-effective measure, especially for existing buildings, as a reduction of only 10 W/m² will reduce internal temperatures by about 1°C (Energy Group, 2000). It is feasible for nearly all office buildings to reduce lighting intensity levels to at most the current NZBC standard of 18 W/m², and down to 9 W/m² or less. This may require:

- changing light bulbs or tubes to more efficient types (such as compact fluorescent lights), or reducing the number
- changing light fixtures and reflectors
- changing lighting controls
- installing daylight dimmers.

If additional protection from overheating is desired, then increased ventilation and air circulation rates, or reduction of solar window gain are required. Reduction of solar window gain can be achieved most easily by either shading the windows with awnings or overhangs, installing reflective glazing, or by installing heat reflective internal blinds. Cost, ease of installation, and maintenance will be an important part of the decision.

Examples of the use of natural and/or mechanical ventilation in office buildings do not abound in New Zealand. Good local examples are the new library and service centres in south Christchurch and Paraparaumu (Finlay, 2003). Internationally, good examples of implementing displacement ventilation include Portcullis House in London and the refurbished Reichstag (parliament building) in Berlin (Smith, 2001).

Saville-Smith (1999) found that the perception in the office-building market was that air-conditioned buildings attracted a price premium, and are considered high quality office space. Fitting un-conditioned buildings with air-conditioning appears to happen frequently as part of office building refurbishment, though with good design this could be rendered unnecessary, or be implemented at a reduced initial operating cost. For new office buildings, a thermal design strategy should be developed early on in the design process to minimise the need and demand for air-conditioning.

- **Flooding**

A key strategy to reducing flood problems is one of avoiding siting buildings on river flood plains and low-lying coastal areas (as has been clearly demonstrated by the North Island flooding events of 2004). Territorial authorities ought to have information and databases which readily identify such problem areas and deny resource and building consent to flood- pone areas. Much of the guidance that follows is directly applicable to domestic rather than commercial properties (although of some relevance for single storey commercial properties). There are a number of options for reducing the risk and impact of flooding. These include:

Reduce risk by siting buildings correctly

The risk of flooding may be determined by factors outside the property boundary, for example flood protection schemes instituted by a territorial authority. Within the property boundary however, there are a variety of steps that can be taken to reduce the risk and severity of damage should flooding occur. These include raising or moving the house, flood-proofing (see next bullet point) or building a small levee or flood-wall immediately around the house.

Note that the risks of flooding may not be known in areas of new development, and may not be limited to low-lying areas. Phenomena such as earthquakes or landslips may alter such areas after development or commitment to development.

Reduce risk by adapting the building itself

Exceeding the minimum floor level clearance requirements for the area can substantially reduce the risk of flooding damage. This is probably more easily achieved with a suspended floor (concrete or timber), than a concrete slab-on-ground floor, though some polystyrene raft slab systems can give large ground clearances. A pole house or building can give a very high floor level for little or no extra cost and as a co-benefit, be a useful design for properties in regions where the weather will become hotter and more humid.

Consideration should also be given to building a multi-storey building, as it is only likely to be flooded on the ground floor, which could reduce the cost of flood damage by 50% or more, and allow faster re-occupation, especially if services and high-cost rooms such as bathrooms and kitchens are not on the ground floor. Obviously this approach is considerably less expensive than retrofitting at a later stage.

If piled foundations are strong, they can resist being undermined by erosion or scouring by flood waters. Massive masonry constructions will withstand minor flooding with relatively little damage but will be difficult to reinstate after a major flood event. Subsidence can be a problem for concrete slab foundations.

Know how to recover

Almost inevitably, flooding will occur in some areas where it was not predicted or a 'one in a hundred' event occurs more frequently, exacerbated by climate change. Once flooding has occurred, a building needs cleaning, drying and repair before it can be re-occupied. By choosing water-resistant materials (see Table 4), and the flood-proofing of key building services, the clean-up can be made faster and less expensive.

Access to internal walls is needed for cleaning and repair of services, which may involve ripping out and replacing part of the wall linings. By using water-resistant materials, replacement may not be necessary. The materials listed in Table 4 as water resistant should withstand direct contact with flood waters for more than 72 hours, and require at most low cost cosmetic repair (such as painting).

Table 4: Water-resistance of some common building materials

(Camilleri 2001, adapted from FEMA, 1993)

	Water resistant	Non-water resistant
Insulation Floors	Closed cell foam (polystyrene or polyurethane) Concrete (bare or coated) Floorboards, durable or treated timber Concrete or clay tile	Fibreglass, mineral wool, wool, cellulose, foil Particleboard, MDF, plywood[22] Ceramic tile[23]
Walls	Fibre-cement Concrete block Durable or treated timber PVC Brick (glazed or faced)	Particleboard, plywood
Interior	Concrete block Fibre-cement Durable or treated timber	Plasterboard Plywood Hardboard Softwood Carpet or vinyl Particleboard

[22] Marine grade or CCA treated plywood is water resistant.
[23] Resistant to clean water flooding only if has acid and alkali-resistant grout. Otherwise not flood resistant.

To make building services water resistant, install vulnerable equipment (such as wiring, hot water cylinders, meter boards etc) above possible flood levels or as high up as practical. Plastic coated electrical wires should be adequately waterproof provided that the ends are not immersed, but junctions, joints, outlets and switches are not, and will need cleaning and/or replacement. For example, floor level outlets (typically 20 cm -30 cm above floor) may need replacing after flooding, and perhaps also their wiring. For outlets at least 1m above floor level, it is less likely that the outlet or wiring will need to be replaced.

Other fixed appliances and plant also need cleaning or replacement. By mounting critical equipment as high as possible, damage and disruption can be minimised.

For more information on how to recover from a flood, download the following free information: www.branz.co.nz/branzltd/pdfs/B.308.pdf

Prepare

Being prepared for a flood, and knowing what defensive or protective action to take, can dramatically reduce the damage and disruption caused. Steps include:

- recognising that a flood could occur at very short notice during periods of heavy rain (and that the flood can be generated *remotely* from nearby catchment regions and then affect down gradient localities).
- if living in a flood risk zone, be aware of early warning systems, and make sure you will be able to access early warnings during heavy rainfall periods.
- being prepared, as for any civil defence emergency, for forced evacuation with a survival kit of food, clothing, and essentials, and having a getaway kit of essential medications and personal items on standby
- considering the storing of valuables and mementos above likely flood waters.
- having a procedure to turn off electricity, gas and water supplies[24].

New building recommendations

Many options are available to reduce the flooding risk and damage potential when building new. The best option is not to build on a vulnerable site. In order of priority:

- avoid build on a flood-prone site (check first extent of insurance cover)[25]
- exceed minimum floor levels
- consider multi-storey construction
- use water-resistant materials (see Table 3)
- install essential, vulnerable equipment as high as possible.

Existing building recommendations

Retrofitting for flooding is more difficult than building a new structure to be water-resistant in the first place. More often than not, retrofitting is often done after a building has been flooded, which is a waste of resources that could be spent more productively. Costs are likely to be considerably more at the retrofit stage than at construction, which may preclude some measures. Similar to the new building recommendations, measures include:

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24 To prevent, respectively: the risk of electrical shorting or electrocution; uncontrolled venting of gas from appliances if safety shutoffs fail after inundation; and the contamination of the household water supply, or backflow of floodwater into the mains supply.

25 Gaining a building consent, or having a clear land title does not guarantee a site is not flood-prone.

- raising or move the building
- building a second or multiple stories and use first storey as non-living or ‘non-productive’ space
- replacing cladding, flooring, and linings with water-resistant materials
- moving services (hot water, meter board) above flood levels
- building a levee or floodwall around the building
- raising flood awareness and preparedness with building occupants.

- **Tropical cyclones**

The main concerns with tropical cyclones and storms are the effects of extreme winds and driving rain. Wind loads on new buildings can be reduced by designing and building more aerodynamically efficient structures that assist in minimising wind loads, i.e. curved corners, minimising the overhang of eaves (though this type of alteration would be region specific and need to be balanced with requirements to prevent driving rain), using mansard roofs instead of pitched roofs, etc (Sanders and, Phillipson 2003). There are also additional construction and fixing requirements which are necessary to hold down roofs (edges of gable end roofs are susceptible to damage) against cyclone uplift wind forces.

In terms of dealing with driving rain, successful weathertightness is achieved by good moisture management. Design is the key and involves four key principles: deflection, drainage, drying and durability (the 4 Ds). The building elements that need to be considered are:

- roof edges
- open decks
- walls and joinery
- retaining walls
- floors
- balconies
- wall/roof junctions
- roofs.

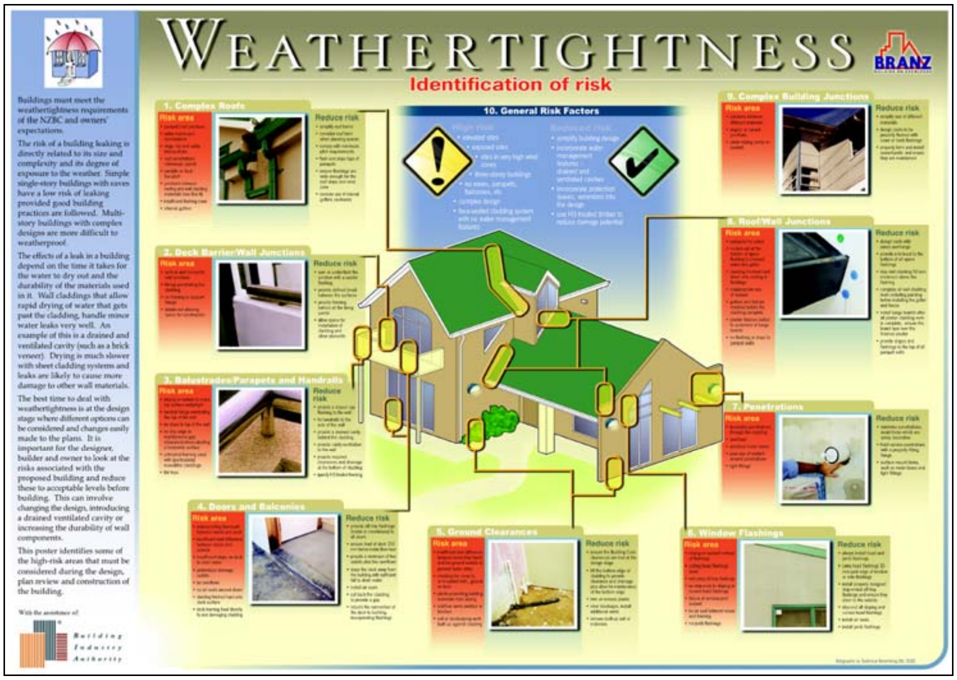

Figure 7: High-risk areas for weathertightness problems

(BRANZ, 2003)

Figure 7 highlights these pressure points in a dwelling. Further detailed advice on how to construct a weathertight building for these elements using the 4 D principles can be found in the following publications and websites:

- www.branz.co.nz/free-publications
- www.weathertightness.govt.nz/diawebsite.nsf/wpg_URL/Resource-material-Weathertightness-Index?OpenDocument

2.5 Cost-benefit analysis of building adaptation

This section examines, at a preliminary level, the costs and the benefits of providing features for typical New Zealand housing adapted to climate change impacts. The analysis was carried out on a new 195m^2 two-storey house[26] with climate change adaptation features added to the design. For the purposes of this analysis, climate change impacts are assumed to be at their most threatening in 30 years (ca. 2030).

The analysis results are shown in Table 5, in two parts, first the estimated additional costs and second, the expected benefits and rate of return on the adaptation features. The purpose of the cost-benefit analysis is to ascertain whether it is worth including adaptation measures in houses that are being built now.

The features to be included are in the three main categories identified as the main impacts on New Zealand buildings. That is, the features are designed to: improve resistance to wind damage; adapt to or prevent flood damage and reduce internal heat gain by undertaking passive solar design.

[26] Current BRANZ economic data indicates average house size is 195 m^2.

Wind resistance measures for tropical cyclones include increased number of roof fasteners, strengthened roof and wall framing, strengthened windows and additional bracing in the wall linings.

The **flood adaptation** measure was a raised building platform, built 0.5 metres above existing ground level, using imported fill material which is compacted. A 150mm basecourse layer was placed on the compacted fill next to the concrete slab, as per normal practice.

Passive solar measures were increased eaves width, double glazing, built-in window vents, and additional envelope insulation.

The house used to estimate the cost increases is the Exemplar House (Willson, 2002), a two storey house with $149m^2$ on the ground floor and $46m^2$ on the upper floor. Costs were obtained from the Rawlinsons Construction Cost handbook (Rawlinsons, 2003).

Wind damage adaptation was costed assuming that the sample house is presently in a high wind zone and in 30 years time, due to climate change, it will be in a very high wind zone, as defined in NZS3604.[27] The Standard provides details of timber sizes, roof cladding fasteners and bracing requirements, from which the cost data was estimated. For flood adaptation, it was arbitrarily assumed that a 0.5m rise in ground floor level for the house footprint and near surrounds would provide protection for a typical house at risk of flood damage in 30 years time. The internal overheating adaptation measures include wider eaves, extra insulation and improved windows.

The cost-benefit analysis summary is in the lower part of Table 5. Wind damage strengthening measures are well worth doing now, even though the extra capacity may not be required for another 30 years.

Flood adaptation measures have a return of about 5.7% which is a worthwhile after-tax return to the homeowner. The Christchurch City Council derive similar costs (ca. $3,000) for measures to adapt homes in flooding at-risk areas[28]. The owner may also be charged lower flood insurance premiums than would otherwise be the case, and this benefit has not been included.

The heat adaptation measures used in the cost-benefit calculation are features that need to be built-in at the time of construction, namely extra eaves width, and extra insulation in the walls. The rate of return, at 4.9% after tax, is marginally worthwhile for the owner. Installation of extra ceiling insulation, double-glazed windows is not included in the initial construction as these can be more economically installed nearer the time of assumed need (30 years time).

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[27] NZS3604 (1999): Timber framed buildings

[28] Communication: in presentation by Jenny Ridgen (Christchurch City Council) at 'Local Government and Preparing for Climate Change' workshop, 12th October 2004, Wellington, New Zealand., October 2004.

Table 5: Cost increases for a typical new house due to built-in climate change adaptation measures

Item	Unit	Quantity	Unit rate		Cost increase $	Comment
WIND DAMAGE ADAPTATION						
Timber framing						
Wall	cum	0.141	640	$/cum	90	Increase stud size in lower storey (2)
Roof	cum	0.7	640	$/cum	444	Increased truss sizes in roof (3)
Roof fasteners	Number	180	3	ea	541	Additional fasteners required (4)
Aluminum windows	sqm	42	25	$/sqm	1053	Heavier frame, better seals, glazing thickness may increase.(5)
Linings Plasterboard	sqm	161	3	$/sqm	484	Increased use of Gib Braceline for wind bracing, $3/sqm
					2611	
FLOODING ADAPTATION						
Slab subgrade fill	cum	160	22	$/cum	3520	Increase grd floor sub-base level by 0.5 m. (Imported compacted fill)
INDOOR HEAT ADAPTATION						
Eaves extension	sqm	15.4	100	$/sqm	1539	Increase eaves width lower story from 460/610 mm to 800 mm.
Double glazing	sqm	42	80	$/sqm	3368	Double glazing and tinted windows
Extra insulation walls	sqm	117	3	$/sqm	351	From R1.8 to R2.6 in walls.
Extra insulation ceiling	sqm	147	3	$/sqm	441	From R2.2 to R4 in ceiling.
Vents in windows	sqm	42	20	$/sqm	842	Built-in secure vents in windows
					6541	
				Total	12672	$
			Total % cost increase		5.0	Assume house cost of $1300/sqm = $ 253500

(1) House is the Exemplar House (1996), Two storey, 195 sqm, concrete slab ground floor.
(2) Go from high to very high wind, in upper storey tyically 100 x40 studs to 100 x 50 studs @ 600 centres.
(3) Rafters typically go from 150 x 50 @ 900 centres to 200 x 50 @ 900 centres. Assume similar volume increase in truss construction.
(4) Increase from 3 to 5 fixings per purlin per 762 mm cover sheet, for 25% of the roof (namely the edges) i.e. extra 2.6 fasteners per m of purlin.
(5) Estimate by BRANZ window specialist. Small cost increase, probably 5 to 10%.
(6) Increase wind zone High to V High. Lower storey bracing required is increased by about 35BU/m in both wind directions.
hence about 14.4m * 35 BU=504 extra BU, either direction. With standard 10mm Gib have 75BU/m and Braceline 90 BU/m
So we need 504/15 = 34 m of braceline in place of ordinary Gib, i.e 28 sheets, each way. BU = Bracing unit.

Damage savings due to adaptation measures

Wind	Spend $2611 now to save $253,500 in 30 years time (i.e. total loss of house).
Rate of return =	16.5% pa
Flood	Spend $3520 now to save $8,938 in year 30, 40, 50 and 60. (Replacement of linings and wall insulation at 10 yr intervals).
Rate of return =	5.7%
Heat adaptation	Spend $1890 now (extra insulation and extra eaves only) to save $500 per yr after 30 yr on cooling energy and appliances.
Rate of return =	4.9% pa

PART C: CASE STUDIES

Part C identifies a selection of buildings that have been adapted to climate change, and/or initiatives planned or underway to adapt the built environment in developed countries. It has been difficult to source best practice examples, i.e., a building or project that has been adapted to multiple climate impacts, e.g., overheating, flooding *and* cyclones. However, a number of projects exist where at least one impact has been addressed. The emphasis was to find projects that had deliberately sought adaptive solutions, rather than showcase examples where an aspect of adaptation had been achieved as a by-product rather than by intent i.e.: minimisation of overheating due to energy management and other mitigation techniques. Despite this intent, much of the information described below (for houses) is 'design/construction for climate' as opposed to the more robust or future-proofing approach, 'design/construction for climate change'.

2.6 United Kingdom

Although general awareness of climate change is not high within the UK construction sector (except at institutional level), there are a number of important research and practical adaptation initiatives underway. From the UK Climate Impacts Programme, the research projects below (part of an overarching programme called 'Building Knowledge for a Changing Climate' Climate' (www.ukcip.org.uk/built_enviro/built_enviro.html)) are in progress:

- *Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE)*

This project aims to 'improve our understanding of the key impacts that are likely to affect towns and cities in the future, and how to anticipate change and plan an appropriate response'. The project will examine the consequences for buildings, urban greenspace and human comfort, and develop and test appropriate adaptation strategies. The demonstration projects will show how cities and urban neighbourhoods can be adapted for climate changes through planning, design and management. See the following website for more details and for updates on the demonstration projects:
www.art.man.ac.uk/PLANNING/cure/PDF/ASCCUE_brochure.pdf

- *Adaptable urban drainage – addressing changes in intensity, occurrence and uncertainty of stormwater (AUDACIOUS)*

The AUDACIOUS project aims to investigate key aspects of the effects of climate change on existing drainage in urban areas and provide tools for drainage managers and operators to adapt to uncertain future CC scenarios. This plugs a gap in current drainage related research, in that it is proposed to establish a rational framework for problem-oriented, cost-efficient, adaptable and sustainable decision-making for those owning and responsible for managing, operating, regulating and developing urban drainage systems to mitigate likely future problems arising as a result of climate change. For more information visit, www.eng.brad.ac.uk/audacious/

- *Adapting buildings to hot summers*

New research commissioned by the Department of Trade and Industry provides a template for how UK buildings can be adapted to cope with increasingly hot summers. Using the UKCIP Climate Change Scenarios data, the research identified the key characteristics in different types of building, including houses, flats, offices and schools, which determine how well they will cope with higher outside air temperatures. The research outlines ways in which those buildings can be adapted to improve comfort levels for people who have to work or live in them. For more information view:
www.cibse.org/index.cfm?action=showpage&pageID=437&TopSecID=16

The Construction Industry Research and Information Association (CIRIA) has a range of projects underway or nearing completion, including:

- *Climate Change – Practical Solutions*

This project will provide clients, designers and contractors with past examples of where various technical risks associated with climate change have been assessed and managed. It will also provide practical guidance to help them assess, identify and manage the technical risk associated with different types of climate change-related impacts on a range of construction projects (e.g. building, road works, embankment, etc). (www.ciria.org/rp668.htm)

- *Development and flood risk – guidance for the construction industry*

This project provides guidance on the assessment of flood risk from a number of sources of flooding such as fluvial, coastal, estuarial, groundwater, overland flow, drainage systems and infrastructure failure. Technical guidance on sources of information and methods of analysis which may be used when assessing flood risk for a proposed development is given for each flood type, taking account of national planning policy guidance.

Intended primarily for the construction industry, in particular developers, builders, designers and planners, this report also provides background information for other parties involved in the development process, including insurers, mortgage lenders and the owners and occupiers of developments. It provides practical guidance that will help the construction industry meet the challenge to achieve sustainable communities that give proper consideration to flood risk. (www.ciria.org/rp675.htm)

- *Guidance for home owners living in flood-prone areas*

The Building Research Establishment (BRE) and the Association of British Insurers (ABI) have recently released a factsheet which outlines steps that home owners living in flood risk areas can take to minimise damage if flooding occurs (refer to the ABI website – www.abi.org.uk/Display/File/Child/228/Flood_Resilient_Homes.pdf).

This fact sheet outlines the most cost-effective approaches for incorporating flood-resilient measures into a home either after a flood event or during renovation/retrofitting. A full technical report 'Assessment of the cost and effect on future claims of installing flood damage resistant measures is also available (refer to (www.abi.org.uk/Display/File/78/Flood_Resistance_report.pdf).

- *Reducing the effects of climate change by roof design*

The BRE and the UK roofing industry have prepared good practice guidance regarding roofing and the impacts of climate change.

This project summarises the views of experts in the roofing industry who have put forward views as to how roof design may mitigate the effects of climate change. Possible effects, such as higher temperatures and thermal movement, are listed; the use of green roofs to reduce heat transfer to the inside of the building and to absorb rainwater is described.

The Tyndall Centre for Climate Change Research (www.tyndall.ac.uk) is undertaking a major project (Tyndall Centre Theme 3 Flagship Project) to develop theoretical insights into the processes of adaptation. Through an exploration of the market, institutional and behavioural drivers of adaptation, this project aims to explore the pre-conditions for adaptation to extreme weather events and rapid climate change at different social and institutional scales. For more information, view www.tyndall.ac.uk/research/theme3/theme3_flagship.shtml

A further project being undertaken in the UK is the Thames Estuary upgrade (Department for Environment, Food and Rural Affairs). Much of the Thames Gateway area is below sea level. Plans are underway to upgrade the Thames barrier and though renewal may take up to 40 years, the planning is including higher allowances for river flooding, sea-level rise and storm surges.

Figure 8: Thames Gateway

(Photo from www.findaproperty.com/cgi-bin/story.pl?storyid=6166)

2.7 Norway

Norway's construction industry has a concerted programme of research specifically aimed at the potential impacts of climate change (Lisø et al, 2003). Some of these projects include:

- *Climate 2000 – Building Constructions in a More Severe Climate*

The research programme is being undertaken by a large number of key actors in Norway's construction industry. Objectives include developing methods for planning/designing buildings in terms of increasing their durability and reliability.
(www.byggforsk.no/Prosjekter/Klima2000/english/default.htm)

- *FLOWS*

'FLOWS' is an acronym for Floodplain Land Use Optimising Workable Sustainability. It is a trans-national project with participants from Germany, the Netherlands, Norway, Sweden and the UK. A government agency from each country acts as lead partner in the respective participant countries. FLOWS involves several projects, all with the ultimate aim of providing decision-makers with more and better information on flood risk to help them:

- make better decisions about where to site new housing
- design family houses with a culture of living in and around water
- provide practical solutions about how to make existing flood-risk housing more resistant
- provide better warning systems when floods are forecast.

One of the work programmes (work programme 2) is specifically focused on retrofitting existing buildings for flooding. The project plan is as follows:

'The aim of the project will be to develop one residential retrofit scheme to appropriate flood risk mitigation standards that demonstrate what can be achieved at reasonable cost. This will be complimentary to the works to be carried out as part of the Environment Agency Flood Alleviation Project and will help to raise community awareness of flooding issues. Involvement of a major UK insurance company (Norwich Union Limited) will help ensure that results from the Norfolk Project could be of use to householders and local authorities or companies elsewhere, both in the UK and trans-nationally.

'This project is linked with all other work packages in FLOWS and will help to demonstrate how people can continue to live in flood-risk areas. It is extremely important to demonstrate that risk of flooding in such areas should not lead to blight of peoples' lives and properties and, importantly, should not be allowed to damage the local economy. These are important considerations of trans-national transferability for which FLOWS will be the vehicle.

As above, this project will help to demonstrate economic and social cohesion by showing that people can continue to live and work in flood-risk areas to the benefit of the local economy and community. The Broads Authority will be closely involved in the project. Equal opportunities will be an important part of the demonstration project as the house will need to be accessible to all, regardless of mobility or age". The retrofit project will take place in, Lowestoft, Norfolk. For more information see: www.flows.nu/

Figure 9: FLOWS Retrofit project location, showing evidence of flood water level

(Photo courtesy of Norfolk County Council)

2.8 Canada

The Government of Canada has a 'Climate Change Impacts and Adaptation Program'. The overarching goal of this program is to reduce Canada's vulnerability to climate change. Emphasis is placed on research that examines processes, barriers and drivers for adaptation. The program to date has supported more than 150 projects. Reports on these projects can be found on www.adaptation.nrcan.gc.ca Examples include:

- Adaptation of Prairie Cities: the role of climate
- Climate Change, Permafrost Degradation and Infrastructure Adaptation: Community Case Studies in the Mackenzie Valley
- Adaptation Strategies to Reduce Health Risks from Summer Heat in Toronto
- Evaluating Rooftop and Vertical Gardens as an Adaptation Strategy for Urban Areas
- Impacts and Adaptation of Drainage Systems, Design Methods and Policies
- cities^{plus} Sustainable Urban System Design: Climate Change Impacts and Adaptation Component

Further projects include:

- *Charlottetown, Prince Edward Island*

Charlottetown city planning officials are changing their building permit procedures in regard to climate change and are creating a long-term adaptation strategy for their city. The city's past history of development was oriented towards the water and many services ran to the water. Now, the development is focused on boardwalks, parks, etc along the waterfront, to minimise flooding risk to buildings. In particular, they are looking to restrict specific development in areas that are prone to sea-level rise. There is considerable infrastructure in the predicted sea level-rise areas already. The city is still deciding which adaptation techniques to use in these areas, but the thinking is underway to decide what to do to protect against sea-level rise and future storm surges. For more information see:
www.geospatial-online.com/geospatialsolutions/article/articleDetail.jsp?id=58322&pageID=3

- *Confederation Bridge*

Confederation Bridge, between New Brunswick and Prince Edward Island, was built a metre higher then currently required to accommodate sea level-rise over its 100 year lifespan. For more information, see
www.elements.nb.ca/theme/climate03/cciarn/adapting.htm

Figure 10: Confederation Bridge

(Photo: K. McKenzie, from
www.elements.nb.ca/theme/climate03/cciarn/adapting.htm)

2.9 The Netherlands

Instead of holding back the water, designers in the Netherlands are designing buildings to float on water. Although not a new technique, the Dutch are investigating innovative ways of dealing with flooding risk. One prototype design includes a floating platform made of Styrofoam wrapped in a thin shell of concrete, the walls and floors from light-weight prefabricated wooden panels, with a façade clad in coated aluminium. The houses can also be moved from one site to another. Although this idea may currently have limited application in New Zealand waterways, it is being taken seriously in the Netherlands and in Canada. For more information see:
www.findaproperty.com/cgi-bin/story.pl?storyid=6166

Figure 11: Houses that float on water

(Photo from www.findaproperty.com/cgi-bin/story.pl?storyid=6166)

2.10 Australia

The Australian Bureau of Meteorology provides generic information on designing buildings for the local climate (www.greenhouse.gov.au/yourhome/about/order.htm). The Australian Greenhouse Office in their 'Your Home' publication, (www.greenhouse.gov.au/yourhome/about/order.htm – refer also to listing Appendix 1) provides technical advice for consumers on adaptive (passive design) approaches to house design. Included is a fact sheet which provides a reference guide to the six main climatic zones and conditions experienced in Australia: (www.greenhouse.gov.au/yourhome/technical/pdf/fs11.pdf).

The Charles Sturt University in Thurgoona (Albury) on the New South Wales-Victoria border is a good example of adaptation (of a series) of buildings to the dry climate of southeast Australia, a region that receives most of its rainfall in winter and spring (refer to www.csu.edu.au/division/marketing/tms/T101/T101p3.htm). The designers made specific recognition of the climate when plans were developed for a formerly degraded (by land clearing and farming) site. The Student Pavilion (completed in 1996) became the prototype for other buildings on the site. It includes rammed earth walls, concrete floors for optimum solar capture, solar panels that heat collected seasonal rainwater, and shaded windows framed with recycled plantation timber.

Lessons learned from the Pavilion process have allowed for improvements to be incorporated during the subsequent construction of other buildings and infrastructure on the campus (for example: stormwater recycling; grey water treatment and re-use and composting toilets).

Figure 12: Student Pavilion

The Gold Coast House in southeast Queensland is another good example where the designers deliberately chose to build for the local (sub-tropical) climate (where temperatures can go well over 38°C during summer) rather than opt for mechanical cooling. Thin-framed, movable glass walls forming a large part of the building fabric allow for unrestricted flow of cooling breezes (these walls are also designed to be resistant to tropical storms and cyclones). The outdoor verandah (a vernacular style for the region) and roof overhangs provide shade from summer sun. Concrete floors provide thermal mass for the cooler months, rainwater is collected and waste water is managed entirely on-site.

Figure 13: The Gold Coast House

(Refer to www.architectureweek.com/2003/0326/design_1-2.html)

The Gold Coast City Council have recently endorsed implementation of a 'sustainable housing code' as part of the city's planning initiatives for adapting to climate change (refer to www.goldcoast.qld.gov.au/t_std.asp?pid=4100)[29].

2.11 New Zealand

As part of its portfolio of climate change work, the New Zealand Climate Change Office (NZCCO) within the Ministry for the Environment (MfE) has begun a programme to assist regional councils and territorial authorities to better understand and take into account climate change effects when carrying out their day to day operations. In particular, the programme aims to develop guidance materials for local authorities to assist them in assessing and managing the risks of climate change in their planning processes. This guidance material, including more information about the following New Zealand case studies, can be sourced from the NZCCO website: www.climatechange.govt.nz/resources/local-govt/guidance.html

- *Assessment of the impacts of sea-level rise on floodplain management planning for the Avon river (PDF 857 KB), December 2003*

This project was commissioned to investigate the impact of climate change-induced sea-level rise on risk management planning for the Avon river catchment and associated coastal areas. Although this report is geographically specific in its scope, it is expected that many of the issues, challenges and methodologies relating to coastal hazard planning within a climate change framework presented here will also be applicable in other regions and catchments in New Zealand.

Investigation of the lower Avon and associated coastal area is particularly pertinent because the current stopbank system in that area provides adequate protection for most properties under current sea level, but with sea-level rise the stopbanks are likely to be overtopped with increasing frequency. It is also timely because Christchurch City Council is currently working through a proposed variation to the City Plan on flooding issues. This proposed variation would change the minimum floor level in the floodplain to a level that will accommodate predicted sea-level rise, and would restrict the minimum section size in a very low-lying area in the suburb

[29] Communication: in presentation by Evan Thomas (Gold Coast City Council) at 'Local Government and Preparing for Climate Change' workshop, 12th October 2004, Wellington, New Zealand.

of Bexley to 650 m^2 to reduce intensity of asset build-up in the area and to assist with recession plane problems associated with the minimum floor level.

Flood risk arising from future precipitation changes in Gleniti, Timaru (PDF 449 KB), December 2003

This project assessed flood risk arising from possible future precipitation changes in Gleniti, Timaru, due to climate change effects. The report describes the projected climate change effects, discusses the outcomes of a re-worked flood model, which takes into account these effects, and assesses the implications for two of the catchments.
The objectives of the project were to:

- estimate the projected rainfall in 2030 and 2080 and compare them to 2001 rainfall
- assess the implications of the increased flood risk in the catchments posed by the projected future rainfall changes
- produce an industry best-practice example report available for public access that will help users get a feel for the relevance of incorporating climate change scenarios in their stormwater planning. It should also demonstrate the relative extra work and cost required in carrying out a climate change assessment as part of a bigger stormwater planning exercise.

Local Government Adaptation to Climate Change: Environment Bay of Plenty and Coastal Hazards: "Issues, Barriers and Solutions" (PDF 106 KB), December 2003

In drawing upon council experiences, this project sought to gain an understanding of where to target future coastal hazards and climate change guidance materials and related training activities targeted at local government. It was also intended that this case study would provide a review of key issues for Environment Bay of Plenty and relevant territorial local authorities in order to focus future council work programmes.

The view from the ground: A farmer perspective on climate change and adaptation (PDF 3.29 MB), July 2003

Significant adaptation of and in New Zealand's built environment is still a long way off but much could be learnt from New Zealand farmers who are recognised as collectively having a lot of capacity (via a series of rural adaptation workshops in 2003) to adapt to climate change (Kenny and Fisher 2003).

New Zealand farmers also recognise the need for a more co-operative environment in which a strong sense of community is needed along with greater communication between farming and non-farming communities (Kenny and Fisher 2003).

Although much discussion in this document centres on the 'hard' infrastructure of the built environment, aspects such as how urban communities will feed themselves sustainably in the future is an often overlooked aspect. Food production in developed countries including New Zealand, is heavily reliant on fossil fuels for production (Pritchard and Vale 2000), an issue that will become increasingly important to address in adapting both urban and rural environments. As well as the need to reduce the carbon intensity for food requirements, urban and rural communities will need to adapt to living off land which will become more or less productive (depending on geographic location) in the future for crop growing.

The production and usage of bio-fuels (for example, harvested from 'retired' rural land) will also become more prominent as the country seeks to meet national and regional renewable energy targets. In some areas of the country, this may mean reverting to traditional and practical methods of food production and distribution (e.g. suburban and peri-urban market gardens).

Strengthening the link between rural (farming) and urban communities is, therefore, an important consideration as New Zealand communities adapt to climate change.

3. CONCLUSIONS AND FUTURE WORK

Climate change will bring about new ways of living in all sectors of New Zealand society. The climate system is changing, and will undergo further change, regardless of any sudden decline of greenhouse gas emissions or implementation of worldwide abatement policies under the Kyoto Protocol or other mitigation regimes. Adaptation is therefore a critical element of any climate change response.
The time to adapt is now. Built assets are long-term features of our environment and action needs to be taken now to ensure that buildings and communities can cope with the predicted impacts for at least the upcoming generation.

Central, regional and local government have an important role to play, so too the building and construction industry. Although certain sectors of government and the industry are engaging with climate change issues, adaptation strategies are really only just emerging in New Zealand. It may be helpful to look to international examples of best practice, especially progress in the UK and Canada.

In considering international examples, there are a range of adaptation strategies available to the New Zealand government. The challenge lies in the choice, prioritisation and integration of these strategies. Future work should involve the development of an overarching 'adaptation framework' for the government to successfully deliver these strategies. Similarly, there are a range of methods and techniques to construct or retrofit a building so that it is adapted to key climate change impacts facing New Zealand: overheating, flooding and tropical cyclones. Again the challenge lies in the prioritisation and integration of actions for both new and existing buildings.

All of the information provided in this manual must be viewed in a wider context. There are a number of barriers and obstacles to be overcome, or at least understood better, to further advance the adaptation agenda in the physical form of the built environment (such as transportation infrastructure).

Understanding also needs to be enhanced with regard to other factors, particularly the 'soft' aspects which shape the built environment's social landscape, and the interactions of the building sector with political, social and economic processes. To successfully implement adaptation, there will need to be a considerable move away from the 'think and live for today' mindset to one which is more long-term, holistic and strategic in nature – this applies to all stakeholders in the built environment.

Last but not least, any adaptation advice cannot act in isolation. Critical to the success of a fully adapted built environment is its integration with other agendas for change and capturing synergies with mitigation responses. The costs of taking integrated approaches may be higher initially, but when considering the value of the building stock at stake, these costs are much lower than having to retrofit later on, or to completely rebuild.

This manual provides practical advice on the ways buildings and the built environment can be adapted to climate change and provides the rationale for incorporating such adaptation into present and future building design. It is anticipated that this guidance will open the way for action by the building industry and the government to further advance the adaptation agenda.

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APPENDIX 1: FURTHER RESOURCES

Author	Title	Description	Access details
Overseas Publications			
Dauncey G and Mazza P	Stormy Weather: 101 solutions to global climate change	Offers a range of responses and proffers solutions, including adaptive ones, for range of stakeholders to dealing with climate change.	New Society, Gabriola Island, BC (Canada) ISBN 0 8657 1421 5
Hawken P, Lovins AB and Lovins LH (1999)	Building Blocks, Chapter 5 in Natural Capitalism: Creating the next industrial revolution, pp 82-110	Describes, with several practical examples, how individuals, businesses, etc, benefit from the creation of green buildings in a variety of climates.	Little, Brown & Co, Boston (USA) ISBN: 0 3163 5300 0
Roaf S (2004)	Adapting Buildings and Cities for Climate Change: A 21st century survival guide	This author makes the case for construction of buildings that can survive in the changed climates of the future while halting construction of climatically unsuitable building types.	Architectural Press (UK) ISBN: 0 7506 5911 4 (to be released November 2004)
Smith P F (2001)	Architecture in a Climate of Change: A guide to sustainable design	Guidance on sustainable design set against the backdrop of climate change. Discusses sustainable technologies, examines pitfalls and presents case studies.	Architectural Press, Oxford (UK) ISBN 0 7506 5346 9
Vale B and Vale R (2000)	The New Autonomous House	Book: Features include the theory, practice and performance of building a zero-emissions house in the UK. There is some discussion of relevance to the New Zealand situation in the book.	Thames & Hudson, London (UK/Australia) ISBN 0 5003 4176 1

Author	Title	Description	Access details
New Zealand publications			
Auckland Regional Council, BRANZ and Hamilton City Council (2003)	Easy Guide to Eco-building: Design, build and live with the environment (2nd edition)	An introduction to green building highlighting important issues to consider. Provides links to relevant New Zealand material.	Available online: www.branz.co.nz/branzltd/publications/pdfs/EcoGuide2003.pdf Email: romanjaques@branz.co.nz Ph: (07) 839 5360
Australian Greenhouse Office (AGO)	Your Home: Design for lifestyle and the future	Website: A suite of consumer and technical guidance material to encourage the design, construction or renovation of homes to be healthy, comfortable and environmentally sustainable. The associated book contains fact sheets and case studies available on a CD-ROM.	Available online: www.greenhouse.gov.au/yourhome The text 'Your Home Your Future Your Lifestyle' (pub. 2001) can be ordered online via: yourhome.gov.au/ (Australia)
Bates, S, Bayne, K, Killerby, S (2001)	Room for a View: Three visions for the future urban environment in 80Australasia	A visualisation of three future scenarios for the built environment in 10-15 years time, based on a range of drivers, including climate change, and degree of response by the population to perceived impact of these drivers.	Available from Forest Research Email: info@forestresearch.co.nz Ph: 0800 737 327.
BRANZ (2004)	Being a Climate-friendly Kiwi: At home and in the office (2nd edition)	A guide that offers New Zealand homeowners, small business owners and tenants the practical advice they need to reduce their greenhouse gas emissions.	Available online: www.branz.co.nz/branzltd/publications/pdfs/ClimateFriend04.pdf Publication also available as a hard copy. Email: MiriRussell@branz.co.nz Ph: (04) 237 1170. ISBN 1 8773 3010 8

Author	Title	Description	Access details
BRANZ (2004)	'Sustainable Construction', Bulletin 446.	Outlines some of the specific actions that individuals, business and industry can take to secure a range of financial, social and environmental benefits when sustainable construction is put into practice.	Copies available from Miri Russell at BRANZ Email: MiriRussell@branz.co.nz Ph. (04) 237 1170
BRANZ (1967)	Sunshine and Shade	Guidance to the use of sun-path diagrams, solar position and radiation tables for optimum solar orientation of a proposed building.	Copies available from Miri Russell at BRANZ Email: MiriRussell@branz.co.nz Ph. (04) 237 1170
Christchurch City Council (2004)	Sustainable Building Guide	Guidance that promotes and encourages environmentally sustainable design of new residential buildings.	Available online: www.ccc.govt.nz/Publications/DesignGuides/#SustainableBuildingGuide
Collins M, Barnard T, Bayne K, Duignan A and Shayer S (2003)	Building Green in New Zealand: Wood – a sustainable construction choice	Examines the role that timber and wood products can play for sustainable building in the built environment.	Email: info@forestresearch.co.nz Ph: 0800 737 327.
Mobbs M (1998)	Sustainable House: Living for our future.	The story of two householders who renovated their small inner-city Sydney family house to make it almost entirely self-sufficient in energy and water, with all sewage processed on site.	University of Otago Press, Dunedin. ISBN 1 8771 3362 0
Pacific Energy Design Ltd (1985, updated 1994)	Energy-wise Design for the Sun: Residential guidelines for New Zealand (Volumes 1 and 2)	Provides comprehensive and conceptual information and guidance for designing energy-efficient and passive solar houses in the New Zealand environment.	Available from EECA

Author	Title	Description	Access details
Standards NZ (2004)	NZS 4244 Standards New Zealand 'Insulation of Lightweight –Framed and Solid Timber Houses'	Standard which provides general design guidance on improved insulation levels. Also examines the application and benefits of passive solar design.	Available from Standards New Zealand $39.95 + GST
Waitakere City Council (1998)	Sustainable Home Guidelines	A comprehensive guide for healthier and more sustainable residential building, renovating and living.	Available online: www.waitakere.govt.nz/abtcit/ec/bldsus/shsummary.asp Email: info@waitakere.govt.nz Ph: (09) 839 0400.