Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 4.8: Overview of a Building Flood Protection Decision Framework

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1. Introduction

1.1 Background

All New Zealand's regional and territorial authorities are obliged to assess the risks to their community and built environment posed by climate change. The Ministry for the Environment has provided guidance material that can be downloaded from their website [see Tool 1.7]. However, additional guidance and tools are needed for councils to tailor an appropriate response to these risks. Ideally, such supplemental guidance will enable local government staff to find and utilise the best knowledge available to serve their needs.

The overall purpose of the *Impacts of Climate Change on Urban Infrastructure & the Built Environment Toolbox* is to provide information and methods for councils to assess climate change impacts and risks in their urban environments. An additional requirement was to address the difficulties faced by some councils in accessing state-of-the-art knowledge.

1.2 Purpose of the Building Flood Protection Decision Framework

This report [Tool 4.8] provides a Building Flood Protection (BFP) Decision Framework with a linked set of tools for adaption of individual buildings that are prone to enhanced flood risk due to climate change. Flood risk mitigation for individual buildings can be encouraged by councils and insurers; however building owners need to adopt the strategies that are encouraged. This Framework provides stakeholders (mainly councils but also insurers, communities, building owners and occupants) with a range of potential adaptation options for flood-prone buildings. A series of 'ready to use' methods is provided to assess the suitability of the mitigation options under different flood risk conditions, thereby supporting the decision making of involved stakeholders.

1.3 Structure of Tool

The BFP Decision Framework is part of a wider portfolio of tools presented in the Toolbox. The structure of this tool is: first, the overall framework will be presented; second, the scope and background to the Framework will be given; and, third, the context, structure and application of the Framework will be discussed. Most of the details of the Framework can be found in separate appendices.

1.4 Obtaining this Building Flood Protection Decision Framework

Contact the author of this report for information about obtaining and using this tool.

2. Overview of the BFP Decision Framework

Any response to mitigate flood risk for buildings starts with the realisation that a building is built on flood-prone land. Identifying flooding risk and sharing this information is a precautionary measure. Councils are required by law to consider all potential flood and other hazards to their community, and hold any known information about potential flooding risks. These are commonly found on both Land Information Memorandums (LIM's) and Project Information Memorandums (PIM's) for land and buildings within their communities. Providing this information gives building owners the opportunity to make good decisions about the need for protection of a building on a property.

For many areas, climate change is predicted to result in an increase of the flood risk, both in frequency and intensity. More land and buildings will become prone to flooding, and will gradually be exposed to higher and more frequent floods. Existing flood defences might not be able to provide adequate protection over time. It is important to realise that engineered flood protection of flood-prone buildings reduces, but does not remove, the flood risk as demonstrated in New Orleans during Hurricane Katrina. This residual risk corresponds to those extreme circumstances under which the protection may fail.

With the prospect of climate change, councils have an obligation to inform building owners about potential changes in the flood risk to their buildings. Addressing flood risk by means of mitigation measures at the single building level can be part of a community flood protection scheme. In some countries, for instance in the US, flood risk mitigation at the building level is driven by a national insurance scheme. However, in New Zealand, the choice to mitigate flood risk will often be the sole responsibility of the building owner. Councils can choose to assist and encourage owners to consider flood mitigation options for their building (residential or non-residential).

2.1 Theoretical Basis of BFP Decision Framework

The New Zealand approach to flooding of buildings has been in general to repair the damage after a flood event, or to demolish buildings that are exposed to unacceptable risk levels from a health and safety perspective. BRANZ (the Building Research Association of New Zealand) has provided guidance publications for the building industry to support the repair of flood-damaged buildings (for more information, see section 4).

The most comprehensive literature sources investigating the adaptation options for at-risk buildings are publications from several federal agencies of the US federal government. The Federal Emergency Management Agency (FEMA) of the US Department of Homeland Security has produced a comprehensive series of publications (see section 4, US) aimed at working with homeowners to retrofit their building to mitigate flood risks from rivers. Some earlier publications of the US Army Corps of Engineers also provide some useful guidance on the same subject. Local governments in the UK (see section 4, UK) have produced guidance documents looking at strategies for the construction of flood-resilient buildings, neighbourhoods and streetscapes. Australian sources go one step further in providing a strategic framework to transform cities into water-sensitive cities (see section 4, Australia). Due to differences in New Zealand's urban form and construction, all of these sources of information need to be interpreted and tailored for local conditions.

2.2 Data Needs

For the adaptation of buildings in response to flood risk, there is a need to collect data and information on the following topics:

1. *The physical properties of the land.*
2. *The flood conditions at the site of the building.*
3. *The physical design details of the existing (or proposed new) building.*
4. *The vulnerability of the building to damage by inundation.*
5. *Design considerations regarding the adaptation options.*
6. *Cost and benefits.*

Information on Topics 1 to 4 is considered to be essential input data for assessment of building flood mitigation options. This particular tool assists with the primary selection of design solutions for flood mitigation under Topic 5. For a more detailed evaluation of the design considerations, the selected best options need to be worked out to their full extent in all details. Topic 6 *Cost and benefits* is presented in [Tool 4.4] of the Toolbox.

In Table A1 in Appendix B an overview is provided for each of the data and information topics in the previous listing respectively indicating:

- The typical parameters on which data is needed
- The right people to talk to
- Organisations that can provide relevant local information
- Decision support tools.

2.3 Outputs of the BFP Decision Framework

The emphasis of the Framework presented is to provide a process and associated tools to councils and building owners to explore and evaluate the viability of retrofit protection options for mitigation of imminent flood risk to a building.

The Framework provides for:

- The main range of mitigation solutions for existing and new buildings
- A filtering system to identify less viable solutions based on local conditions
- A system for ranking the viable solutions based on design and preferences.

2.4 Assumptions and Limitations

The Framework can be used to identify less viable options. However it is still recommended to use the output – a ranking of viable retrofit options – as a guide only. It is also recommended to use the assessment as a starting point for further detailed analysis of the best options in collaboration with specialists.

3. How to Apply the BFP Decision Framework

3.1 Building Flood Protection

A flood is a temporary inundation of land by an expanse of water. Buildings, occupants and infrastructure on this land risk being adversely effected by this inundation.

Flooding has a source and follows a pathway before reaching the built structures (Figure 3.1).

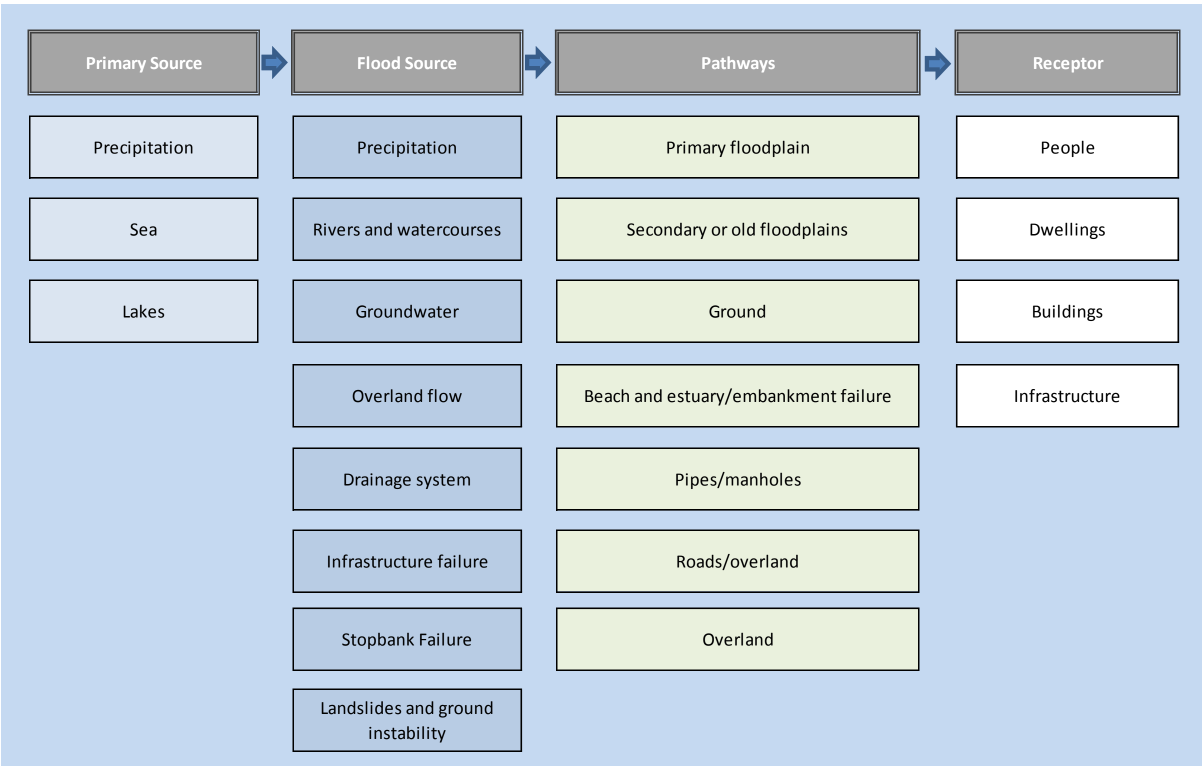

Figure 3.1: Flooding source-pathway-receptor

Climate change affects the primary source of the flood. For mitigation of flood risks under climate change, it is crucial to understand and quantify the changes in the source and use them to establish the change in local flood risk.

Flood risk can be mitigated using any or a combination of the following six main approaches:

1. Modify the hazard (e.g. dams, retention ponds, diversion channels).
2. Modify the water courses (e.g. stop banks, ground elevation).
3. Modify the receiving structures (e.g. elevation, strengthening).
4. Modify the land use (e.g. subdivision regulation).
5. Insure the receiving structures (e.g. national or local flood insurance).
6. Provide warning and emergency management (e.g. an alert and evacuation system).

This specific tool targets mitigation of flood risk on the individual building scale by physical measures. It will touch on at least four of these main approaches (2, 3, 4 and 5).

When a building is prone to flood risk, an owner needs to be convinced that it is beneficial to do more than a passive approach. This is to essentially wait for the flood to occur and repair the damage, rebuild or abandon the site. From an economic point of view there is limited impetus for owners to mitigate flood risk, unless the cost of a flood (business interruption, damage to stock, reinsurance etc) exceeds the cost of adaptation. As well as economic drivers, social drivers may also be effective at encouraging mitigation, because sometimes personal safety is not guaranteed.

Effective drivers for mitigation of flood risk at the building level are:

- Requirements for flood insurance of a building.
- Costs associated with expected damage, including business interruption.
- National or local regulations that aim to protect building occupants from hazards.
- Incentives provided by third parties, such as local or national government.
- Threat to personal safety.
- Community pressure.

Local government planners have an important role to play in ensuring that appropriate drivers are in place to stimulate building owners to mitigate the flood risk. A crucial next step is therefore to support these owners to assess the possible adaptation techniques in an appropriate manner.

3.1.1 Forces on the Building

For assessment and scaling of the adaptation techniques, the nature of the flood risk to the building needs to be quantified. Depending on the magnitude of the flood on the particular site of interest, a range of specific force characteristics of the type of flooding will act on a built structure. A building's structural elements, services and materials must be designed and built to adequately deal with these forces.

Inundated built structures are potentially prone to:

- Buoyancy and pressure differentials – hydrostatic forces
- Flow – hydrodynamic forces
- Debris impact
- Erosion of the land
- Changes in the properties of construction materials.

Depending on the nature of the flood and a building's physical and structural design, these forces can be resisted without structural damage. If the forces are known, the requirements for the structural design of flood-resistant building design are clear.

3.1.2 Approaches to Hazard Mitigation

For buildings the following general flood hazard mitigation design strategies should be considered in this order of preference from a safety point of view:

- **Avoid the Hazard**
    - *Relocation* – this means moving the building to higher ground where the exposure to flooding is greatly reduced or eliminated altogether.
- **Separate the Hazard**
    - *Elevation* – this is raising the building so that the lowest floor is above the appropriate flood risk level, and is the most common way to avoid flood damage.
    - *Floatation* – constructing a building with anchored buoyant foundations that move with changes in water levels.
    - *Stop-bank and floodwall protection* – levee and floodwall protection means constructing barriers to prevent flood waters from entering the building.
    - *Dry flood-proofing* – this means sealing the building to prevent flood waters from entering.
- **Reduce the Impact of the Hazard**
    - *Wet flood-proofing* – this makes the building resistant to flood damage when water is allowed to enter uninhabited areas during flooding.

Each of these protection approaches has a typical inundation application range that will limit its use. The cost and benefits for each of these options will be different and depend on the flood risk. Other limitations might come from regulatory, practical or aesthetic considerations. If none of these options provides a satisfactory level of protection and risk reduction, then demolition of the building should be considered.

3.1.3 Limited Protection

Another important point is that for all flood protection measures there is an upper limit above which the protection will fail. This is a very important design parameter called the "*design flood elevation"*. This elevation corresponds to the reference "*base flood elevation*" and an additional vertical safety margin called "*freeboard*". The base flood corresponds to a flood with a return period of typically 50 or 100 years. A crucial aspect of the design of flood protection is a sensible setting of the freeboard height, because it should accommodate all uncertainty related to flood prediction and also the impact of climate change.

Flood mitigation design therefore sets rigorous requirements about the minimum amount of data that should be delivered by surveyors and hydrologists, especially given the prospect of climate change.

3.2 Structure and Content of the BFP Decision Framework

Buildings in or adjacent to floodplains face an increased risk of flooding under most climate change scenarios. What options do building owners and communities have to respond to this risk? Urban areas face planning challenges such as pressure for land development in floodplains. Councils recognise the need for new planning approaches to manage existing and future flood risks in these areas.

The tendency is to look for new ways to distribute responsibilities between different types of stakeholders, to take advantage of different initiatives over differing spatial scales, from the catchment level down to the individual building level. In this respect, there is a clear need to include resilience measures taken at the building scale as part of either a top-down or bottom-up approach. This kind of measure includes the flood-proofing of buildings and associated infrastructure as well as adapting building activities to the risk.

The extent to which such measures on the building scale will be provided will probably be dictated by micro and macro economic factors. However, as yet there is little information surrounding the influence of these factors in the New Zealand context.

Consequently, the economic efficiency of these technologies is unclear. Here, a suite of tools is presented that allows building owners and planners to select appropriate adaptation measures with consideration of mostly technical limitations and the option to incorporate economic information.

This BFP Decision Framework incorporates a set of flood damage protection measures suitable for New Zealand circumstances, which has been constructed from a combination of secondary sources, such as FEMA (US) guidance, and from the real experience of practitioners with insight into the effectiveness of mitigation measures during flood events. Further, the Framework provides a means to select viable and preferred options from the main solutions for the local situation. This enables the exploration and evaluation of the viability of retrofit protection options for mitigation of unacceptable levels of flood risk to a building.

To allow the appropriate selection of suitable retrofit options, the nature of the climate change enhanced flood risk to the site of the building must be known. The process diagram in Figure A5 in Appendix B shows the steps that this tool supports (shown in yellow):

1. Define a set of potential flood protection options.
2. Assess residual risk and viability of flood protection options.
3. Rank remaining viable options.

These preliminary steps in the evaluation with the Framework are essential to scope the breadth of mitigation options available for each site. Also, the design specifications of buildings will further limit the number of potential mitigation options.

The Framework is a selection procedure with tools for building-specific mitigation of flood risk. The procedure has four linked tools (see Figure A6 in Appendix B):

1. **List of building retrofit options**
    - Gives characteristics of the main solutions for building retrofit-based risk mitigation.
        - *For a more detailed description see Appendix A.1 and*
        - *Figure A1.*
2. **Protection height design tool**
    - The design tool allows a designer to translate the local flood risk and appropriately set the protection height at a defined residual risk level.
        - *For a more detailed description see Appendix A.2 and Figure A2.*
3. **Retrofit suitability assessment tool**
    - Provides the designer or assessor with a range of selection criteria, which if they are considered to be crucial in the local context can be used to rank particular retrofit options.
        - *For a more detailed description see Appendix A.3 and*

- *Figure* **A3**.

4. **Retrofit preference tool**
   - Provides the assessor with a simple framework to work with the owner(s) in selecting the preferred viable retrofit options.
     - *For a more detailed description see Appendix A.4 and*
     - *Figure* **A4**.

With these basic tools councils can build up an action plan to work effectively with building owners to address the initial assessment of viable options for adaptation of their buildings. However, it is evident that any retrofit of a building is a construction project for which specialist consultation will be necessary. Contact the author of this report for information about obtaining and using this tool.

4. References and Relevant Literature Sources

Most of these referenced literature sources are easily accessible and can be downloaded for free over the internet.

New Zealand

"Repairing flood-damage to houses", *BUILD* 85 (2004/2005).

"Restoring a house after flood damage", *BRANZ Bulletin* 455 (2004).

"Preparing for future flooding: A guide for local government in New Zealand", *Ministry for the Environment Technical Report ME 1012* (2010).

"Tools for estimating the effects of climate change on flood flow", *New Zealand Ministry for the Environment Technical Report ME 1013*, prepared by NIWA (2010).

"A methodology to assess the impacts of climate change on flood risk", *New Zealand Ministry for the Environment Technical Report ME 1013*, prepared by NIWA (2005).

New Zealand Standard NZS 9401:2008 *Managing flood risk – A process standard*.

UK

Bosker P, Escarameia M, and Tagg A. "Improving the flood performance of new buildings – Flood resilient construction", Communities and Local Government (2007).

Australia

"Water by Design, Concept design guide lines for water sensitive urban design Version 1", *South East Queensland Healthy Waterways Partnership*, Brisbane (2009).

US

Information about Multiple Flood-Proofing Techniques

"Homeowner's guide to retrofitting: Six ways to protect your house from flooding", *FEMA* 312 (1998).

"Homeowner's guide to retrofitting – Six ways to protect your house from flooding", *FEMA* (2nd ed.) P-312 (2009).

"Repairing your flooded home", *FEMA* 234 (1992).

"Selecting appropriate mitigation measures for flood-prone structures", *FEMA* 551 (2007).

"Engineering principles and practices for retrofitting flood-prone residential structures", *FEMA* 259 (2001).

"Flood-proofing: How to evaluate your options", US Army Corps of Engineers (1993).

"Coastal construction manual – principles and practices of planning, siting, designing, constructing, and maintaining residential buildings in coastal areas", *FEMA* 55 (3rd ed.) Vol. II (2000).

Elevation and Relocation of Buildings

"Above the flood: Elevating your flood-prone house", *FEMA* 347 (2000).

"Manufactured home installation in flood hazard areas", *FEMA* 85 (1985).

"Raising and moving the slab-on-grade house with slab attached", US Army Corps of Engineers (1990).

Dry Flood-Proofing

"Add waterproof veneer to exterior walls", Fact sheet, *FEMA* (2008).

"Dry flood-proof your building", Fact sheet, *FEMA* (2008).

"Non-residential flood-proofing – Requirements and certification for buildings located in special flood hazard areas", *Technical Bulletin 3-93, FEMA FIA-TB-3* (1993).

"Below-grade parking requirements for buildings located in special flood hazard areas", *Technical Bulletin 6-93*, *FEMA FIA-TB-6* (1993).

Wet Flood-Proofing

"Wet flood-proofing requirements for structures located in special flood hazard areas", *Technical Bulletin 7-93*, *FEMA FIA-TB-7* (1993).

Flood-Resistant Materials and Construction

"Flood damage-resistant materials requirements for buildings located in special flood hazard areas, *Technical Bulletin 2*, *FEMA FIA-TB-2* (2008).

"Flood-resistant design and construction", *ASCE/SEI 24-05, American Society of Civil Engineers* (2006).

Protecting Utilities and Equipment

FEMA fact sheets about various techniques for protecting your property from flooding:

- *Protect wells from contamination by flooding*
- *Install sewer backflow valves*
- *Raise or flood-proof HVAC equipment*
- *Anchor fuel tanks*
- *Raise electrical system components*
- *Build with flood damage-resistant materials*.

"Protecting building utilities from flood damage: Principles and practices for the design and construction of flood-resistant building utility systems", *FEMA* 348 (1998).

"Elevator installation for buildings located in special flood hazard areas", *Technical Bulletin 4-93, FEMA FIA-TB-4* (1993).

Appendix A: Brief Description of BFP Decision Tools

A.1 List of Building Retrofit Options

Description

Dealing with flood risk is different for existing and new buildings. New built buildings should preferably not be built in flood-prone areas. However new design can incorporate flood protection, but the viability of some possible mitigation options for existing buildings is questionable as protection for new buildings. The tool shown in Figure A1 provides an illustrative overview of the main design options for flood mitigation and their potential for existing and new built buildings.

Purpose

- Explain main flood hazard mitigation option for buildings
- Provide initial list of potential solutions for existing buildings and new built.

Input

- Does the assessment concern an existing or new built building?

Output

- Initial list of flood mitigation options for a building.

Flood Risk Mitigation at the Building Level

Symbol	Option	Description	Existing Buildings	New Buildings
	Do Nothing	Can you get away with it? Consider other (not building-related) options	?	✘
	Elevation	Elevation is raising your house so that the lowest floor is above the flood level. This is the most common way to avoid flood damage.	✔	✔
	Wet floodproofing	Wet floodproofing makes (uninhabited) parts of your house resistant to flood damage when water is allowed to enter during flooding.	✔	?
	Relocation	Relocation means moving your house to higher ground where the exposure to flooding is eliminated altogether.	✔	✘
	Dry floodproofing	Dry floodproofing is sealing your house to prevent flood waters from entering.	✔	?
	Levee and floodwall protection	Levee and floodwall protection means constructing barriers to prevent flood waters from entering your house.	✔	?
	Amphibious	House construction is bouyant and anchored to move with change waterlevels	?	✔
	Demolition	Demolition means razing your house and rebuilding properly on the same property or buying a house elsewhere	✔	✘

✔	*Possible Option*
✘	*Not Viable Option*
?	*Questionable option*

Figure A1: Overview potential viability of flood mitigation options for new and existing buildings

A.2 Protection Height Design Tool

Description

For buildings in flood-prone areas that are going to be retrofitted with protection measures, the protection level is defined by the remaining residual flood risk, which is the risk that the protection will fail. In Figure A2, a generic spreadsheet design tool is presented so that the probability of failure for a protection measure of a given height can be determined. The protection height is the height of the base flood elevation plus an additional safety margin called "*freeboard*". Climate change will decrease the level of protection and should result in an additional safety margin being included in the design of the protection.

Purpose

Define the required height of flood protection to reduce flood risk to acceptable levels.

Input Parameters

- Ground elevation of the site (parcel)
- Elevation of lowest floor of the building
- Design flood elevation
- Freeboard safety margin (on top of base flood elevation, AEP = 0.02)
- The site-specific probability for a particular flood height to occur with/without climate change (*see the Tools in 2.1 of the toolbox*).

Output

- Probability of failure of protection measures
- Setting of the main design parameters for the protection of a building.

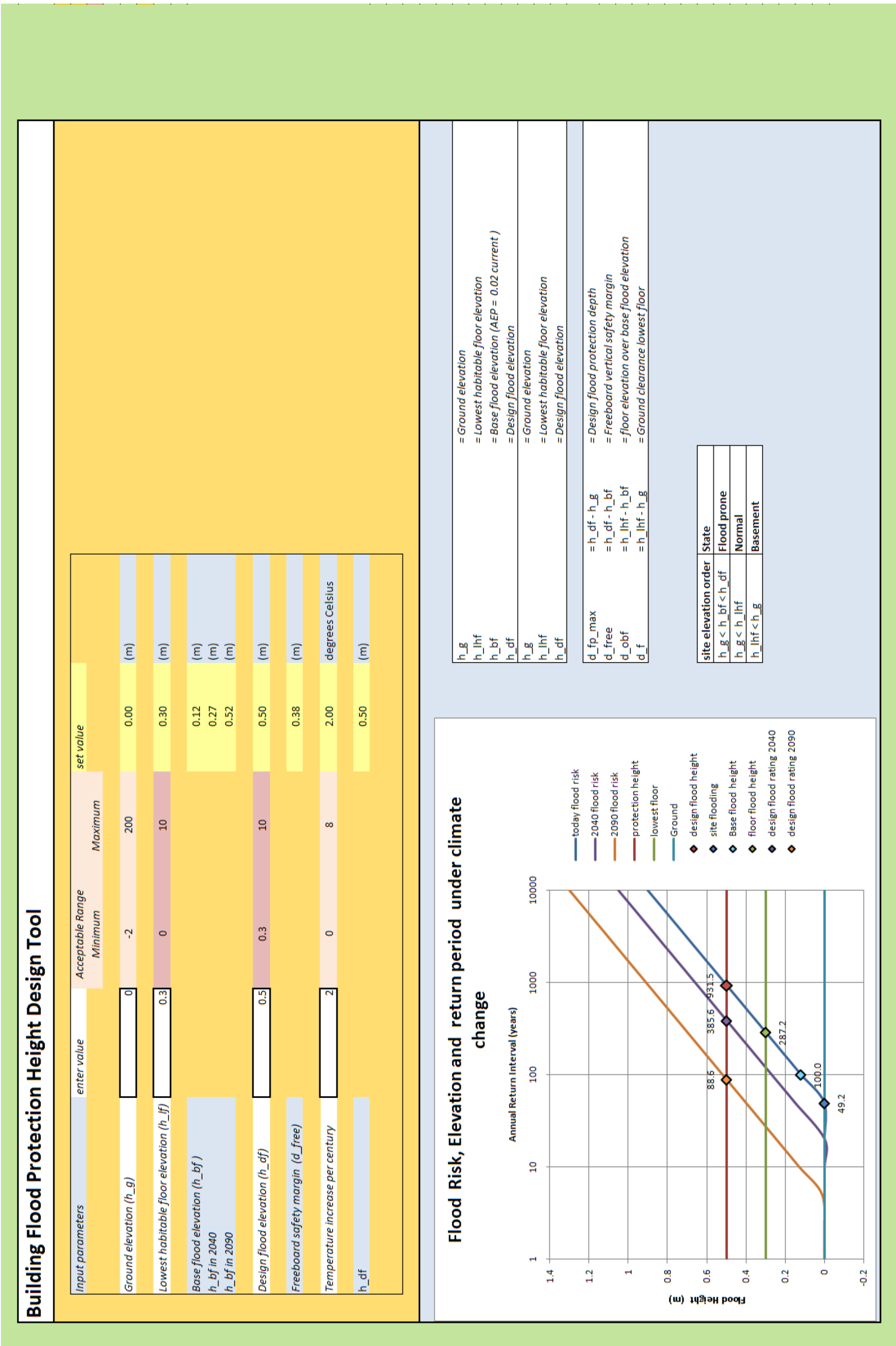

Figure A2: Building flood protection height design tool

A.3 Retrofit Suitability Assessment Tool

Description

Depending on the site characteristics, the building design and expected flood conditions, a set of building-specific mitigation options to reduce flood risk can be identified. This particular tool is shown in Figure A3. The tool is a spreadsheet that allows the user to identify less viable mitigation options.

The tool provides support for assessing the qualities of different protection measures with regard to sustainability aspects e.g. economic, social and environmental criteria.

Purpose

Identification of less suitable mitigation options, and assessment of sustainability aspects of potential viable protection measures.

Input

- Site characteristics
- Building design
- Expected type of flood
- Flooding conditions on-site (forces on the structure)
- Target protection height.

Output

- Reduced list of viable mitigation options.

Flood Impact Reduction Matrix

Flood Damage Reduction Measures

		Building Focused Flood Mitigation Measures											Non-structural				Flood Reduction Infrastructure			
		Elevation on Foundation Walls	Elevation on Piers	Elevation on Posts or Columns	Elevation on Piles	Elevation on Fill	Relocation	Buyout/ Acquisition Demolition	Floodwalls and Levees	Floodwalls and Levees with Closures	Dry Flood Proofing	Wet Flood Proofing	Flood Warning Preparedness	Flood Plain Regulation	Flood Insurance	Flood Mitigation Programs	Channel	Levee/Wall	Dams	Diversions
Flood	Flood Depth																			
	Shallow (<1m)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (1 to 2 m)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Deep (greater than 2m)	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	Flood Velocity																			
	Slow (less than 1mps)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (1 to 1.5 mps)	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	Fast (greater than 1.5 mps)	N	N	N	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	Flash Flooding																			
	Yes (less than 1 hour)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Ice and Debris Flow																			
	Yes	N	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Site	Site Location																			
	Coastal Flood Plain																			
	Beach Front	N	N	N	Y	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	2	N	N
	Interior (Low Velocity)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Riverine Flood Plain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Soil Type																			
	Permeable	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Impermeable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Building	Structure Foundation																			
	Slab on Ground	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Crawl Space	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Basement	Y	N	N	N	N	Y	Y	Y	Y	N	Y	Y	y	Y	Y	Y	Y	Y	Y
	Structure Construction																			
	Concrete or Masonry	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Metal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Wood	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Structure Condition																			
	Excellent to Good	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fair to Poor	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	Y	3	Y	Y	Y	Y
Sustainability	Economic																			
	Structure Protected	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	5	N	Y	Y	Y	Y	Y
	Cost to Implement	M	M	M	M	M	H	H	M	M	L	L	L	L	L	H/M	H	H	H	H
	Potential Flood Insurance Cost Reduction (Residential)	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	-	Y	Y	Y	Y	Y
	Potential Flood Insurance Cost Reduction (Commercial)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	-	Y	Y	Y	Y	Y
	Potential Adverse Flooding Impact on Other Property	N	N	N	N	Y	N	N	Y	Y	N	N	N	Y	N	N	Y	Y	Y	Y
	Reduction in Admin Costs of NFIP	N	N	N	N	Y	Y	Y	N	N	N	N	N	6	-	3	7	7	7	7
	Reduction in Costs of Disaster Relief	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Reduction in Emergency Costs	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	3	Y	Y	Y	Y
	Reduction in Damage to Public Infrastructure Elevation Exceeded	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	3	Y	Y	Y	Y
	Potential for Catastrophic Damages if Design	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	N
	Promotes Flood Plain Development	N	N	N	N	N	N	N	N	N	N	N	N	N	8	N	Y	Y	Y	Y
	Environmental																			
	Ecosystem Restoration Possible	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
	Potential Adverse Environmental Impact	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
	Recreation																			
	Recreation Potential	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	3	N	N	Y	N
	Social																			
	Community Remains Intact	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	4	Y	Y	Y	Y
	Population Protected N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	3	Y	Y	Y	Y	
	Potential Structure Marketability Increase	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	5	N	Y	Y	Y	Y	Y

(Adapted from USACE form)

Y	Yes
N	No
L	Low
M	Medium
H	High

Figure A3: Flood impact reduction matrix form

A.4 Retrofit Preference Tool

Description

Protection of a single building can only be done in close collaboration with the building owner. This tool illustrated in Figure A4 is an inventory sheet that can be used by a council advisor to work with the building owner towards a best choice for flood mitigation. The tool provides a practical two-step structure to assess and cover most relevant aspects associated with reducing the flood risk to the building under scrutiny. The first step eliminates the non-viable options. The second step identifies the option that is likely to be the most acceptable to the building owner.

Purpose

Creation of a ranking of the viable protection measures in close collaboration with the building owner.

Input

- Reduced list of viable mitigation options from previous analysis tools
- Assessment of the legal framework for these mitigation options e.g. are they allowed?
- Meet and interview the building owner
- Illustration material to inform building owner such as: "Homeowner's guide to retrofitting – Six ways to protect your house from flooding", *FEMA* (2nd ed.) P-312 (2009)
- Cost-benefit information of potentially viable options.

Output

- Hierarchy of the best building adaptation options for mitigation of flood risk
- A better informed and committed building owner.

NIWA Taihoro Nukurangi GNS Science Te Pū Ao BRANZ MWH Building a Better World

Retrofitting Preference Matrix

Owner's Name: Address : Property Location:	Prepared By: Date:

	Considerations	Building Focused Flood Mitigation Measures										
		Elevation on Foundation Walls	Elevation on Piers	Elevation on Posts or Columns	Elevation on Piles	Elevation on Fill	Relocation	Buyout/ Acquisition Demolition	Floodwalls and Levees	Floodwalls and Levees with Closures	Dry Flood Proofing	Wet Flood Proofing
Step 1	Measure **Not** Allowed											
	Not Feasible due to Owner Requirement											
	Total "X's" of step 1											
Step 2	Aesthetic Concerns											
	High Cost Concerns											
	Risk Concerns											
	Accessibility Concerns											
	Code required Upgrade Concerns											
	Off-Site Flooding Concerns											
	Other Concerns (Fill in):											
	Total "X's" of step 2											

Instructions:		
	Step 1	Determine whether or not a mitigation measure is allowed under the local regulations or if there is homeowner requirement. Put an "X" in the box for each measure which is not allowed under one of these two categories. Only Those measures with no "X's" will be considered in the next step.
	Step 2	For those measures that are allowable or owner required, evaluate the considerations to determine if the homeowner has concerns which could impact its implementation. A concern is defined as an homeowner issue which if unresolved would make the retrofitting method(s) in feasible. If the homeowner has a concern place an "X" in the box under the appropriate measure/consideration. Total the number of "X's" . The flooding measure with the least number of "X's" is the most preferred.

* (Adapted from USACE form)

Figure A4: Retrofitting preference matrix form

Appendix B: Pictorial Overview of the BFP Decision Framework and Other Content

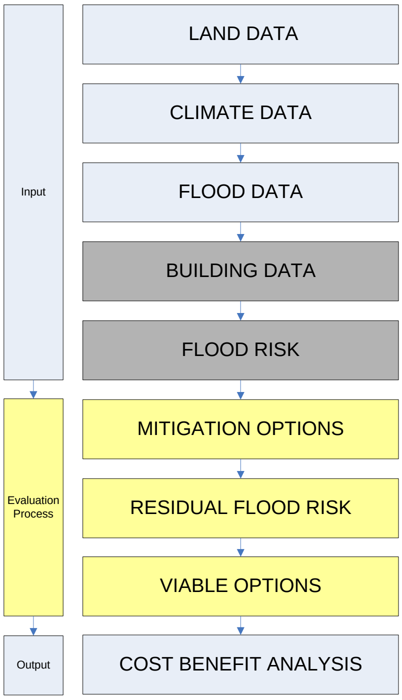

Figure A5: This tool supports the selection of viable building-specific retrofit options that mitigate risk from climate change enhanced flooding of buildings (it focuses on the yellow-coloured steps)

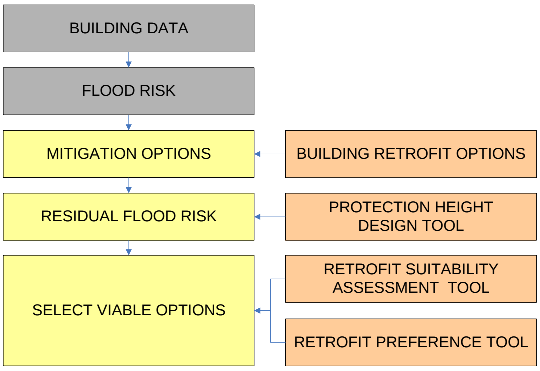

Figure A6: This tool set provides for four structural elements to support the selection process: a main set of building retrofit options; a protection height design tool; a retrofit suitability assessment check list; and a retrofit preference ranking tool

Table A1: Information Needs and Support

Data Category	Aspects	Such as
The physical properties of the land	Parameters	Site boundaries, polygon, area and elevation, slope, soil typology, site coverage
	Professional(s)	Chartered surveyor and geotechnical engineers
	Information	Local council and LINZ
	Tool(s)	Survey equipment, geographic information systems and maps
The flood conditions at the site of the building	Parameters	Design flood data including: source of flooding, flood depth, flood velocity, flood duration, rate of rise and fall, wave effects, flood-borne debris, scour and erosion
	Professional(s)	Hydrologist
	Information	Local and regional council
	Tool(s)	Hydrological or hydraulic models and long-term flood monitoring
The physical design details of the existing (or proposed new) building	Parameters	Structural and physical design of foundation, floors, walls, and roofs
	Professional(s)	Structural engineer and a building technologist
	Information	Local council records
	Tool(s)	Manual and digital drawings
The vulnerability of the building to damage by inundation	Parameters	Forces on building, structure and materials
	Professional(s)	Hydrological engineer, structural engineer and a building technologist
	Information	Local council, GNS
	Tool(s)	Riskscape
Design considerations regarding the adaptation options	Parameters	Forces on building, protection and adaptation specifications
	Professional(s)	Designer/architect, structural engineer and hydrologist, local government building official
	Information	Local council
	Tool(s)	Start point for professionals provided by set of adaptation options in Appendix A.1
Cost and benefits	Parameters	Material and labour cost
	Professional(s)	Economic planner or advisor, quantity surveyor
	Information	Trade and market literature
	Tool(s)	Cost benefit tools in the climate change toolbox

5. Contact Details

The BFP Decision Framework was developed by BRANZ. Should territorial authorities wish to make use of the tool they will need to provide data for each house they wish to assess. The data needed are the site-specific flood risk conditions and design details of the house. BRANZ can quickly tailor the tools in the Framework to suit local council needs.

Contact Johannes (Hans) Roberti at BRANZ, ph. (04) 237 1170, or email for further details and support.

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