Government of Western Australia
Department of Housing and Works

# DHW Technical Guideline (TG050)

## Building Resilience to Climate Change for Non-Residential Government Buildings Projects

July 2026

# Document Control

## Revision History

| Version | Date | Author/Editor | Summary of Changes |
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| 1.0 | July 2026 | BTS Climate Research Team/Graham McDonald | First Published |
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## Approvals

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| 1.0 | July 2026 | Dean Wood | Principal Architect |
| | | | |

*Acknowledgment: The Department of Housing and Works (DHW) would like to acknowledge the collaborative efforts of the Cyclone Testing Station and the JCU team, especially Dr Geoff Boughton, whose dedication and teamwork were instrumental in drafting the advice relating to extreme wind events.*

## Contents

# Executive Summary

Although the rate of growth has slowed in recent years, global greenhouse gas emissions continue to increase, and the full extent of climate change impacts on society will take decades to fully emerge.

In this context, the climate resilience measures outlined in this technical guideline (the Guideline) establishes the Department of Housing & Works' (DHW) framework for integrating climate resilience into the planning, design, construction and ongoing management of non-residential government buildings, as delivered by the Building & Contracts Division.

The Guideline's mandate is to ensure climate-related risks are identified early, consistently assessed, and managed through proportionate planning, design, construction, and operational responses that safeguard asset performance, service continuity, and community wellbeing, while enabling stakeholders to make timely, risk-informed decisions aligned with policy, standards, and budget constraints.

*The minimum expected action under this Guideline is to:*

- Complete a Climate Change Pre-screening Checklist at Project Initiation.

This checklist aims to highlight climate hazards relevant to the site, building, and its intended use by the client agency. It aligns with the Minimum Requirement of the Green Building Council of Australia's Green Star Buildings Submission Guideline[1] – Credit 17 Climate Resilience and DHW's technical guideline for environmentally sustainable design (TG040)[2].

*Encouraged but not mandated* are risk assessments and the application of risk treatment measures for the risks identified during the climate change pre-screening activity. Therefore, ideally:

- Undertake a climate change impact (risk) assessment,
- Identify, document and treat high and extreme risks,
- Embed agreed resilience measures into project documentation and delivery, and
- Monitor and evaluate the effectiveness of those measures through client agency feedback.

The following Sections provide detail for building practitioners on the above expectations and encouraged activities are intended to guide and inform planning, design and construction decisions, rather than represent a comprehensive solution.

While climate related bushfires risk treatments are not addressed in this Guideline, they have their own specific reference document, DHW's Technical Guideline TG015 - Building in Bushfire Prone Areas[3]. TG015 highlights to designers the need to be "climate aware" due to our drying climate, more extreme temperature events, and extended fire seasons.

[1] Green Building Council of Australia's Green Star Building Submission Guideline
[2] DHW - Technical Guideline TG040 - Environmentally Sustainable Design for Non-Residential Government Buildings
[3] DHW - Technical Guideline TG015 - Building in Bushfire Prone Areas

# 1. Introduction

## 1.1 Climate Change

Our planet is warming, and a clear correlation exists between the rate of warming and the accumulation of greenhouse gases (GHG) in the atmosphere. As can be seen in Figure 1.1 below, there is a non-linear accelerating growth rate of GHG in our atmosphere.

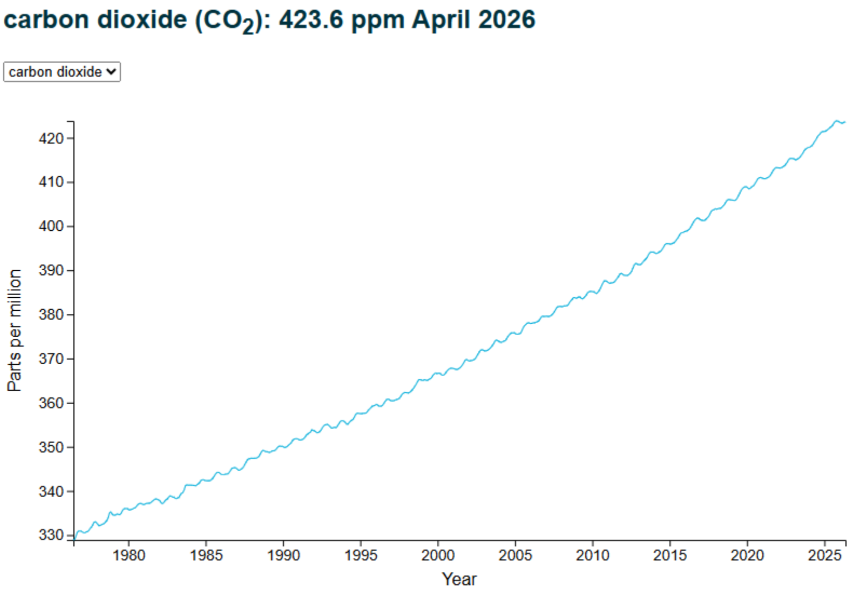


**Figure 1.1 Cape Grim (Tasmania) Greenhouse Gas Data (Source CSIRO[4])**

Efforts to reduce anthropogenic GHG emissions are underway in most regions of the world, to try and contain the warming to no more than 2°C above the 1850-1900 baseline.

Australia's commitment to the global emission reduction response, in-line with many developed countries, was to set a target of net zero GHG emissions by 2050, referred to as our commitment to the Paris Agreement.

The WA state government has affirmed its support for this target and through their Climate Adaption Strategy[5] encourages agencies to address the impacts of rising temperatures on government services and infrastructure.

## 1.2 Purpose of the Guideline

The purpose of Technical Guideline TG050 (this Guideline) is to promote the siting, design and construction of non-residential government buildings in a manner that maintains functional performance under a changing climate; hence focusing on protecting assets, services, and community wellbeing. Further, the Guideline requires the building owners and operators to be informed of the resilience measures adopted and the need to monitor and evaluate their effectiveness as the climate continues to change.

[4] CSIRO - Cape Grim (Tasmania) Greenhouse Gas Data
[5] WA Government - Climate Adaptation Strategy

## 1.3 Core Objective

The core objective of this guideline is to assist with integrating climate risk assessments into project business cases, project definition planning, and the building design, construction and facilities management processes.

## 1.4 Governing Status

The Department of Treasury and Finance's Strategic Asset Management Framework (SAMF) requires consideration by Government Agencies of:

> *Potential impacts of climate and seasonal variations on design, project delivery, and asset whole-of-life operations.*

For Project Definition Planning (PDP), the SAMF requires Government Agencies to:

> *Summarise how the changing climate may impact the asset life and identify what climate resilience, durability, and adaptation measures are necessary.*

These requirements afford the client agency the opportunity to address and manage climate resilience measures on their projects.

It is important to note however that inclusion of climate resilience measures in asset investment proposals for Expenditure Review Committee (ERC) consideration, does not guarantee such costs being included in proposal budgets. Therefore, Project Managers need to confirm with the client agency on a project-by-project basis, what climate resilience measures have been afforded on the project.

## 1.5 Guideline Application

This Guideline is to be used by the project team (client agency's representative, DHW's project managers, the design teams and contractors) to support consistent consideration of climate-related risks, but does not replace, applicable legislation, statutory approvals, the NCC, Australian Standards, whole-of-government policies and project-specific contractual requirements. Where there is any inconsistency between those requirements and this Guideline, those instruments prevail to the extent of the inconsistency, unless this Guideline presents a higher standard for resilience, in which case the higher standard needs to be considered by the project team.

The client agency's emergency management plans take precedence for all operational resilience matters. Managing climate risks, (e.g. addressing power and water loss) needs to be addressed in that context.

# 2. Roles and Responsibilities

## 2.1 Client Agencies

Client agencies are responsible for lodging and obtaining Government approval for each project. As part of this process, a client agency establishes the appropriate scope to address its service delivery requirements and stakeholder concerns, secure sufficient budget, and set achievable timelines for delivery in accordance with the SAMF.

When undertaking the Business Case and Project Definition Plan (PDP), it is incumbent on each client agency to ensure robust, high-quality cost estimates are prepared, including commitments to address climate change impacts, and to champion the highest resilience standards that will be supported during the Expenditure Review Committee process. Therefore, client agencies, while continuing to work within approved funding limits and project budgets, are responsible for:

1. *Identifying the most appropriate site for the proposed building that minimises exposure to climate impacts.*
2. *Ensuring the Business Case and PDP clearly articulate the climate change risks associated with the site selected and the client agency's risk tolerance: informing DHW's Project Managers of any strategic risk treatments to be integrated into the project delivery phase. The Climate Change Pre-screening Checklist in Appendix 1 may be used to aid in identifying the strategic risk treatments.*

## 2.2 Department of Housing & Works

DHW delivers capital works projects for its client agencies within agreed time, cost, and quality parameters, in accordance with Government priorities, procurement requirements, and the obligation to achieve value-for-money outcomes.

DHW, and the design teams it engages, are committed to working collaboratively with client agencies and responding to their requirements, while maintaining primary accountability to Government priorities.

Design teams are fully responsible for ensuring that project designs achieve the required climate resilience performance within budget, factoring in the project lifecycle, and consistent with the State Government's Architectural Services Brief for Non-Residential Government Buildings.

In this context, DHW is responsible for:

3. *Embedding the client agency's climate change requirements into the Design Team's scope.*
4. *Integrating climate risks into design and construction risk management processes.*

## 2.3 Project Control Group

Given the long-term implications for asset performance and resilience, the project team must proactively and effectively address the above four key responsibilities. This is in addition to the normal design activities that address operational risk, such as requirements for onsite standby electrical generation and water storage systems to maintain operations in the event of utility supply interruptions.

# 3. Climate-Related Risk Management

## 3.1 Environmentally Sustainable Design

DHW developed a technical guideline (TG040) to address all aspects of environmentally sustainable design (ESD) on non-residential government building projects delivered by DHW's Buildings & Contracts Division.

Used extensively in TG040 to rate the ESD performance of the building design, is the Green Star Buildings Submission Guideline[6], as provided by the Green Building Council of Australia (GBCA).

## 3.2 Credit 17: Climate Resilience

GBCA's Submission Guideline provides a pathway for the project team to address climate resilience on the project. This pathway comes under Credit 17, which has two components: a *Minimum Expectation* (Climate Change Pre-screening Checklist) requirement and a *Credit Achievement* (Climate Change Impact Assessment).

Note, the application of Credit 17 is an important aspect of this Guideline and will be discussed further below.

### 3.2.1 Minimum Expectations (Pre-screening Checklist)

In the GBCA's Submission Guideline, the requirements of all Minimum Expectation categories need to be met before any points can be awarded for addressing the requirements of the Credit Achievement categories. To meet the Minimum Expectation on Credit 17, a Climate Change Pre-screening Checklist needs to be completed for the project. This is equally a requirement of DHW's Technical Guideline for ESD (TG040).

The pre-screening for climate impacts should form part of the project briefing started by the client agency and kept up to date by the design team throughout the project. Note: any climate risks found during pre-screening do not have to be addressed at this stage. See **Appendix 1** for details of what should be included in the project's Climate Change Pre-screening Checklist.

### 3.2.2 Credit Achievement (Impact Assessment)

For the project to attain the Credit Achievement, i.e. improve on the Minimum Expectation, the project should build on the Climate Change Pre-screening Checklist by:

- Completing a Climate Change Risk & Adaptation Assessment (the Assessment), and
- Managing the Risks.

Summarised below in Figure 3.1 is the typical climate change impact assessment process which assists in managing the risks.

[6] Green Building Council of Australia's Green Star Building Submission Guideline

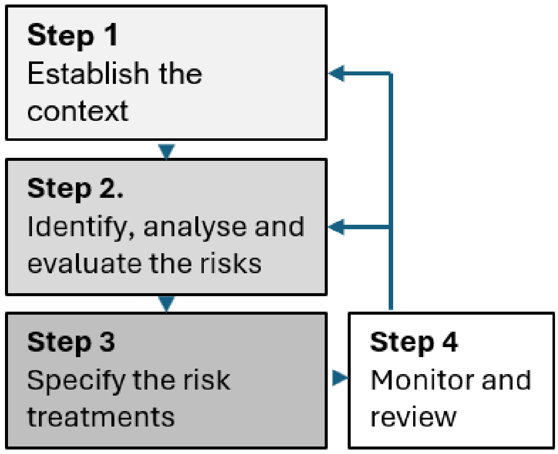


**Figure 3.1: Climate Change Impact Management Process**

Step 1: Establishing the Context can be achieved by using the Climate Change Pre-screening Checklist (Appendix 1).

Step 2: Includes the Climate Change Risk and Adaptation Assessment.

Step 3: Focuses on Managing the Risks.

Step 4: Client agency's asset management process, informed by Steps 1 - 3.

The Assessment should be undertaken early, during the initial phases of the project to better inform design decisions. Suitably qualified professionals should conduct the assessment for the building and its site, using information from the Climate Change Pre-screening Checklist and the historical data and future climate projections for the project location, as further detailed in the Assessment section below.

**The Assessment –** the project team should, as required by GBCA's Credit 17:

- Apply future climate change projections based on **IPCC-AR5 RCP 8.5 or IPCC-AR6 SSP 3-7.0** scenarios. *Due to a lack of easily accessible data, this requirement is not fully supported by DHW - see section 3.3.3 for the recommended climate change projections to be used.*
- Use two lifespan-appropriate timescales: medium-term (**2050**) & long-term (**2090**).
- Identify relevant primary and secondary climate change variables and each risk for the project from the Table 3.1 below (extracted from *table 2* of AS 5334:2013[7]).
- Document a brief justification for the exclusion of remaining climate change variables from Table 3.1 based on their relevance to the project.
- Define and incorporate the consequence and likelihood criteria, along with the risk matrix, used to evaluate climate-related risks. See Section 3.4.
- Conduct risk assessments in consultation with the client agency, and relevant design disciplines, and local government.
- Develop a climate change risk register for the building and external works.

[7] AS 5334:2013 Climate change adaptation for settlements and infrastructure

- Provide treatment for risks or residual risks identified as *High* and *Extreme* risks.
- Align the climate change impact assessment with AS 5334:2013, ISO 14091:2021[8] and the risk management principles of AS ISO 31000:2009[9].

| Element | Climate Change Variable (Indicative) |
|---|---|
| Water | • Riverine (Fluvial) Flooding<br>• Flash (Pluvial) Flooding<br>• Sea level rise<br>• Storm surge and storm tide<br>• Extreme rainfall events<br>• Drought<br>• Ground Stability (Landslides) |
| Temperature | • Long term changes<br>• Extreme temperature events |
| Humidity | • Long term changes |
| Wind | • Cyclones<br>• Gales and extreme wind events<br>• Storms (including hail) |
| Bushfire | • Bushfire Attack Level<br>• Smoke |

**Table 3.1: Climate Change Variables**

**Managing the Risks** - the project team addresses identified risks as follows:

- Risks rated "***High***" should be managed through the application of project-specific design and/or operational measures.
- Risks rated "***Extreme***" should be managed through project-specific design measures.
- A minimum of two identified risks, regardless of their assigned risk rating, should be mitigated through project-specific design responses. Noting that all *High* and *Extreme* risks should be mitigated.
- Note, the client agency is required to approve the initial and residual risk ratings from the assessment.

Assessment outcomes must be communicated to all key project team stakeholders, including the client agency's representative, DHW's project manager, design team, and head contractor.

[8] ISO 14091:2021 Adaptation to climate change
[9] AS ISO 31000:2018 Risk management - Guidelines

## 3.3 Climate Data

### 3.3.1 Current Climate Data

Although the National Construction Code does not mandate the use of the latest weather data, up-to-date climate data is essential to ensure adequate sizing of plant and systems, particularly HVAC systems. The latest site-specific weather files can be obtained from reliable sources such as the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH)[10] and the Bureau of Meteorology (BOM)[11].

Data files for energy modelling using historic weather data, referred to as Typical Meteorological Year (TMY) is available from Commonwealth Scientific and Industrial Research Organisation (CSIRO)[12].

### 3.3.2 Future Site-specific Climate Data

More importantly, again for energy modelling there is a lack of building projects using weather files that have climate change factors incorporated. While comprehensive region-specific climate files are still being developed, datasets from the CSIRO[13] are available for immediate use.

Heatwave files have still to be developed for Western Australia, referred to as the Extreme Meteorological Year (XMY). Until these become available, the use of AIRAH's DA09 - critical temperature data for critical plant design, and CSIRO's Projected Weather Data for future year, that is used to stress test the critical plant design, is acceptable.

### 3.3.3 Climate Projections

To complete the Climate Change Impact Assessment in TG050, GBCA's Credit 17 *Climate Resilience*, requires the use of the following climate projections:

- Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report Representative Concentration Pathway 8.5 (RCP 8.5) or
- IPCC Sixth Assessment Report Shared Socio-economic Pathway 3 (SSP3-7.0).

CSIRO and Bureau of Meteorology's, Climate Change in Australia website provides a Climate Futures Exploration Tool[14].

This tool enables selection of the climate scenario (RCP 4.5, RCP 8.5, etc), climate variables (mean surface temperature, rainfall, etc), year of interest (2050, 2090, etc), and the climate region (Southern and South-Western Flatlands, Rangelands, and Monsoonal North) and provides a level of probability for changes to the climate variables.

RCP 8.5 has previously been applied as a high-end scenario for stress testing purposes. However, it is now generally considered to represent a low-likelihood pathway, particularly if extended beyond 2050, and hence its use should be contextualised accordingly.

[10] AIRAH DA09 - Air Conditioning Load Estimation and Psychrometrics (Extracts)
[11] BOM - Climate Data Online
[12] CSIRO - Typical Meteorological Year (TMY) Data for Building Energy Modelling
[13] CSIRO - Projected Weather Files for Building Energy Modelling
[14] CSIRO & Bureau of Meteorology - Climate Futures Exploration Tool

Therefore, RCP 8.5 can still be used in climate risk assessments up to 2050 as a high-end or stress-testing scenario, as emissions and temperature projections under different pathways do not diverge substantially before mid-century.

Beyond 2050, where only RCP-based datasets are available and the use of RCP 8.5 beyond 2050 is not considered appropriate, RCP 4.5 (or equivalent) may be adopted as a central scenario. For stress testing purposes, upper-bound conditions should be approximated through the application of scaling factors. Scaling factors may be informed by the relative difference between RCP pathways at mid-century to maintain internal consistency, i.e. if RCP 8.5 rainfall intensity is x% more than RCP 4.5 at 2050, apply this (x%) scaling factor uplift to the values of RCP 4.5 beyond 2050. Note, in some cases the scaling factor will decrease the variable quantity, i.e., rainfall quantity in the Southern and South-Western Flatlands.

Hence, the climate data that should be used, for the Assessment noted in section 3.2.2 above, is:

- *RCP 8.5 - applied up to and including 2050.*
- *RCP 4.5 - applied, with an appropriate scaling factor uplift, to dates beyond 2050, up to and including 2090. Scaling factors will need to be declared.*

It is recognised that projected climate data, and the lack thereof currently, add to the complexity of climate risk assessments. The flowchart in Figure 3.2 below provides an overview to assist in reducing this complexity. Designers need to satisfy themselves that they are applying the most current data to the correct application, such as plant sizing.

As a final note on climate projections, SSP3-7.0 scenario is now considered an appropriate current high-end scenario and broadly aligns with the direction of upcoming CMIP7 scenarios. However, until the data is made available in a useable format to WA designers, the Climate Futures Exploration Tool’s RCP data should be used.

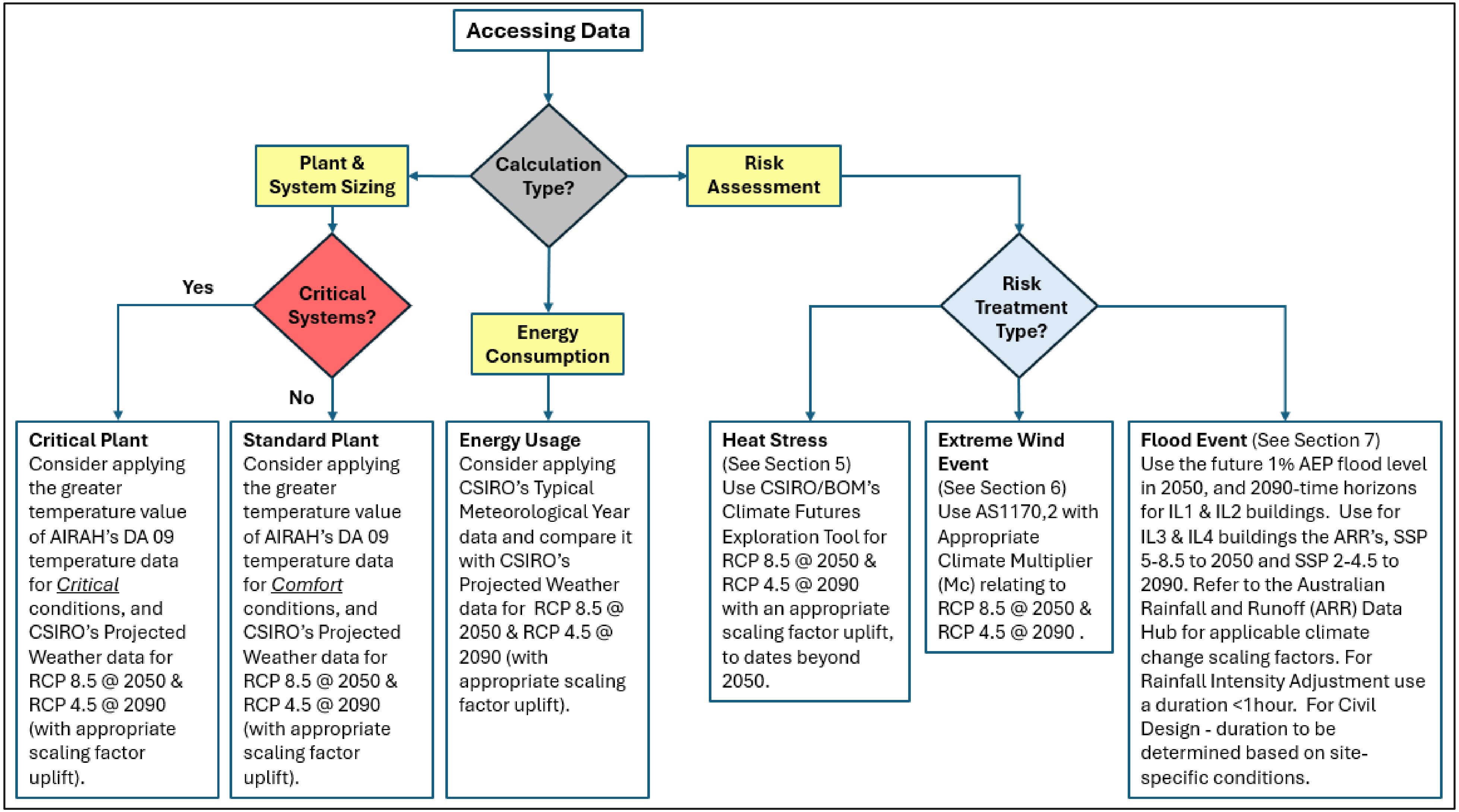


**Figure 3.2 – Flowchart of Data Access**

## 3.4 Assistance with Climate Change Impact Assessments

The Department of Water and Environmental Regulation (DWER) has published the Western Australian Climate Change Risk Management Guide (Interim)[15], which provides practical guidance for undertaking a first-pass assessment of physical climate risks.

DWER's guide seeks to develop agencies' capacity to assess, manage and report on the implications of climate change on the State's finances, infrastructure, physical assets and service delivery. Available in support of the Interim Guide is a Climate Risk Assessment Tool,[16] as shown in Figure 3.3 below.

| | | | | | Natural hazards (climate related) | | | | | | | | Worst case risk rating based on 2030 climate change projections | | | Worst case risk rating based on 2090 climate change projections | | | Existing Controls | | Risk Treatment Options | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Risk ID | Risk description | Business area/Risk owner | Date last assessed DD/MM/YY | Risk category | Sea level rise & coastal flooding | Mean temperature | Heatwaves/extreme heat days | Relative humidity | Bushfires | Extreme rainfall and flooding | Extreme storms (incl wind & hail) | Droughts | Likelihood | Consequence | Risk rating | Likelihood | Consequence | Risk rating | Controls & treatments (existing) | Control effectiveness for 2030 period | Proposed treatments (adaptation actions) | Residual risk level 2031 | Review and reporting requirements | Comments |
| Unique identifier | Refer to Guidance for advice on developing a climate risk statement, or refer to the Example Risks tab | Who is responsible for managing the risk | | e.g. financial, service delivery, work health and safety. Note: your organisation may have different categories. | e.g. map against natural hazards to help understand how many risks relate to specific natural hazards and/or identify any gaps | | | | | | | | The risk if the current control strategy fails completely, based on the risk assessment criteria outlined by your organisation's enterprise risk management framework/guidance | | | The risk if the current control strategy fails completely, based on the risk assessment criteria outlined by your organisation's enterprise risk management framework/guidance | | | Current controls | Select level of effectiveness from drop-down list | Additional control if risk is not acceptable. Refer to Example adaptation actions tab | Expected level of risk remaining after adaptation actions are implemented | How and when the risk and controls are to be reviewed and reported | Uncertainties or sensitivities; potential impact on organisational objectives; resources required (financial, physical, human resources, knowledge) |
| 1 | *EXAMPLE* Increased number of health issues related to heat stress in the workplace due to higher temperatures and increased severity of heatwaves. | Operations | 20/09/19 | | | I | I | I | | | | | Possible | Minor | Medium | Likely | Moderate | High | Upgrade of building HVAC undertaken in 2018; shading and fans provided in outdoor areas | Substantially effective | Heat stress communications and corporate awareness to be embedded in corporate OSH by 2022 | Medium | Embed in corporate risk register and OSH Strategic Plan. Review as part of annual strategic planning process | |
| 2 | User input | User input | DD/MM/YY | | | | | | | | | | Select | Select | N/A | Select | Select | N/A | User input | Select | | Select | | User input |
| 3 | User input | User input | DD/MM/YY | | | | | | I | | | | Select | Select | N/A | Select | Select | N/A | User input | Select | | Select | | User input |

**Figure 3.3 – DWER's Climate Risk Assessment Tool**

Provided, the Climate Change Pre-screening Checklist has been completed for the project, DWER's Climate Risk Assessment Tool can be used to assess the risks, with the assessments conducted using the projections and timescales outlined in section 3.3.3 above.

When using DWER's Climate Risk Assessment Tool, best practice is to tailor risk categories to those relevant to the project and clearly show; current risk, future climate risk, risk treatment measures to be applied and resultant residual risk.

## 3.5 Specifying Risk Treatments

Risk treatments are designed to address the priority risks identified through Steps 1 & 2 of the Climate Change Impact Management Process, see Figure 3.1. These measures aim to reduce the project's vulnerability and enhance its resilience by targeting specific risks through practical interventions.

This Guideline is structured to assist with the identification of Risk Treatments through the following sections:

Section 4 Climate-Responsive Site Planning
Section 5 Design Phase Considerations for Heat Stress
Section 6 Design Phase Considerations for Extreme Wind Events
Section 7 Design Phase Considerations for Flood Events
Section 8 Construction Phase Considerations

Other complementary technical guidelines are available through DHW's Consultant's Guidance and Forms webpage[17]. Most relevant for building resilience to climate change include:

[15] DWER - Western Australian Climate Change Risk Management Guide (Interim)
[16] DWER - Western Australian Climate risk assessment tool
[17] DHW - Consultant's Guidance and Forms

- TG015: Building in Bushfire Prone Areas (TG015 must be referenced for climate related bushfires risks).
- TG016: Corrosion Protection.
- TG030: Glass Panels in Non-Residential Government Buildings.
- TG040: Environmentally Sustainable Design Guideline for Non-Residential Government Buildings.
- Northern Regions Heating, Ventilation and Air Conditioning Design Guideline.

It is the responsibility of the design team to critically evaluate the relevance and effectiveness of these risk treatment measures, identify any additional treatments needed, and incorporate them into the project in collaboration with the rest of the project team members.

## 3.6 Risk Monitoring and Review

The risk monitoring and review process should align with relevant government policy and the client agency's asset management agenda, such as its Strategic Asset Management Plan. This helps ensure that climate risks and treatment measures are understood, implemented and remain effective during the building's operation and maintenance phase, and that lessons learned are fed back into future assessments.

To be actioned by the client agency, it is recommended that the monitoring and review process entails:

- Monitoring risks and controls.
- Reviewing effectiveness of controls.
- Responding to change.
- Periodic formal reviews.
- Continuous improvement.
- Documentation and communication to building users and future design teams.

Further details are provided in Appendix 4.

## 3.7 Implementation and Cost Analysis

Climate resilience measures should be evaluated for cost-effectiveness and project-specific impact. Passive measures should be considered first, with active measures used where passive strategies are unlikely to fully address the risk, such as maintaining the required internal conditions.

Project teams can then prioritise measures based on impact and feasibility. For example, installing ceiling fans in large-volume spaces offers a low-cost, high-impact improvement for heat resilience and can be implemented immediately as a short-term gain.

# 4. Climate-Responsive Site Planning

Climate-responsive site planning is coordinated actions that requires anticipating the climate related hazards simultaneously, when assessing the risks associated with site location and services to be delivered on site.

## 4.1 Integration Strategy for Site Planning

The following stages outline a methodology for integrating climate resilience measures into the site planning activities. This assumes that zoning under the Western Australian State Planning Policies [18] and rules relevant to Western Australia have already been addressed and utilities to site are available with appropriate future capacity.

## 4.2 Initial Hazard-Informed Site Analysis

Site Analysis should:

- Prioritise life safety, then operational continuity, then passive resilience.
- Map the risks and in particular heat exposure, flood risk, and wind hazard zones.
- Identify conflicts (e.g., heat resilience wants breezeways; wind resilience wants shelter).

## 4.3 Zoning & Land Allocation

From the mapping exercise in Section 4.2 above, designate:

- Low-risk zones for critical infrastructure and buildings.
- Moderate-risk zones for non-critical facilities, parks, and circulation spaces.
- High-risk zones for flood storage, and wetlands, while maintaining setbacks from river riparian zones and coastlines.

## 4.4 Building Placement & Orientation

From the conflicts identified in Section 4.2 above, balance heat, wind and flood risks noting that:

- Heat resilience favours the long axis having an east-west orientation, with air movement between the blocks and the ability to provide crossflow ventilation when the conditions are advantageous.
- Wind resilience seeks to build in the sheltered area. Where feasible, orient narrow faces toward dominant extreme winds.
- Flood resilience requires buildings to avoid obstructing natural drainage paths and to be placed on higher ground within the site, with safe evacuation routes above flood levels. Raising building platforms above design flood level (DFL) or freeboard height if high ground is not possible.

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[18] Western Australian State Planning Policies

## 4.5 Landscaping

- Where landscape maintenance can be assured, vegetation is a strong passive climate resilience tool. Drought-tolerant trees provide shade and wind buffering and are more able to cope with drying-climate stresses. Aim to continuously shade pedestrian routes (see Figure 4.1 below) and provide cool refuges (shade, seating, airflow) for large campuses.

**Figure 4.1 - Shaded Pedestrian Route**

- Work with natural systems to absorb and slow water. Wetlands and bioswales provide flood attenuation. Apply SuDS (Sustainable Drainage System) and WSUD (Water Sensitive Urban Design) approaches to urban water management.

## 4.6 Materials & Surfaces

- Use light-coloured, permeable pavements for heat and water management.
- Avoid large hardscapes that store heat and increase runoff.
- Use water-resistant materials below flood levels.
- Use low conductivity materials where exposed to the sun and in contact with building patrons.

## 4.7 Infrastructure Resilience

- Elevate critical systems above flood levels.
- Wind-rate all exposed equipment, especially when located on roofs.
- Consider providing redundancy for cooling, power and water services as appropriate to the building type and services to be delivered.
- Assume failure scenarios could combine hazards, such as heatwaves + power outage, and storm + flooding.
- Protect infrastructure (solar panels, HVAC, utilities) from uplift and debris.

## 4.8 Movement & Access

- Provide shaded, breezy pedestrian routes, as noted above.
- Ensure evacuation routes remain safe during floods and wind events.
- Avoid placing access paths in wind corridors or flood channels.

## 4.9 Long-Term Adaptability

- Allow space for additions that the initial project budget could not sustain, such as additional shading, wind protection and expanded infrastructure to cope with future extreme climates.

## 4.10 Planning & Design Guidance Notes

Climate Resilience – Planning & Design Guidance Notes, in Appendix 2, provides a non-exhaustive list of risk treatment actions that should be assessed and applied as appropriate to the specific context and risk profile of the project. Guidance Notes are intended to support, not replace, professional judgement and relevant standards.

# 5. Design Phase Considerations for Heat Stress

This Section provides risk treatments for Heat Stress. The suggestions and recommendations provided here are not exhaustive and hence the design team need to consider the treatment measures in the context of the building project as outlined in Section 3.

## 5.1 Thermal Comfort Design Parameters

Thermal comfort design parameters should reflect the function of each space and the needs of its occupants, considering asset criticality and occupant vulnerability. These parameters are typically defined early in the design process. For building resilience to climate change they should:

- Address performance under typical operating conditions as well as during extreme events, such as heatwaves.
- Consider projected temperature increases over the building's design life due to climate change, ensuring long-term resilience and occupant wellbeing.

## 5.2 Comfort Assessment

Dynamic simulation is generally required to assess whether thermal comfort design parameters will be achieved over the life of the asset.

The following recommended comfort criteria should be applied for mechanically ventilated spaces:

- The standard thermal comfort level as referenced in the National Construction Code Vol.1[19] is to achieve a Predicted Mean Vote (PMV) between -1.0 and +1.0 for not less than 95% of the occupied floor area for not less than 98% of the building's operational hours. This requirement applies equally to assessments based on suitable future weather files.
- For spaces accommodating vulnerable occupant groups, such as the elderly, disabled, infirm or very young children, designers must apply judgment beyond the standard.

## 5.3 Thermal Comfort During Heatwaves

Buildings should be designed to maintain acceptable thermal comfort during heatwaves. While it may not be feasible to maintain comfort in all spaces under extreme conditions, critical areas, particularly those serving vulnerable occupants or essential functions, should be designed to perform under anticipated elevated temperatures.

- To evaluate performance under future heat stress, dynamic thermal simulations, as Figure 5.1 below, should incorporate climate change projections. CSIRO's[20] Projected Weather Files—based on the RCP 8.5 scenario for the year 2050 & RCP

[19] NCC 2022 Volume One - Building Code of Australia Class 2 to 9 buildings
[20] CSIRO - Projected Weather Files for Building Energy Modelling

4.5 scenario for the year 2090 (with an appropriate scaling factor uplift, See Section 3.3.3.)—may be used to assess long-term resilience.

**Figure 5.1 - Model of a Typical Primary School**

## 5.4 Minimising the Risk of Overheating

### 5.4.1 External Heat Gains

Once site planning and overall cooling strategies are established, it is essential to begin individual building design by minimising excessive external heat gain through early integration of passive design measures. These include building-integrated solar shading, high-performance insulation (where appropriate) in walls, roofs and floors, operable glazing systems for venting the building when the conditions permit, optimised window-to-wall ratios and thermally efficient glass.

Reducing external heat gain not only enhances occupant thermal comfort but also decreases dependence on mechanical cooling systems, contributing to improved energy efficiency and long-term climate resilience.

Recommended approach:

- **Apply the passive design** measures, tailored to the specific requirements of each climate zone.
- **Use thermal modelling** to demonstrate a minimum 10% reduction in annual external heat gain—including solar radiation, conductive transfer, and air infiltration—compared to the NCC J1V3 reference building.

### 5.4.2 Cooling Loads

After external heat gains have been addressed, internal cooling loads should also be minimised. This can be achieved by exhausting heat at its source, using ceiling fans where appropriate, reducing lighting power density, and implementing effective operational controls. These measures can improve thermal comfort while reducing cooling demand and energy use.

Recommended approach:

- Design teams should aim to demonstrate at least a 10% reduction in annual internal heat gain compared to the NCC J1V3 reference building, using thermal modelling and energy performance analysis.

Strategies to achieve this include:

- **Exhausting warm air** through or above light fittings and from above other heat sources in the room.
- **Ceiling Fans** or personal fans can be used either as a supplement or alternative to mechanical cooling. Increasing air movement can create a ventilative cooling effect, allowing for higher indoor temperatures (2-3°C above the normal setpoint) while still maintaining thermal comfort, as Figure 5.2 below.
- **High-efficiency lighting systems**, such as LED fixtures with high luminous efficacy, combined with smart controls like occupancy sensors and dimmable lighting to reduce unnecessary energy use.
- **Smart plug load management**, where aligned with client agency's policy, include scheduled shut-off settings and programmable timers to automatically disconnect non-essential equipment when not in use.
- **Energy-efficient IT appliances and equipment,** preferred to reduce both energy consumption and associated heat emissions.

**Figure 5.2 – Ceiling Fans Used in Learning Spaces**

## 5.5 Mechanical Cooling

Mechanical systems should be designed to accommodate current and projected thermal loads, particularly given the increasing frequency and intensity of heatwaves and the associated risk of operational disruption.

If we consider the rise in temperature associated with climate projection RCP 8.5, a building constructed in Perth, Western Australia in 2030 with a cooling plant capacity of 1,000 kW and floor space for cooling plant of 120 $m^2$ may need a cooling plant capacity of 1,200 kW in 2050, and a floor space of 144 $m^2$.

Therefore, cooling systems, plantrooms, service risers and service routes must be appropriately sized and configured with operating parameters that ensure reliable performance under extreme heat conditions – and ideally incorporating design provisions that facilitate future upgrades or replacements that may require larger equipment footprints.

Key recommendations include:

- **Use Updated Climate Data:** Define HVAC design conditions using the most current climate datasets available from sources such as the AIRAH DA09: Air Conditioning Load Estimation and Psychrometrics[21]. Project teams should also incorporate site-specific data from the Bureau of Meteorology (BoM), their Climate Data Online[22], to account for the increasing frequency of extreme weather events.
- **Design for Heatwave Resilience:** Ideally HVAC systems should be sized and specified to operate effectively under heatwave conditions, reducing the risk of system failure and operational disruption. Designers will need to inform the Project Team, and in particular the client agency, of any potential risk of HVAC plant shutting down under extreme temperature conditions.
- **Plan for Future Upgrades:** Allocate additional plant space to accommodate larger or more efficient thermal equipment, allowing flexibility for future retrofits and system enhancements. This should include any provisions for moving from fossil fuel fired equipment to all-electric alternatives.
- **Optimise Equipment Placement:** Relocate outdoor HVAC units to shaded and well-ventilated areas to improve operational efficiency and reduce thermal stress.
- **Balance Cooling and Heating Needs:** While cooling demand is expected to rise, there may be opportunities to downsize heating equipment due to milder winters associated with climate change.
- **Integrating Thermal Mass**: Incorporate thermal mass where air is recirculated (e.g. plenums, exposed soffits) in association with appropriate thermal insulation into the building envelope to moderate indoor temperatures and reduce peak cooling demand. Although unlikely to be useful in the tropical northern regions, introducing thermal mass into buildings in the southern regions that experience

[21] AIRAH DA09: Air Conditioning Load Estimation and Psychrometrics
[22] BOM - Climate Data Online

high diurnal (day-night) temperature ranges, where the nighttime temperatures can be significantly lower than the air conditioning setpoint for the building, allows the mass to be used as a heat sink.

However, caution must be taken to prevent heat from being trapped inside so provided external walls are insulated and shaded and the building is ventilated through the night, this strategy can be highly effective.

- Warmer air temperature, due to climate change, enables more moisture to be carried in the air, leading to more intense rainfall events. External louvres, if not properly located or specified as two-stage, can permit the passage of rainwater into the building causing extensive damage. This is particularly the case for tropical northern regions of WA.

## 5.6 Selecting Materials to Enhance Heat Resilience

To ensure long-term thermal performance and durability under extreme heat conditions, it is essential that designers specify building materials capable of withstanding elevated temperatures and sun exposure. In addition to the recommendations below, consider the preparation of this material into the National Building Specification NATSPEC[23] format and the manufacturer's details for assistance in selection.

Key recommendations include:

- **Selecting Vegetation, Light Colours and Reflective Materials**:

  External landscaping and finishes within the site should aim to reduce the heat island effect and comply with the Green Building Council of Australia's Green Star Buildings Submission Guidelines, Credit 20 - Heat Resilience. See DHW's technical guideline for environmentally sustainable design (TG040)[24] for additional guidance.

  Surface coatings and reflective materials are effective strategies for enhancing heat resilience in buildings and surrounding environments. When applied to roofs, walls, and outdoor pavements, these treatments can significantly reduce ambient air temperatures and lower energy consumption within buildings.

  Advanced technologies—such as nano-engineered coatings that incorporate microscopic reflective elements—can further improve thermal performance by reflecting solar radiation and minimizing heat absorption.

  Studies 25 have shown that cool roof coatings can reduce roof surface temperatures by up to 30 °C under extreme conditions, with typical reductions exceeding 10–20 °C. This can translate to reductions in ambient air temperature of approximately 1–2 °C at the urban scale, contributing to improved outdoor thermal comfort and reduced building heat gains.

[23] NATSPEC - National Building Specification
[24] DHW - Technical Guideline TG040 - Environmentally Sustainable Design for Non-Residential Government Buildings
[25] Wai, C.Y. et al - Experimental Analysis of Cool Roof Coatings

- **Selecting Thermally Stable Materials**: Use materials that maintain structural integrity and performance under high temperatures. These should resist deformation, degradation, and loss of function under projected climate conditions.
- **Specifying Low-Conductivity Materials**: Care should be taken where direct contact with the skin is to be expected. For elements such as handrails and outdoor fixtures, select materials with low thermal conductivity—such as timber or recycled plastic—to minimize heat transfer and reduce the risk of occupant discomfort or injury (refer to ISO 13732-1 and AS 4685.1).
- **Choosing UV-Stable and Heat-Durable Finishes, Seals and Sealants**: All externally exposed finishes and components should be constructed with materials that are resistant to UV radiation and capable of enduring prolonged exposure to extreme temperatures.

## 5.7 Planning & Design Guidance Notes

Climate Resilience – Planning & Design Guidance Notes, in Appendix 2, provides a non-exhaustive list of risk treatment actions that should be assessed and applied as appropriate to the specific context and risk profile of the project. Guidance Notes are intended to support, not replace, professional judgement and relevant standards.

# 6. Design Phase Considerations for Extreme Wind Events

This section provides advice relevant to risk treatments for extreme wind events. It requires action by the designers with reference to establishing the functionality and Importance Level of the building. Note, **Importance Levels provided here must be observed on all DHW projects** unless instructed otherwise in writing by the client agency's representative.

## 6.1 Functionality

Different types of buildings have different functionality criteria for severe winds. The range covered in this chapter includes:

- Continued function during severe wind event.
- Quick return to full functionality after event.
- Non-urgent return to functionality.
- High Valued Contents or Irreplaceable Assets.

In some cases, parts of buildings may have a requirement for a higher level of performance than the rest of the building.

Each of these criteria requires different levels of resilience in the building, and many of these can be addressed in the design brief.

Note: provision of Safe Shelters during an emergency could be classed as a separate category. However, this Guideline is provided for DHW's Buildings & Contracts Project Managers, hence relevant to hospitals, schools, police stations and the like. It does not cover safe shelters that would, as standard, be designed to the highest level of resilience.

### 6.1.1 Continued Function During Severe Wind Event

Buildings such as hospitals, fire stations, police stations, and prisons typically should be capable of IL4 level of performance. It requires:

- **Structural design for higher wind speeds**. All buildings that need to remain functional during a severe wind event in both cyclone and non-cyclone regions should be designed for high internal pressures, even if openings are protected from wind-borne debris. This recommendation is a resilience requirement and may be more stringent than that required in the NCC. Windows and doors should also be rated for the same high-wind actions.
- **Prevention of entry of wind-borne debris** (cyclone zones), through vulnerable and lightweight cladding elements, including windows and doors. The protection can be on the outside of the elements (e.g. debris protection screens) or installed inside the element (e.g. weatherproof sheeting under wall cladding).
- **Appropriate waterproofing** that is sufficiently resilient enough to remain intact and functional during very high winds.
- **Protecting more vulnerable areas** by positioning the areas that will require full functionality during the event away from external windows or under roofs that may

permit wind-driven rainwater ingress. The whole structure should be designed for the loads imposed by the highest resilience requirement in the building, but careful planning may minimize the number of windows and doors that need to be protected.

### 6.1.2 Quick Return to Functionality After Event

Some buildings that are involved in the provision of essential services should be able to deliver a high level of functionality immediately after a strong wind event. These buildings may include large medical facilities, schools, vital administrative centres, and service delivery offices such as regional offices for government departments that will be important for community response and recovery after an event. Additionally, some buildings due to their high occupancy patterns need to be treated similar to schools, such as Rec Centres

A high-level of functionality means the building needs to be substantially intact after an event. For instance, damage to windows in one or two rooms may compromise the continued functionality of those rooms, but the building must be capable of delivering its core function, and any damage should be controllable by sealing off in a way that preserves the security of the rest of the building, and safety for the building occupiers.

The specific performance criteria should be selected based on speed of return to full functionality and level of occupancy:

- These buildings should be designed to at least Importance Level 3 loads, which provide a small reserve of strength compared with normal buildings in the community.
- Again, because of the importance of an intact roof system, these buildings should be designed for high internal pressures in all wind regions.
- Windows should be glazed with laminated glass rated for the pressures obtained from the Importance Level 3 loads. Laminated glass may keep most of the glazing within the frame even if it is damaged by small debris. Openings in the building envelope during severe wind events will compromise the functionality, so debris protection will reduce the likelihood of windows being broken.
- If the function of the building is sensitive to water damage (e.g. it accommodates electronic equipment), then features that may let water in must be avoided, e.g., avoid roof designs that require box or valley gutters. It is also recommended that:
  - Closed cell foam is installed under flashings to prevent stormwater blowing up roofs and under flashings.
  - Specify windows and doors with high water exclusion performance.
- Where possible, install ancillary items such as solar panels or communication aerials separate to the building so that the building is not compromised if those elements are damaged. This also makes them more accessible for repairs after the event.

### 6.1.3 Non-urgent Return to Functionality

Some government buildings such as workshops, storage facilities and support buildings, may have no urgency to return to functionality after an extreme event. This will need to be determined by the client agencies representative.

These buildings can be designed in accordance with the NCC and will have client agency defined resilience requirements.

### 6.1.4 High Valued Contents or Irreplaceable Assets

For some buildings, the nature of the asset stored demands special consideration, such as expensive machinery, government archives, police evidence, art gallery or museum artefacts or data centres. For a building that will only house valuable contents, a slightly different philosophy can be used, as the comfort of occupants or provision of support services doesn't need to be considered:

- The building should be sited clear of storm surge, riverine flooding or flash flooding.
- The building should be designed as at least an importance level 3 or 4 building, depending on the significance of the contents.
- Waterproofing and preventing wind-driven rain entering the building should be a priority.

## 6.2. Structural Design Working Life

Under the National Construction Code (NCC), the assumed design working life of a building informs the level of structural reliability, durability, and performance required to meet the Performance Requirements, particularly those relating to structural safety.

While the NCC does not prescribe explicit design working life values, it references Australian Standards (such as AS/NZS 1170.0 and AS 3600), which are generally based on a nominal design working life of around 50 years for typical buildings.

This assumed design working life influences decisions such as material durability, exposure classifications, corrosion protection, and structural safety factors to ensure the building remains fit for purpose over its intended life with appropriate maintenance.

For buildings requiring longer design working lives or located in aggressive environments, designers must adopt more stringent durability measures and detailing to satisfy NCC performance requirements for safety, serviceability, and sustainability over time.

Hence, it is important that the client agency either specifies the design working life or endorses the design teams recommendations.

## 6.3. Importance Level

Importance Level (IL) is a classification system used to determine the level of structural design and construction required for buildings and structures. It reflects the potential consequences of a building's failure, especially regarding human safety and property damage.

The National Construction Code (NCC) in Australia, for example, defines four importance levels: 1 (lowest), 2 (default), 3 (higher occupancy or critical facilities), and 4 (essential post-disaster recovery or hazardous facilities).

When applying this Guideline (TG050), the Importance Level (IL) of the building needs to be applied as noted above. DHW have developed an IL Classification Table (Table 6.1) aligned with the NCC that is to be used for all DHW projects. Any deviations from the IL Classifications requires justification from the client agency and project team and signed off by the client agency's representative.

The National Construction Code (NCC) sets the minimum design requirements to preserve the life and safety of people who are inside the building at the time of a significant event that loads the building.

The level of loading that a designer must consider is set in the NCC and is a function of the Importance Level assigned to the building. The definitions of the Importance Levels and the building types (building characteristics associated with these IL's) are indicated in NCC 2025 and are reproduced in Figure below.

If an Importance Level 3 building is to be built in wind region A (non-cyclonic), or in cyclonic regions B2, or C, it must be designed for an Ultimate Limit State (ULS) wind speed with an annual probability of exceedance of 1/1000. If in cyclonic wind region D, then it should be 1/2000. The wind speed that this corresponds to is set out in AS/NZS 1170.2 (Standards Australia, 2021a). The ULS wind speed is used by the designer to ensure that the building has sufficient strength. The building should have little or no structural damage at winds lower than this wind speed.

**NCC 2022 Table B1D3a Importance Levels of buildings and structures**

| Importance level | Building Types |
|---|---|
| 1 | Buildings or structures presenting a low degree of hazard to life and other property in the case of failure |
| 2 | Buildings or structures not included in Importance Level 1, 3 and 4. |
| 3 | Buildings or structures that are designed to contain a large number of people |
| 4 | Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities. |

**NCC WA 2022 -**
**Table B1D3b Design events for safety – Annual probability of exceedance**

| Importance Level | Non-cyclonic wind | Cyclonic wind (regions B2 and C) | Cyclonic wind (region D) |
|---|---|---|---|
| 1 | 1:100 | 1:200 | 1:250 |
| 2 | 1:500 | 1:500 | 1:1000 |
| 3 | 1:1000 | 1:1000 | 1:2000 |
| 4 | 1:2000 | 1:2000 | 1:5000 |

**Figure 6.1 Importance Level for Buildings (re-presented from NCC 2025)**

Many buildings have performance requirements that exceed the simple preservation of life within the building. Compliance with the NCC will not necessarily result in a building that can perform its intended function during or after a severe weather event. To address the functionality of the building, other design requirements should be added to those of the NCC. This Guideline details these additional design requirements.

The recommendations in this Guideline have been written for new buildings but can be applied to upgrading existing buildings.

| Importance Level Classification | | | | |
|---|---|---|---|---|
| | IL1 | IL2 | IL3 | IL4 |
| **NCC Definition** | Buildings or structures presenting a low degree of hazard to life and other property in the case of failure | Buildings or structures not included in Importance Levels 1, 3 and 4. | Buildings or structures that are designed to contain a large number of people. | Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities. |
| **DHW Building Type Examples** | • Agricultural Shed<br>• Greenhouse<br>• Minor Storage Facility, e.g.<br>  - Fertiliser store<br>• Minor Temporary Facility | • Low rise residential<br>  - Residential College<br>  - Step up/ step down facility<br>• Transportable school building<br>• Low rise office building<br>• Manufacturing Facility<br>• Laboratory<br>• Medical facility (no surgery or emergency treatment facilities) capacity <50 occupants e.g.:<br>  - Community health clinic<br>  - Renal dialysis clinic<br>  - Dental clinic<br>  - Aged/ palliative care facility<br><br>**Note:** It may be prudent if an IL2 Building needs to operate during an extreme event or be quickly returned to operation after the event, for the design team in collaboration with the client agency to consider the possibility of upgrading to an IL3 or IL4. | • Primary school*<br>• Secondary school*<br>• Early childhood facility*<br>• TAFE building<br>• Recreation centre<br>• Prison/ detention centre<br>• Courthouse<br>• Medium to large office<br>• Medical facility (no surgery or emergency treatment facilities) capacity >50 occupants e.g.:<br>  - Community health clinic<br>  - Renal dialysis clinic<br>  - Dental clinic<br>  - Aged/ palliative care facility<br>• Buildings where >300 people can congregate in one area<br>• Buildings with >5000 occupants<br><br>* Reference the Primary School Brief and Secondary School Planning Guide | • Police station<br>• Fire station (career or volunteer)<br>• Emergency vehicle garage<br>• Emergency rescue facility<br>• Building with a post disaster function, e.g., emergency shelter<br>• Hospital/ medical facility with emergency or surgery facilities<br>• Facility capable of causing hazardous conditions beyond property boundaries |

**Table 6.1. Importance Level Classification Table for DHW Projects**

## 6.4 Matrix of Design Requirements

The NCC specifies the minimum requirements for design. These requirements principally cover life safety for the occupants of the building. At present they do not include any requirements for resilience that may ensure functionality of the building during or immediately after an event. Therefore, any additional functionality requirements must be specified separately within the design brief.

The functionality requirements for different government buildings vary. A matrix has been provided (Table 6.2) to assist in converting the functionality requirements for a specific building to tailored elements for a design brief. These are suggested design criteria only to be considered by the designers. Where there are no specific requirements for functionality either during or after the event, there is no need for special resilience features to be incorporated into the design brief.

Table 6.2 has columns that reflect different functional requirements for the building. Consider selecting the appropriate column for the building's functional requirements and then select the items for the design brief depending on the wind region in which the building is located. In some cases, Table 6.2 will indicate a value that is the same as that specified in the relevant standard, e.g. for a building located in Region C with a 50-year design working life, $M_c$ = 1.05 in both AS/NZS 1170.2 and in Table 6.2. In other cases, Table 6.2 gives a more stringent value than AS/NZS 1170.2 to enhance the resilience of the building, e.g. for a building with a 50-year design working life and some resilience requirements, located in Region A, Table 6.2 gives $M_c$ = 1.05 and AS/NZS 1170.2 gives $M_c$ = 1.0. In these cases, using Table 6.2 values will improve the resilience of the building.

### *Accompanying Notes to Table 6.2*

**Note 1**: *Importance level determines design load probability. While the NCC sets minimum requirements, client agencies may specify higher levels for special needs. Higher importance increases the likelihood the building remains functional after an event and improves protection for occupants.*

**Note 2**: *For wind region D, the Annual Probability of Exceedance used for each Importance Level are different from those in regions B2 and C (see NCC).*

**Note 3**: *Designers determine internal pressures using AS/NZS 1170.2 Tables 5.1(A) or 5.1(B); however, for buildings with special performance requirements, only Table 5.1(B) coefficients, which assume there are some openings in the building envelope, are used. As external personnel doors are not wind-rated, at least one is likely to fail (as for wind region A in table 6.2), and in tropical cyclones the envelope is highly susceptible to damage from wind-borne debris. Additionally, doors may be opened during occupancy. These assumptions represent minimum requirements for a robust design.*

**Note 4**: *The NCC has requirements for wind-rating windows and glass doors in all wind regions, but there are no requirements for wind-rating timber or garage doors in region A.*

**Note 5**: *Plywood sheets (typically 12 mm thick) can be screwed over windows and doors before severe wind events to help protect against debris. This approach is widely used across building types in cyclone-prone regions of Queensland and the Pacific.*

| Issue | Wind Region | Buildings with Quick Return to Functionality After Event | Buildings that Remain Operational During Event |
|---|---|---|---|
| Building Importance level (Note 1) | Region A | Importance Level 3 | Importance Level 4 |
| | Region B2, C and D (Note 2) | Importance Level 3 | Importance Level 4 |
| Climate change multiplier ($M_c$) used in AS/NZS 1170.2. (50-year life) | Region A | $M_c$ = 1.05 | $M_c$ = 1.05 |
| | Region B2, C and D | $M_c$ = 1.05 | $M_c$ = 1.05 |
| Climate change multiplier ($M_c$) used in AS/NZS 1170.2. (100-year life) | Region A | $M_c$ = 1.05 | $M_c$ = 1.1 |
| | Region B2, C and D | $M_c$ = 1.1 | $M_c$ = 1.1 |
| Internal Pressures used in design. Reference Section 5.5 of AS/NZS 1170.2 (Note 3) | Region A | Designers should consider factoring in the effect of Internal pressure | Designers should factor in the effect of Internal pressure |
| | Region B2, C and D | Designers should factor in the effect of Internal pressure | Designers should factor in the effect of Internal pressure |
| Doors, garage doors and windows (Note 4) | Region A | All doors, garage doors and windows wind rated | All doors, garage doors and windows wind rated, windows debris rated or protected |
| | Region B2, C and D | All doors, garage doors and windows wind rated | All doors, garage doors and windows wind rated, windows and doors debris rated or protected. Avoid garage doors in areas where there may be people. |
| Automatically opening glass doors<br><br>Plan for there to be an alternative entrance to the space e.g. a wind rated swinging glass door, so that the automatic door can be disabled and braced.<br><br>In addition: (Note 5) | Region A | No special measures. | Disable the door and temporarily brace the automatically sliding glass door at the bottom. |
| | Region B2, C and D | Disable the door and temporarily brace the automatically sliding glass door at the bottom. | Disable the door and temporarily brace the automatically sliding glass door at the bottom. Protect the door with plywood sheeting. |
| Window glass | Region A | No special measures beyond requirements of Australian Standards | Laminated Glass |
| | Region B2, C and D | Laminated glass | Laminated glass with debris protection |
| Ensure that critical elements in the tie-down chain can be checked and maintained easily | Region A | Inspection of roofing fasteners. | (Inspection of roofing fasteners, purlin to rafter connections. |
| | Region B2, C and D | Inspection of roofing fasteners, purlin to rafter connections | Inspection of roofing fasteners, purlin to rafter and roof to wall connections. |

**Table 6.2 Design Brief Matrix (Suggested Resilience Measures to Support Building Functionality)**

## 6.5 Structural Design Process

### 6.5.1 Functionality

Establish the functionality during or after an extreme weather event.

### 6.5.2 Structural Design Working Life

Select a realistic design working life for the building – the expected time to the first major structural upgrade of the building. The default building life in standards referenced in the NCC is 50 years, however some client agencies favour a 100-year design working life. Therefore, selection of the structural design working life will need to be done in collaboration with the client agency.

### 6.5.3 Importance Level

An appropriate Importance Level for the use of the building should also be selected in collaboration with the client agency's representative.

### 6.5.4 Climate Change Multiplier

From AS/NZS 1170.2, select an appropriate climate change multiplier (Mc), based on the selected structural design working life and Importance Level. (Guidance is provided in Table 6.2.) In some cases, this value may be higher than that currently required in the NCC. Typically, the higher value may increase the wind speeds by 5% and the wind loads by 10%.

### 6.5.5 Internal Pressure

Select an appropriate internal pressure coefficient for structural design based on the selected Importance Level and the intended structural performance of the building. (Guidance is provided in Table 6.2).

### 6.5.6 Load Paths

Use a tie-down load path that has some redundancy so that alternative load paths can accommodate local failures. This creates a mechanism that can arrest a failure if it starts. In many cases, the selection of the next larger size of fastener gives sufficient redundancy.

### 6.5.7 Lateral Load Resistance

Evaluate the lateral load resistance system's ability to resist the applied lateral loads with minimal eccentricity. Where eccentricity cannot be avoided, design additional capacity to resist the moment created by the eccentricity. An example of this is shown in Figure (a). This figure shows a roof plane that has roof bracing, but the posts on the end wall bear on the underside of the roof truss introducing an eccentricity. This can be addressed by either extending the wind beams to the roof plane (Figure (b)) or by introducing fly braces to transfer the lateral loads to the roof plane (Figure (c)).

- Ensure that critical structural elements in the tie-down system can be easily checked and maintained.

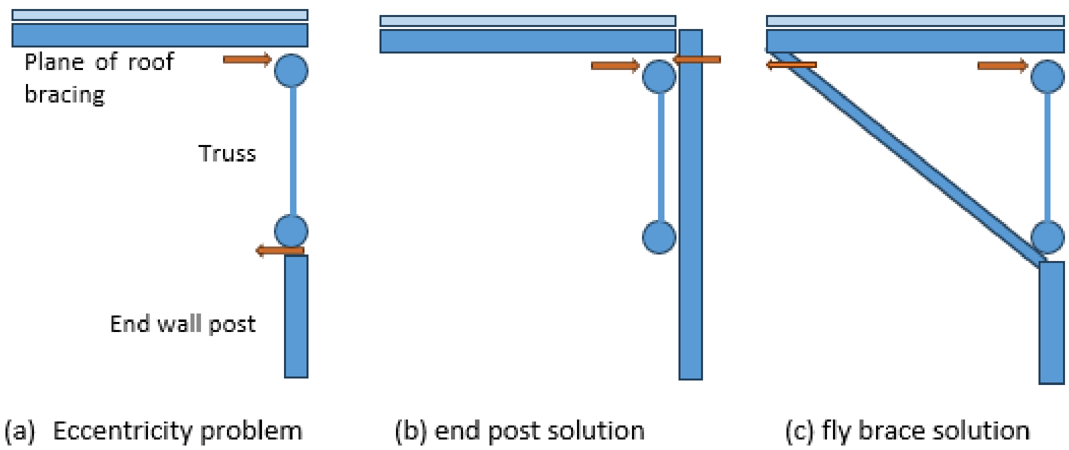


**Figure 6.2 - Eccentricity in Lateral Load Systems**

### 6.5.8 Wind-rated Components

Select wind-rated components for all doors, garage doors and windows. For garage doors, ensure that the additional loads from wind locks can be transmitted to the building structure and then to the slab. Windows complying with AS 2047 should already comply, and garage doors in regions B2, C and D should already comply with AS/NZS 4505. Although garage doors in region A are not required to be wind-rated currently, they should be reviewed during the risk assessment process.

The exposure of glass doors needs to be considered carefully, especially in cyclonic wind regions, where they have been known to perform poorly due to a lock of central support.

## 6.6 Building Envelope

Suggested actions for the designer to consider.

- Use simple roof and building geometry—as well as being more resilient, simple roofs are among the most cost-effective structural forms.
- Avoid large roof cantilevers.
- Avoid large and exposed attachments to the roof, such as large sky signs, communication aerials, and air conditioning units. This may require relocating, omitting, or building these elements into a special enclosure within the building.
- Use a tested cladding system which comprises cladding and fasteners, (AS/NZS 1562.1 references appropriate test methods for cladding to be used in cyclonic or non-cyclonic regions). Where material is sourced from overseas, it is still important to ensure that it has a certificate that indicates it has met the tests specified in AS/NZS 1562.1. Most Australian-made systems have supporting NATA-accredited test information, which means this requirement can be met. This is a requirement for all sheet roof systems.
- Where secret-fixed roofing is specified, use the direct-fixed strengthening specified for high-wind areas.

- In addition to the NCC's building class 7b. make it suitable to install solar panels at any location on the roof.
- Avoid using gravel ballast on flat roof as very strong winds can strip the gravel, which becomes wind-borne debris and can cause injury and damage property.
- Tiled roofs must satisfy AS 2050 (Standards Australia, 2018). This standard specifies sarking and anchorage requirements. Irrespective of requirements in AS 2050, any building with a tiled roof, with special resilience requirements, should be sarked to reduce water ingress and all tiles and capping should be mechanically fixed with a system that has been tested for the expected wind pressure.

## 6.7 Ancillary Items (Plant, Equipment and Signage)

Factors to consider when assessing the role of ancillary items in the resilience of a building include:

- The probability of failure is higher if there are a large number of ancillary items.
- Size of ancillary items – larger items usually do more damage when they fail.
- Strength of attachment – consider corrosion of fasteners, and what structural elements the items are attached to.
- Protection from wind or storm surge.
- Deterioration of items – e.g. corrosion, general wear and tear.

## 6.8 Waterproofing

The following suggestions indicate the risk treatment options available to minimise water damage caused by wind-driven rainwater ingress in future severe wind events. A given building type in a specific location may use some of these suggested risk treatment options.

### 6.8.1 Roof and Gutters

- All tiled roofs should be sarked, as noted above.
- Conservatively design roof drainage systems for rainfall intensity associated with climate change, Refer to Section 7 Design Phase Considerations - Flood Events.
- If possible, avoid box gutters. If not, ensure that each box gutter has overflows at each end.
- Avoid valley gutters where possible. If not possible, use closed-cell foam under all edges of the valley gutter.
- Use closed-cell foam under all apron flashings, ridge caps, and hips. Turn up the upper end of all sheets under ridge caps, hips, and apron flashings. If appropriate construction procedures are followed, the upper edge of sheets should be turned up.
- Fasten all flashings along both surfaces with screws at a maximum spacing of 500 mm in accordance with AS/NZS 1562.1 (Standards Australia, 2018). This should be the normal requirement, but it is not always followed.

- Install gutters with overflows for all perimeter gutters. Gutter brackets should be no more than 600 mm apart, and no more than 150 mm from any angle or stop end.

### 6.8.2 Windows and Doors

- Use windows with weep hole protection.
- Use systems where seals can easily be replaced.
- Use seals under all external doors.

## 6.9 Planning & Design Guidance Notes

Climate Resilience – Planning & Design Guidance Notes, in Appendix 2, provides a non-exhaustive list of risk treatment actions that should be assessed and applied as appropriate to the specific context and risk profile of the project. Guidance Notes are intended to support, not replace, professional judgement and relevant standards.

# 7. Design Phase Considerations for Flood Events

This section is principally aimed at assisting designers to manage the potential risk of damage from flooding. It is acknowledged that the simplest method to build flood resilience into the building project is through selection of an appropriate site. Though greatly influenced by the client agency, this is a key aspect of the Climate-Responsive Site Planning activities. Where the ideal site is not available the risk treatments in this section can assist to minimise disruption and damage due to flooding.

It is assumed that the risk of failure of the incoming water supply to the site, and hence need for water storage, would be considered as part of the normal design risk assessment process by the Hydraulic and Fire Engineers. Therefore, only water management with respect to flooding is considered here.

## 7.1 Raising Finished Floor Levels (FFLs)

This measure aims to address the impact climate change is expected to have on flood levels. Traditionally, design flood estimation has relied on the assumption that past recorded data accurately reflects both present and future conditions. Using unadjusted historical observations are no longer considered a suitable basis for design flood estimation: they must be adjusted to reflect the impacts of rising global temperatures. This approach aligns with the Australian Rainfall and Runoff (ARR) guidelines, it is strongly recommended for designers to review Chapter 1, Book 6 [26]: Climate Change Considerations of the ARR guidelines.

Raising Finished Floor Levels (FFLs) improves flood resilience by reducing the risk of water ingress during extreme rainfall and flood events. Elevated FFLs protect building interiors, critical infrastructure, and occupants from damage associated with inundation.

- Set FFLs a minimum of 0.5 metres above the projected 1% Annual Exceedance Probability (AEP) flood level. It is recommended to use the future 1% AEP flood level in 2050, and 2090-time horizons to align with the risk assessment. This measure is recommended for IL 1 and IL 2 buildings.
- Where climate-adjusted flood mapping is unavailable, determine FFLs using Design Flood Estimation or flood modelling, incorporating climate change scaling factors as outlined in the ARR guidelines – Book 1, Section 6.

For IL3 & IL4 buildings it is recommended to conduct site-specific flood modelling to determine future flood risk exposure.

- As the ARR uses SSP projections instead of RCPs, for management of flood risk, use SSP 5-8.5 to 2050 and SSP 2-4.5 to 2090. Refer to the Australian Rainfall and Runoff (ARR) Data Hub for applicable climate change scaling factors.
- Once the future 1% AEP flood level is established, apply a minimum freeboard of 0.5 metres to determine the Finished Floor Level (FFL).

[26] Geoscience Australia - Australian Rainfall Runoff Guidelines and Data Hub

Where Local Government flood planning requirements specify higher levels of flood protection (e.g. higher FFLs), those requirements shall take precedence.

It is essential that the architect clearly denotes the agreed FFL on each plan drawing.

Note: If bunds or levees are proposed to provide flood protection, responsible consultants and stakeholders must agree on the design. It is recommended that the design is modelled using future flood scenarios for 2050 and 2090. The modelling should incorporate projected changes in rainfall intensity, storm frequency, and sea level rise (if applicable), to ensure long-term climate resilience. Additionally, potential impacts on adjacent land, as well as upstream and downstream areas, must be assessed to avoid adverse effects and ensure integrated flood risk management.

It is essential to review the relevant local government's flood studies and mapping to determine the flood hazard status of a site. If they do not incorporate projected climate change impacts (e.g., changes in rainfall intensity, sea level rise), it is recommended that design flood estimation be undertaken using future climate scenario data. See Figure 7.1 for an overview of risk treatments.

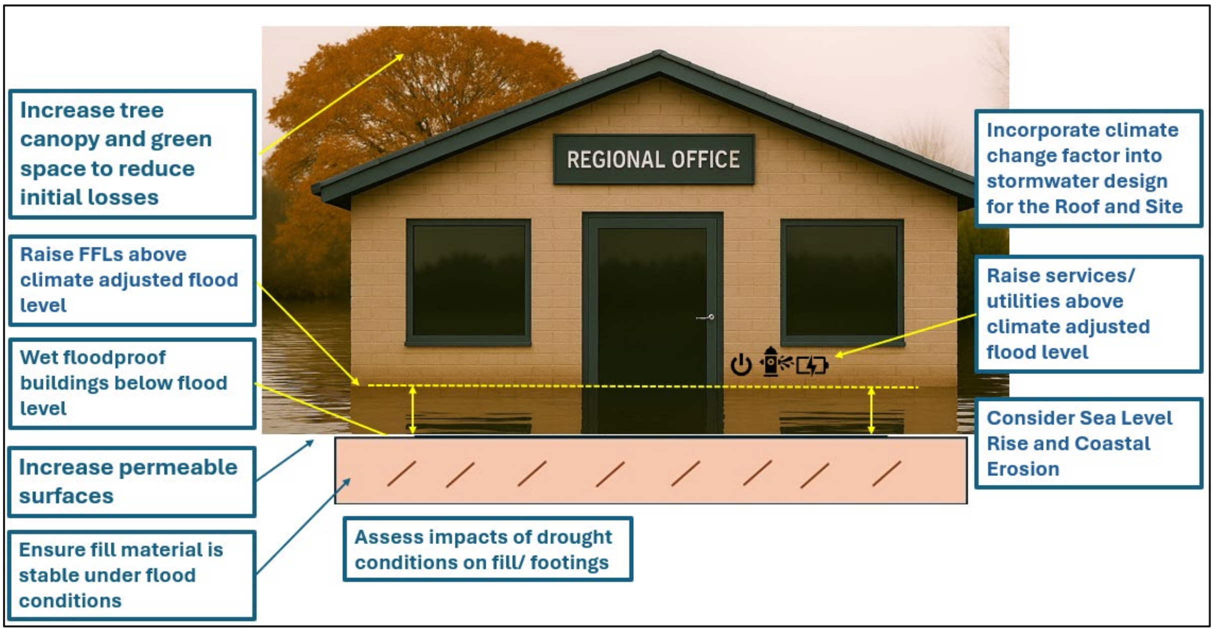


**Figure 7.1 - Pictorial View of Risk Treatments**

## 7.2 Fill Material for Affected Sites

Fill material placed on sites that are, or may become, flood affected must be engineered to remain stable under a range of flood conditions. Properly designed fill reduces the risk of structural damage, ground movement, and erosion, supporting long-term resilience of buildings and infrastructure.

The structural and geotechnical engineer should collaborate and confirm the fill is designed to withstand:

- Rapid rise and drawdown of floodwaters.
- Prolonged inundation.
- Erosion and scour forces.

The Australian Building Codes Board (ABCB): Construction of buildings in flood hazards areas (ABCB Flood Standard)[27] and the associated ABCB Handbook[28], should be referenced by the designers.

Throughout construction, the fill should be placed and compacted under supervision, with field testing to verify quality, obtain certification from the engineers confirming that the fill meets all relevant requirements. This process is based on the ABCB Flood Standard and Handbook, which, while not mandatory, provide valuable guidance for resilient design and construction in flood hazard areas.

## 7.3 Structural Design for Flood Actions

Projects located on sites that may be impacted by flooding during their design life must be structurally engineered to withstand flood-related actions. These include hydrostatic and hydrodynamic forces, buoyancy, scour, and differential ground movement. Proper structural design ensures long-term stability and occupant safety under future flood conditions.

Flood-resilient design should align with Part 2.3 of the ABCB Standard: *Construction of Buildings in Flood Hazard Areas*. Although this Standard is non-mandatory, compliance is strongly recommended to support best-practice outcomes. It is also recommended that qualified consultants assess whether the Flood Load Factor (Yf), as specified in Table 2.3.7 of the Standard, requires adjustment based on site-specific flood risk, building function and criticality, and projected climate conditions.

The structural design of footing systems should comply with Part 2.5 of the ABCB Standard, ensuring stability under flood conditions, including buoyancy forces, scour and erosion, and differential ground movement.

These risk treatments are based on the *Australian Building Codes Board (ABCB) Standard: Construction of Buildings in Flood Hazard Areas* and the accompanying *ABCB Information Handbook*. While the Handbook is non-mandatory, it is strongly recommended that designers and consultants review its guidance and apply relevant recommendations to support resilient and compliant design outcomes.

## 7.4 Designing Utilities & Engineering Services for Flood Conditions

Utilities and engineering services equipment, including backup systems, must be protected from flood-related impacts to ensure continued operation and safety during flood events. This may involve elevating equipment above the climate-adjusted flood level or engineering systems to withstand inundation and associated forces. Architectural and MEP (mechanical, electrical, and plumbing) documentation should demonstrate compliance with the following requirements.

Where feasible, utilities and equipment should be located above the climate-adjusted flood level identified in Section 7.1. If placement below this level is unavoidable, systems must be specifically engineered to resist hydrostatic and hydrodynamic forces, buoyancy, and prolonged inundation. In such cases, the following control measures are recommended:

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[27] ABCB - Construction of Buildings in Flood Hazard Areas - Standard
[28] ABCB - Construction of Buildings in Flood Hazard Areas - Handbook

- Equipment must be designed to remain functional during and after flood exposure.
- A manufacturer's statement, where applicable, should confirm the system's suitability for installation below the flood level.
- MEP components, including cables, connectors, and materials, must be flood-resilient and securely anchored to prevent displacement or damage.
- Buried utility systems must be installed at sufficient depth to avoid damage during flood events.

For Importance Level 3 (IL3) and Importance Level 4 (IL4) buildings and critical facilities, it is strongly recommended that utilities are elevated above the climate-adjusted flood level.

This measure is derived from the *Australian Building Codes Board (ABCB) Standard: Construction of Buildings in Flood Hazard Areas* and the associated *ABCB Information Handbook*.

## 7.5 Wet Floodproofing

Buildings with finished floor levels below the 1% Annual Exceedance Probability (AEP) flood level plus 0.5 m freeboard—whether new developments or major refurbishments—should incorporate wet floodproofing strategies to enhance resilience to inundation and support post-flood recovery. Wet floodproofing measures may include the use of flood-resistant materials, controlled flood water entry and drainage design, and the elevation or protection of internal finishes, services, and systems above flood levels. Floor and wall specifications, including finishes, must be selected for minimal absorption of flood water, to reduce the risk of mould growth after flood waters retreat. Architectural and services documentation should clearly demonstrate how these strategies have been integrated into the design.

Refer to the Queensland Flood Resilient Building Guidance for Queensland Homes[29] for examples and best practices in wet floodproofing design and construction. Designers and consultants are encouraged to review this guidance and apply relevant strategies to support long-term resilience.

Wet floodproofing is particularly recommended for buildings located below climate-adjusted flood levels, as identified in Section 7.1. It involves designing the building structure, materials, linings, utilities, and contents to resist water ingress and minimise damage.

## 7.6 Stormwater Management and Design (Rainfall Intensity Adjustment)

Stormwater management systems should be designed to accommodate projected increases in rainfall intensity due to climate change. Designers are advised to adjust the rainfall intensity values provided in *Appendix D* of *AS 3500.3: Plumbing and Drainage – Part 3: Stormwater Drainage* using the climate change rainfall factors available from the ARR Data Hub.

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[29] Queensland Flood Resilient Building Guidance for Queensland Homes

Recommended parameters include:

- Climate Scenario: for management of flood risk, use SSP 5-8.5 to 2050 and SSP 2-4.5 to 2090.
- Duration: <1 hour.

These adjusted intensities inform the sizing of stormwater infrastructure—such as pits, pipes, detention systems, and overland flow paths—to manage increased runoff volumes and flow rates. Hydraulic modelling and design documentation should reflect these adjustments to demonstrate that the system is capable of performing under projected future climate conditions, reducing the risk of flooding and system failure.

Stormwater systems must be capable of managing the increased runoff volumes and flow rates resulting from these adjusted intensities.

This measure introduces a climate adjustment to current design practices, addressing a gap in *AS 3500.3*, which does not currently account for future rainfall changes. Incorporating these adjustments ensures that stormwater infrastructure is resilient to future climate conditions and reduces the risk of system failure during high-intensity rainfall events.

During the building design process, stormwater management systems are assessed early in site planning and hydraulic design to ensure they can accommodate future rainfall conditions.

## 7.7 Roofs and Gutters (Rainwater Management)

This recommended risk treatment aims to improve the resilience of roof drainage systems against water ingress and wind-driven rain. It promotes the use of simple, robust roof designs and discourages complex gutter systems that are more prone to failure.

Roof drainage systems should be designed to minimise the risk of water ingress and structural damage during extreme rainfall events. To improve resilience and performance, the following measures are recommended:

- Install perimeter gutters with integrated overflow provisions to prevent backflow and roof flooding.
- Position gutter brackets at intervals no greater than 600 mm, and no more than 150 mm from any angled stop end, to ensure structural stability and performance under load.
- Avoid the use of box gutters and valley gutter systems where practical, particularly for buildings with functions sensitive to water damage (e.g. facilities housing electronic equipment or critical services).
- Preference should be given to eaves gutters and minimum 600 mm eave overhangs where practical to enhance drainage efficiency and reduce splashback against the building envelope.

It is noted that in certain regions of Western Australia, gutters may not be appropriate due to local climatic or environmental conditions. Consultants should assess suitability on a case-by-case basis and consult with the relevant Local Government authority.

These measures need to be documented in architectural drawings and specifications to demonstrate compliance with flood resilience objectives and best-practice roof drainage design.

## 7.8 Civil Design (Stormwater Management)

This risk treatment measure introduces climate-adjusted rainfall parameters into site drainage design and promotes the integration of WSUD principles to enhance resilience.

Site infrastructure should be designed to manage increased rainfall intensity and enhance resilience through integrated stormwater and landscape strategies. Detention systems must be sized to accommodate higher peak flows and runoff volumes resulting from climate-adjusted rainfall intensities. Designers should reference the ARR Data Hub and apply the following parameters:

- Climate Scenario: for management of flood risk, use SSP 5-8.5 to 2050 and SSP 2-4.5 (with an appropriate scaling factor uplift) to 2090, See Section 3.3.3.
- Duration: To be determined by the consultant based on site-specific conditions.

Designers should collaborate to incorporate the Water Sensitive Urban Design (WSUD)[30] principles and drought-resilient landscape strategies to improve water management and ecological performance. Conveyance and infiltration features—such as swales—must be designed using updated rainfall intensity data, with appropriate storm durations considered. To reduce runoff and support infiltration, impermeable surfaces should be minimised using permeable paving and green spaces.  These strategies need to be documented in site plans and stormwater management reports to demonstrate compliance with climate-adaptive design objectives.

A maintenance plan should also be established for permeable pavements, as their effectiveness can decline significantly without regular cleaning and upkeep.

By using future rainfall projections from the ARR Data Hub, designers can more accurately size detention and conveyance systems to manage increased runoff volumes, reducing the risk of system failure. Incorporating drought-resilient landscaping and permeable surfaces supports infiltration, reduces flood risks, and contributes to urban cooling and biodiversity.

These strategies ensure site infrastructure remains functional and adaptive under both current and future climate conditions.

## 7.9 Site Assessments for Coastal Areas

It is strongly recommended to avoid new development in areas identified as being at risk of sea level rise, storm surge, or coastal erosion. Projects located outside of mapped hazard areas are better positioned to achieve long-term resilience to climate change.

Therefore, coastal areas are increasingly vulnerable to climate change impacts, including sea level rise, storm surge, and coastal erosion. These hazards pose significant risks to the safety, functionality, and long-term viability of developments located near the shoreline. Conducting comprehensive site assessments within 5 km of the coastline is recommended to identify and manage these risks effectively.

[30] DWER - Water Sensitive Urban Design (WSUD)

Designers and planners should review relevant data sources to assess coastal hazard exposure, including:

- Coastal inundation mapping and hazard publications.
- Sea level rise and inundation studies published by Local Government.
- Local planning guidelines and *State Planning Policy 2.6 – Coastal Planning (SPP2.6)*[31].
- Site elevation, drainage characteristics, and topography.
- Historic flooding records and future risk management plans (consult Local Government).

This information supports informed decision-making around building elevation, drainage design, and material selection, ensuring compliance with planning requirements and enhancing resilience to future climate impacts.

Where coastal hazard exposure is identified, buildings should be elevated in accordance with planning requirements under SPP2.6. Design decisions should incorporate future climate projections and sea level rise scenarios, particularly in relation to building elevation, site drainage, and material selection. These considerations support long-term resilience and compliance with planning frameworks.

## 7.10 Resilience to Sea Level Rise & Inundation (Coastal Flood Adaptation)

Buildings located in areas susceptible to sea water inundation—such as coastal zones and low-lying sites—should be designed to withstand both short-term events (e.g. storm surge, king tides) and long-term impacts (e.g. sea level rise). Integrated floodproofing and resilient systems are essential to protect structural integrity and maintain operational functionality.

Key design strategies include:

- Using materials resistant to water damage and corrosion, with appropriate sealants and coatings to reduce saltwater intrusion.
- Installing flood barriers to prevent sea water entry, while assessing potential impacts on adjacent properties to avoid redirected flooding.
- Designing integrated drainage systems capable of functioning during flood events and managing and effectively removing sea water from the site.
- Locating backup systems—such as power, communications, and critical infrastructure—above projected inundation levels to ensure continued operation during flood events.

Sea water inundation poses unique challenges for buildings, including accelerated material degradation, structural damage, and disruption to essential services. To manage these risks, floodproofing measures should be integrated early in the design process. Material selection, protective coatings, and elevation of critical systems all contribute to long-term resilience.

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[31] DPLH - State Planning Policy 2.6 - Coastal planning

Flood barriers can offer additional protection but must be carefully evaluated to prevent adverse effects on neighbouring sites. Civil engineering input is critical to ensure site drainage systems are capable of handling saline water and preventing prolonged inundation. These strategies collectively support the durability, safety, and functionality of buildings exposed to coastal hazards.

During the building and site design process, resilience to sea water inundation is addressed through a combination of material selection, elevation strategies, and integrated drainage planning. Designers should identify areas at risk of coastal flooding, storm surge, or sea level rise using coastal hazard mapping and planning frameworks such as *State Planning Policy 2.6*. For buildings in these zones, materials are selected for their resistance to saltwater corrosion and water damage, with protective coatings and sealants specified to reduce intrusion.

## 7.11 Planning & Design Guidance Notes

Climate Resilience – Planning & Design Guidance Notes, in Appendix 2, provides a non-exhaustive list of risk treatment actions that should be assessed and applied as appropriate to the specific context and risk profile of the project.  Guidance Notes are intended to support, not replace, professional judgement and relevant standards.

# 8. Construction Phase Considerations

## 8.1 Introduction

Previous damage investigations have shown that buildings have been compromised by elements failing at wind speeds significantly less than the design wind speed. Most of these failures were due to quality control issues stemming from the supply of elements that did not match the specifications or were incorrectly installed. Further discussion on quality control is provided at the end of this Chapter, but it is vitally important therefore, that the building resilience is not compromised by substandard construction practices. The following sections highlight known weakness.

## 8.2 Non-Structural Deficiencies

Poorly fastened flashings can be torn off the building. Even if one leg of the flashing remains attached, wind-driven water can still be forced under the flashing and penetrate the building envelope. Water from above the ceiling line can saturate the ceiling and any insulation over it, causing collapse of the ceiling. Collapsed ceilings can damage contents, floor coverings and reduce the functionality of the building. In the case of multistorey buildings, the water that enters the top floor can percolate downwards through penetrations in the floor slabs. Figure 8.1 shows some flashing damage on larger buildings.

In many cases, damaged flashings were incorrectly fixed with pop rivets or just fixed to the sheeting. The relevant Australian Standard – AS 1562.1 (Standards Australia, 2018) specifies minimum metal thickness for flashings and method of fastening. Specific details on fastening of flashings are not often shown on drawings. Decisions on fastening flashings are then often made by trades during the construction of the building. Designers need to ensure the standard required is understood by the contractor and ideally checked for compliance.

In some cases, water can be driven under adequately fastened flashings and penetrate the interior of the building, compromising its functionality, Figure 8.2 shows examples. In each case, closed cell foam under the flashing would have minimised the water ingress. The arrows on the images show the water entry points.

**Figure 8.1 Lifted flashings after high wind events**

**Figure 8.2 Water penetration under well fastened flashings**

## 8.3 Structural Deficiencies

All structural elements in the structural load path must be correctly installed. Structural load paths include load paths from roof cladding to the ground and load paths for resisting lateral loads and pressures. There are many elements on these load paths, and it is often very difficult to inspect many of these elements in a completed building. Therefore, construction quality control usually involves instructing each installer, supervising as appropriate, and conducting random checks during installation to ensure that all details in the load path chain are comprehensively checked before completion. Elements in the load path and problems that can arise during installation are listed below:

- **Roof sheeting** – in cases where alternative roof sheet systems have been used instead of the specified system, there can be problems unless the alternative has equivalent or better wind ratings.
- **Roof sheet fastenings** – there are different fastening systems:
    - If **secret-fixed roofing**, which is typically specified for low roof pitches or for architectural reasons, is not pressed home into the clip entirely, or if the clip is bent, then the anchorage can be compromised (see two areas of detached roofing in Figure 8.3). This deficiency is very difficult to detect in the completed roof.
    - For **pierce-fixed roofing systems**:
        - over-tightened screws can “dimple” the crests and lead to premature failure under wind loads.
        - Under-tightened screws can lead to leaks, as the neoprene washers are not compressed over the hole. This is particularly the case where there are “cyclone washers” under the fastener heads as the

washers prevent observation of the waterproofing washer under the cyclone washer.

- Some fasteners for pierce-fixed roofing have inadequate corrosion protection and deteriorate quickly in service. Corroded fasteners may not have sufficient strength in a high-wind event.
- Screws installed on the wrong line or at an angle, it may not fix properly into the batten or purlin and could lead to failure.

**Figure 8.3 Failure of part of secret-fixed roofing due to problems with clips**

- **Purlins or battens** rely on their flexural strength to carry loads to the trusses or rafters' underneath. However, they also must have sufficient thickness to secure the screws that hold either the roofing or the secret-fixed clips. Figure 8.4 shows two buildings in which the steel thickness in battens or purlins was less than required to give the design strength for the fasteners.

  Purlins require bridging to provide them with stability against lateral-torsional buckling. Where the bridging is inadequate, the purlins can buckle, or both the bridging and purlins can buckle, as shown in Figure 8.5.

**Figure 8.4 Failures because of low thickness of steel in purlins or battens**

**Figure 8.5 Purlins with lateral-torsional buckling and buckling of the bridging**

- **Batten-to-rafter connections** on smaller buildings, screws must be installed in the correct location and at the correct angle, to avoid failure of this connection.

  On larger engineered buildings, the purlins are bolted to plates welded to the rafters and these connections are rarely installed incorrectly. Some modern construction methods incorporate thermal-break systems and use clips and standoffs to connect the purlins to the rafters. After installation, they are covered by insulation and cannot be inspected. If the clips are not correctly installed, they can be a weak point in the uplift load path.

- Loads from the purlins are transferred to the top of walls by bending of **trusses, rafters or portal frames**. In more recent buildings, these systems are generally well constructed either because of prefabrication or the ease of inspection on site. For some lightweight truss systems, omission of the specified lower chord bracing can prove costly under extreme wind actions, as shown in Figure 8.6. (Both of the trusses visible in this photo experienced bottom chord buckling.)

**Figure 8.6 Failure of lightweight trusses triggered by buckling of bottom chord**

- **Connections between the roof structure and the wall systems** are essential to prevent loss of significant portions of the roof. Partial omission of the specified connection, or substitution of lower capacity connections at the roof/wall junction, can lead to significant roof damage. A number of different failures have been observed in this structural detail. For example, observed instances of connection failure include:

- When the specified quantity and quality of fixings were not observed on a site located in a non-cyclonic region, the roof lifted off in an EF1 category tornado.
- In a case where the roof was tied into wall reinforcement, the reinforcing bar did not have sufficient bond length and was pulled out of the concrete, which resulted in the loss of the entire roof.
- When a specified connection could not be sourced for a building, the connection was omitted completely and the roof lifted off the walls in a low intensity tropical cyclone.

These deficiencies would have been obvious in an inspection of the building during construction. Hence, inspections are a key requirement on DHW projects.

## 8.4 Plant & Equipment Fixings

### 8.4.1 Fastenings in General

Additions to the building have also caused roof damage due to their inadequate fastening to the building. Some of these items can be fitted after the completion of the main building, but many are fitted during the construction of the building. These items can include:

- Solar panels.
- Satellite dishes or other communication aerials.
- Split system air conditioning units.
- Extractor fans.
- Flues.
- HVAC units.

All these items attract wind loads, so their support systems need to be designed to carry the extra wind loads safely into the building structure. They should not be fastened only to the cladding. Figure 8.7 shows some failed attachments that led to damaged roofing, which compromised the performance of the building.

Solar panels led to damage

Air conditioner led to damage

Extractor fan led to damage

Satellite aerial led to damage

**Figure 8.7 Damage to building from attachments**

Attachments to the building must be fastened to the roof structure, and the roof structure checked for its capacity to resist the higher wind actions due to the attachment. In some cases, structural reinforcement within the roof structure will be required to transmit higher wind actions further into the structure where the effect is less significant. A structural engineer will be required to design the reinforcements.

### 8.4.2 Photovoltaic Solar Panel Fastenings

Where solar panels are fitted to roofs, the load in the roofing screws that also hold the mounting rail can increase substantially. Figure 8.8 shows a roof in which the screws securing the ‘L’ feet that anchor the rails to the purlins were pulled out of the lightweight steel battens.

The red circles highlight the missing screws. The tributary area of roofing to a roof screw is shown with a blue rectangle and the tributary area of a solar panel to the ‘L’ foot, which loads a single roofing screw, is shown by the orange rectangle. The disparity in loaded area leads to higher loads, and if the batten or purlin is too thin to carry the increased load, then the screws will withdraw from the purlin as shown by the red circles.

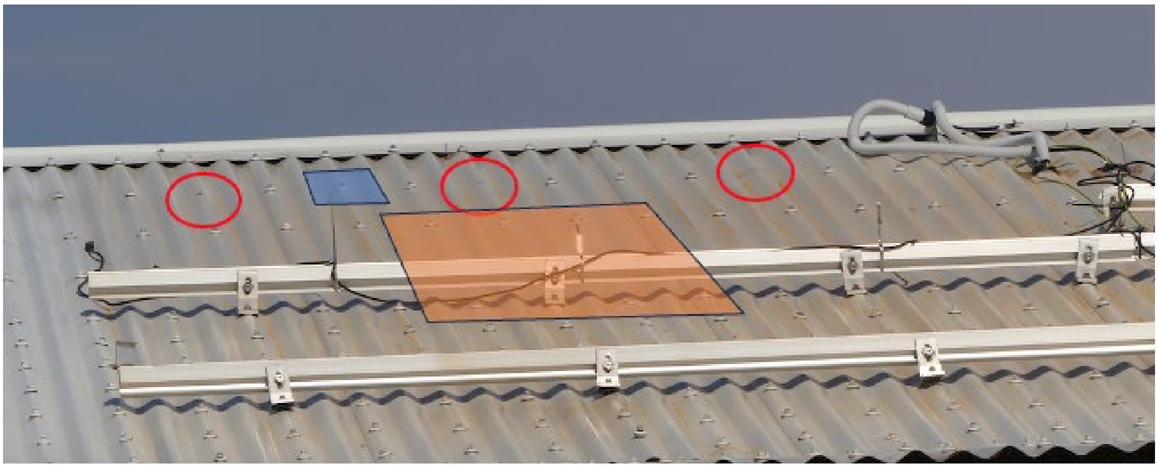

**Figure 8.8 Increased loads in roofing screws under L feet in solar panel systems**

## 8.5 Failure of Fenestration Elements

Failure of fenestration elements can cause internal pressurisation of the building.

- **Windows** - if not supplied to the correct wind rating, they can fail due to net pressure across the window, which in turn can cause the roof to lift off. Added to that, lethal pieces of glass can be released if the window glass is float or annealed glass.

It is important to check that the window delivered to site matches the specification of both the wind rating of the system and the glass type. In addition, window assemblies must be fitted securely into the wall system, otherwise the complete window may be blown into, or sucked out of, the building.

Both the above failures are illustrated in Figure 8.9 below.

**Figure 8.9 Float glass embedded in a wall after glass failure & window sucked out of building**

- **Garage doors** are a potential vulnerability in the wall system. Where the doors supplied are not appropriately wind-rated, they can fail under the differential pressure across the door.

  Where they are wind-rated, the wind-locks on the door can create large tension forces within the plane of the door, as the doors bend inwards and use catenary action to resist the out-of-plane forces. If the connection between the tracks and the building wall system cannot transmit those large forces, then the failure is in the tracks rather than the door. Both failures are illustrated in Figure 8.10.

Roller door failure　　　　Track connection failure

**Figure 8.10 Garage door failures**

- Failures of buildings under lateral load are now relatively rare, but if the **bracing** is omitted or under-designed, then walls can blow inwards, as shown previously in Figure 8.6, with the potential for partial collapse.

## 8.6 Enhancing Construction Quality

The deficiencies highlighted in this Section can be due to either unsatisfactory substitutions or construction errors. The following Sections discuss suggestions to help minimise damage to government buildings during severe wind events that could be caused by incorrect construction practices.

### 8.6.1 Quality Control in Construction

Supervision is the key to quality control in construction. Where there are many repeated items in the finished building, it is impossible to check each one. Instead, the strategy should involve careful training, checking the first few items installed, and then undertaking random checks on the remaining items. If personnel change during the construction period so that different people are performing the task at different times, each person should be trained and checked more frequently when they are new to the task.

An example of this type of item could be roofing screws. Each person required to install the roofing screws should be asked to install some under supervision to demonstrate how to set the impact driver and how to recognise under-driven and over-driven screws. They should be asked what remedial work is necessary if the screw missed the purlin.

Some structural elements are fewer in number such as portal frames. Therefore, it may be possible to inspect each one to ensure that it complies with the drawings. In this example. the limited number makes it possible to check that the portal frames have been correctly fabricated and that the correct number of bolts have been installed. A random check on one or two bolts per frame may indicate whether they have achieved the right tension. Tension indicator washers can assist in checking bolt tensions.

Paint thickness can be checked with gauges or ultrasonics.

### 8.6.2 Site Check and Verification

Use checklists for structural elements and methodologies referred to in the specification to ensure they are used in the building construction. Any climate resilience items are likely to be above minimum construction requirements, and the inspection regime may be outside the experience of the trades who are installing them. Therefore, special attention is required for these items.

The same checklist can be used to confirm that all of the special resilience features on the building have been delivered and installed.

Checklists should be prepared following acceptance of the design with all the key items from the design included in the checklist, which remains live during construction. If an alternative product is requested, it should be checked prior to ordering and the date of the check included in the checklist table. If the requested alternative is not deemed appropriate, it should not be ordered. Wherever the design is changed, the detail should be included in the checklist table, which then functions as a tool for preparing "as-constructed" information.

## 8.7 Maintenance and Post-Event Inspection

Work required on a building already in service must not compromise the structural resilience of the building. Further work may fall into the following broad categories:

- **Planned extensions or renovations** of the building. Design work is generally required in these cases, which should use the same design criteria outlined in the original design brief unless more stringent requirements have superseded it over time. As-constructed documentation can assist in ensuring that the new work is compatible with the, as previously constructed, structure.
- **Planned additions** of other minor items. An example of this work is a planned replacement of an air-conditioning or HVAC system, or re-screwing of the roofing. In these cases, a contract will be created for the work, which could include minimum requirements such as safeguarding other features of the building and specifications that exceed the minimum initially required for the building. Particular care may be needed to protect coatings, firestops and structural components.
- **Unplanned maintenance** and repair works. In these cases, it is not generally possible to consult the previous design briefs or issue a contract that includes the protection of other items in the building. In these cases, appropriate supervision is required. An example of this work is the repair of a leaking roof and water-damaged ceilings. In addition to all of the safe working requirements, there should be checks of the structural elements in the roof space when they are exposed, to check that there are no signs of water damage to them. If corrosion or rot of structural elements is found, appropriate building professionals should be engaged to fix or replace those items before the ceiling is replaced.

## 8.8 Construction Guidance Notes

Climate Resilience – Construction Guidance Notes, in Appendix 3, provides a non-exhaustive list of risk treatment actions that should be assessed and applied as appropriate to the specific context and risk profile of the project. Guidance Notes are intended to support, not replace, professional judgement and relevant standards.

# 9. Project Deliverables

During the project planning phase, project teams should clearly define climate resilience expectations and deliverables for each project stage.

These requirements should be embedded within the project's design and construction documentation, including the service brief, design reports and drawings, construction documents, technical specifications, and operating & maintenance literature.

Table 9.1 below provides a notional list of deliverables to improve resilient building practice.

| Description | Activities | Key Deliverables & Documents |
|---|---|---|
| **Project Planning, Initiation and Definition** | | |
| Client agency's Project Planners prepare a Business Case to define the scope of the procurement and develop the implementation strategy. See Appendix 1 - Climate Change Pre-screening Checklist.<br><br>The DHW Project Manager prepares a Project Definition Plan (PDP) to define the approach to be used by the project team to deliver the intended scope whilst ensuring the minimum requirements of design brief are understood and achievable. Refer to Section 4. | Project planners indicate potential climate risks, if any, together with project's environmental risks.<br><br>The client agency and DHW ensure that climate risk assessment requirements are included in the design brief. Project Manager sets specific requirements for Climate Risk Screening as part of PDP stage consultancy.<br><br>Climate risk is tabled as an item for discussion in Risk Workshops to deliver GBCA's ***Minimum Expectation*** as detailed in Section 3.2, and ideally to address the ***Credit Achievement***.<br><br>For high-risk projects identified by the workshop, DHW's Buildings & Technical Services Team (BTS) review is required. | Climate Impact is captured in the:<br>• Project Business Case,<br>• Project Definition Plan (PDP),<br>• Briefs for architectural and engineering services.<br><br>Refer to the Climate Change Pre-screening Checklist in Appendix 1.<br><br>Climate Risk Management included in Risk Workshops and Risk Registers, using templates referred to and linked within Section 3.4 - Assistance with Climate Change Impact Assessments. |

| Description | Activities | Key Deliverables & Documents |
|---|---|---|
| **Design Phase** | | |
| Schematic Design (SD)<br>Preliminary designs that define overall scope and systems.<br><br>Design Development (DD).<br>Refinement of building design and complete definitions of all systems.<br>All design decisions are completed during this phase.<br><br>Construction Document (CD)<br>Design is translated into detailed, technical documents used for construction. | • Lead consultants or ESD consultants conduct climate resilience assessment and adaptation planning. Refer to Sections 3 - 8.<br>• Discipline consultants incorporate adaptation measures into design decisions. Refer to Sections 3 - 8.<br>• Risk Assessments based on DWER's First-Pass Climate Risk Framework, see Section 3.4. | • Climate adaptation design solutions are incorporated into design consultant's reports and drawings.<br>• Climate adaptation strategies are incorporated in construction specifications.<br><br>Note: Design information should feed back into the requirements of DHW's Technical Guideline for ESD (TG040). |
| **Construction Phase** | | |
| Construction per approved documents | • Consultants respond to contractor questions.<br>• Shop drawings.<br>• Change orders.<br>• Inspections<br>Refer to Section 8. | • Develop Climate Resilience Inspection Checklist, ensuring inspections are conducted at critical points during the construction such as prior to pouring concrete for foundations, before covering up structural steel joints, etc. |
| **Post-construction Phase** | | |
| Ensure the building is ready for occupancy, operates as intended and is properly handed over to the owner or facility manager. | • Final inspection and certifications.<br>• Handover and documentation. | • Commissioning reports and Operating and Maintenance manuals to incorporate climate change risk treatment measures and strategies incorporated (e.g. thermal comfort, standby power). |

**Table 9.1: Project Deliverables**

# Appendices

# Appendix 1: Climate Change Pre-screening Checklist

Completion of this checklist is the necessary foundation for the development of appropriate risk treatments to combat the impacts from climate change.

Many buildings are not currently designed to address the increasing severity and frequency of future extreme weather events. This is largely due to building standards being based on historical weather data.

Being resilient to these impacts is important for government buildings as they often provide critical services to the community. Many of these critical services are required to remain functional during and post extreme climate events, such as the Emergency Department in a healthcare facility.

The following Climate Change Pre-screening Checklist provides the client agency the opportunity to communicate the known climate risks associated with the project site and any vulnerabilities that should be address as part of the project design.

While completion of this document is a necessary component of good design, it is accepted that in some circumstances funding for climate resilience measures may not be afforded at this stage of the assets life and hence will need to be managed through the client agency's Strategic Asset Planning process.

Provided, that during the Pre-screening Assessment the client agency has identified the exposure, vulnerability, and adaptive capacity for their project, DWER's guide and associated tools (see Section 3.4) can be used on the project.

# Climate Change Pre-screening Checklist

| | |
|---|---|
| **Project:** | **Client Agency:** |
| **Buildings & Contracts Project Manager:** | **Project Number:** |
| **Lead Consultant:** | **Last Updated:** |

| 1. Project Details (Input from Client Agency) | | |
|---|---|---|
| **Ref** | **Description** | **Details** |
| 1.1 | **Site location(s), topography and boundaries** (site selection should aim to minimises exposure to climate hazards). | |
| 1.2 | **Building type** (include the primary function i.e. school and any secondary function, i.e. community use). | |
| 1.3 | **Building Importance Level (IL)** (taking into to consideration if the building needs to operation during or immediately after an extreme wind event). | |
| 1.4 | **Critical functions** (shelter, emergency refuge, community use during cyclones). | |
| 1.5 | **Intended building footprint, elevation and orientation if known.** | |
| 1.6 | **Building users and their potential vulnerability to climate extremes** (e.g. children, elderly, low mobility, seeking medical treatment). | |
| 1.7 | **Occupancy patterns,** (for all building user categories, include seasonal adjustments). | |
| 1.8 | **Anticipated asset life**, (50 years unless instructed otherwise by the client agency). | |
| 1.9 | **Adaptive capacity features,** (elevated structures, on-site water storage, off-grid resilience). | |

| 2. Climate Hazards (Input from Client Agency & Project Team) | | |
|---|---|---|
| **Ref** | **Description** | **Details** |
| 2.1 | **Historic Events**<br>Has the project site been impacted by extreme weather events (cyclones, tornados, flooding, heat waves, etc) in the past? If so, confirm the details including any risks identified and treatments considered. Suggested items to report on are provided below:<br>• Asset damage or failure.<br>• Accelerated degradation or reduced design life.<br>• Reduced functional performance.<br>• Disruption to access and egress.<br>• Risks to occupant health and wellbeing.<br>• Cascading impacts (i.e., those arising from dependencies on interrelated infrastructure and services such as loss of energy, water, and telecommunications). | |
| 2.2 | **Future Extreme Weather Events**<br>Has data regarding future climate exposure been reviewed? If so, using the "items to report on" as listed in 2.1 above, confirm the details associated with any climate events likely to impact the project and when the event may occur. Include details of any risks identified and treatments considered. Suggested future climate projections to consider are provided below:<br>• RCP 8.5 should be applied up to and including 2050.<br>• RCP 4.5 should be applied, with an appropriate scaling factor uplift, to dates beyond 2050, up to and including 2090. Scaling factors will need to be declared. See Section 3.3.3. | |
| 2.3 | **Communicate Risks**<br>Communicated to the client agency's representative all risks identified, both current and future. Note the risks identified do not need to be address at this stage. | |

## Appendix 2: Climate Resilience – Planning & Design Guidance Notes

These Guidance Notes are recommended for all projects. They are non-exhaustive, and responsible consultants and stakeholders should assess and apply additional design measures as appropriate to the specific context and risk profile of the project. Guidance Notes provided here are intended to support, not replace, professional judgement and relevant standards.

| No | Item | Reviewed Yes/No |
|---|---|---|
| **1.0** | **General Outline** | |
| 1.1 | Will the Project comply with the Green Building Council of Australia's Green Buildings Submission Guideline's Credit 17 with respect to the Minimum Expectation, i.e. to complete the Climate Change Pres-screening Checklist, as detailed in Section 3 and Appendix 1?<br>*Note, this decision will impact the Environmentally Sustainable Design outcomes as required by DHW's Technical Guideline TG040.* | |
| 1.2 | Will the Project comply with the Green Building Council of Australia's Green Buildings Submission Guideline's **Credit 17** with respect to the Credit Achievement, i.e. Completing a Climate Change Risk & Adaptation Assessment and Managing the Risks? | |
| 1.3 | Has the Western Australian Climate Risk Assessment Tool (refer Section 3.4) been used to conduct the risk assessment? If not, does the Risk Assessment methodology used comply with AS 5334:2013, ISO 14091 & AS ISO 31000? See Section 2.2.2. for guidance. | |
| 1.4 | Has the Climate Projections of RCP 8.5 for 2050 and RCP 4.5 (with an appropriate scaling factor uplift) to 2090 been applied? Noting that SSP 5-8.5 and SPP 2-4.5 can be used as substitutes for RCPs. See Section 3.3.3. | |
| 1.5 | Have appropriate Climate Change Variables (see Table 1 for assistance) been selected for review and for those not selected, has their exclusion been commented on? | |
| 1.6 | Have the Risks rated "High" been managed by project specific design and/or operational measures? See Section 3.2. | |
| 1.7 | Have the Risks rated "Extreme" been managed by project specific design measures? See Section 3.2. | |

| No | Item | Reviewed Yes/No |
|---|---|---|
| 1.8 | Has a minimum of two identified Risks, regardless of their assigned risk rating, been mitigated through project-specific design responses? See Section 3.2 and designers' objectives in relation to DHW's ESD Technical Guideline (TG040). | |
| 1.9 | Has the client agency approved the initial and residual risk ratings from the risk assessment? See Section 3.2.2. | |
| 1.10 | Have the climate risk treatments been properly evaluated for cost-effectiveness? See Section 3.6. | |
| 1.11 | Has the client agency been made aware of the importance of monitoring and reviewing risk treatments as the climate will continue to change in unpredictable ways? See Section 3.6 and Appendix 4. | |
| **2.0** | **Climate-Responsive Site Planning** | |
| 2.1 | Have the appropriate WA State Planning Policies been considered? | |
| 2.2 | Has the site been mapped into low-, medium-, and high-risk zones, and assets assigned to the appropriate location? See Section 4.3 | |
| 2.3 | Have Climate Risk Conflicts been identified and resolved, i.e. building orientation, elevation, breezeways, etc.? See Section 4.4. | |
| 2.4 | Has the landscaping design reduced the heat island effect, provided shading to the buildings and shading to the pedestrian areas? See Section 4.5. | |
| 2.5 | Does the landscaping design slow and absorb rainwater flows and provide flood attenuation? See Section 4.5. | |
| 2.6 | Have light coloured materials been selected, large hardscapes been avoided, and water-resistant materials been selected for areas below the flood levels? See Section 4.6. | |
| 2.7 | Has the infrastructure been made resilient, i.e. critical systems elevated above the flood level, exposed equipment appropriately wind-rated, and an appropriate level of redundancy provided to protect against failure of a critical system? See Section 4.7. | |

| No | Item | Reviewed Yes/No |
|---|---|---|
| 2.8 | Are access ways shaded, sheltered and safe to use during extreme weather events? See Section 4.8. | |
| 2.9 | Is there sufficient space on site to add later, climate risk treatments that cannot be incorporated now due to budget constraints? See Section 4.9. | |
| **3.0** | **Design Phase Considerations – Heat Stress** | |
| 3.1 | Are HVAC systems designed using the latest site-specific weather files obtained from reliable sources? See Section 3.3.1 | |
| 3.2 | Has the thermal comfort level been assessed based on appropriate occupancy groups and function of the space, under both the standard design parameters, as well as elevated temperatures and heatwaves due to climate change? If so, have any concerns been raised in the Design Reports? See Section 5.1, 5.2 & 5.3. | |
| 3.3 | Have passive measures been introduced, and external heat gains and cooling loads been minimised? See Section 5.4 | |
| 3.4 | Are the mechanical cooling systems all-electric and provided with sufficient cooling capacity and/or space to accommodate increases in load due to climate change? See Section 5.5. | |
| 3.5 | Has DHW's technical guideline for environmentally sustainable design (TG040) been reviewed and Credit 20 – Heat Resilience been address in the design? | |
| 3.6 | Have coatings and reflective materials been considered to reduce heat gain and ambient temperatures? See Section 5.6. | |
| 3.7 | Have low-conductivity materials been selected for elements such as handrails exposed to the sun, to prevent scalding? See Section 5.6. | |
| 3.8 | Have thermally stable materials been selected that are UV stable and heat durable? See Section 5.6. | |

| | | |
|---|---|---|
| **4.0** | **Design Phase Considerations - Extreme Wind Events** | |
| 4.1 | Has the functionality of the building been established, i.e. need for the building to remain operational during an extreme event, or be returned quickly to a functioning state after the event, etc? See Section 6.1. | |
| 4.2 | Has the Structural Design Working Life been endorsed by the client agency? See Section 6.2. | |
| 4.3 | Has an Importance Level for the building project been agreed with the client agency, taking into consideration the functionality requirements during an extreme event? See Section 6.3. | |
| 4.4 | Has an appropriate Climate Change Multiplier been selected and the need to incorporate Internal Pressures in the design been considered? See Section 6.4. | |
| 4.5 | Have Load Paths and where relevant Lateral Load Resistances, been detailed? See Section 6.5. | |
| 4.6 | Has the Building Envelope been optimised to reduce the risk of damage or failure during an extreme wind event? See Section 6.6. | |
| 4.7 | Have the Ancillary Items attached to the building been considered for their durability, strength of attachment, and protection from extreme winds? See Section 6.7. | |
| 4.8 | Have water ingress paths during extreme storm activity been considered and in particular, roof and gutter design and window and door detailing? See Section 6.8. | |
| **5.0** | **Design Phase Considerations – Flood Events** | |
| 5.1 | Has the Finished Floor Level been raised to improve flood resilience? See Section 7.1. | |
| 5.2 | Has fill material been considered and detailed in the context of a potential flooded site? See Section 7.2. | |
| 5.3 | Have the forces and damage caused by flooding been considered, i.e. hydrostatic and hydrodynamic forces, buoyancy, scour, and differential ground movement? See Section 7.3. | |

| | | |
|---|---|---|
| 5.4 | Are the Utilities and Engineering Services appropriately protected from flood conditions or sufficiently robust to cope? See Section 7.4. | |
| 5.5 | Has the need for Wet Floodproofing been considered? See Section 7.5. | |
| 5.6 | In the design of the rainwater systems, has the rainfall intensity been adjusted in line with the Australian Rainfall and Runoff (ARR) guidelines, using data from the ARR Data Hub? See Section 7.6. | |
| 5.7 | Have the requirements to simplify the roof and guttering systems been applied? Have gutters been installed with appropriate supports and overflows? See Section 7.7. | |
| 5.8 | Have the requirements of the Water Sensitive Urban Design (WSUD) principles been applied on the project? See Section 7.8. | |
| 5.9 | For sites with 5km of the coast, has a comprehensive site assessment been conducted to support decision-making? See Section 7.9. | |
| 5.10 | For buildings susceptible to sea water inundation, have integrated solutions for floodproofing and resilience management been incorporated? See Section 7.10. | |
| **Remarks:** | | |

## Appendix 3: Climate Resilience – Construction Guidance Notes

These Guidance Notes are recommended for projects requiring climate risk treatment measures. It is not exhaustive, and the responsibility remains with contractors, site managers, consultants, and other stakeholders to assess and implement additional checks suited to the specific site conditions, regulatory environment, and risk profile of the project. Guidance notes provided are intended to support, rather than replace, professional judgement, statutory obligations, and applicable construction standards.

| No | Item | Reviewed Yes/No |
|---|---|---|
| **1.0** | **Site Preparation and Groundworks** | |
| 1.1 | Where relevant, site fill material, design and placement should also be consistent with applicable planning, geotechnical, drainage and floodplain management guidance.<br>If fill material is required, has it been placed in accordance with the approved engineering specifications? See Section 7.2.<br>Note: For flood-prone sites, fill must be designed and compacted to remain stable under flood conditions, including saturation and potential erosion. | |
| **2.0** | **Non-Structural** | |
| 2.1 | Have flashings been fastened correctly in accordance with the design details? See Section 8.2. | |
| 2.2 | Has closed cell foam been installed below the flashing to minimise the risk of water ingress, where applicable? See Section 8.2. | |
| **3.0** | **Structural** | |
| 3.1 | Have structural inspections been conducted by an appropriately qualified professional Structural Engineer? See Section 8.5.2. | |
| 3.2 | Have footings and slabs been constructed in accordance with the approved structural plans? | |

| No | Item | Reviewed Yes/No |
|---|---|---|
| 3.3 | Has the installation of wall and roof tie-down systems, including load distribution paths, been inspected and verified against the approved structural engineering documentation?  See Section 8.3. | |
| 3.4 | Has the layout of roof structural members, including spacing, sizing, and arrangement, been inspected and verified against the approved structural engineering documentation?  See Section 8.3. | |
| 3.5 | Have roof fasteners, purlin-to-rafter connections, and roof-to-wall connections been inspected and verified for compliance with the approved structural details?  See Section 8.3. | |
| 3.6 | Have roof-mounted ancillary items been inspected for compliance with the approved design details, and confirmed to be appropriately designed for the nominated wind region?  See Section 8.4. | |
| **4.0** | **Doors and Windows Installation** | |
| 4.1 | Has glazing, and debris screens where required, been installed in accordance with the approved plans, including confirmation of glazing type (e.g. laminated glass where required)?  See Section 8.5. | |
| 4.2 | If applicable, have wind-rated doors (including garage doors) been installed in accordance with the approved plans? See Section 8.5. | |
| **5.0** | **Building Utilities** | |
| 5.1 | If the site is, or is projected to be flood-prone, have building utilities - including backup systems and plantrooms - been installed above the climate-adjusted flood level and in accordance with approved design documentation?  See Section 7.4. | |
| 5.2 | If building utilities are located below the flood hazard level, has their installation been carried out in accordance with manufacturer requirements, and are they designed to resist flood actions and remain functional during and after inundation?  See Section 7.4. | |

| | | |
|---|---|---|
| **6.0** | **Roof and Gutters** | |
| 6.1 | Have gutter systems been installed with appropriate overflow measures and in accordance with the approved plans? See Sections 6.8.1 and 7.7. | |
| 6.2 | If box gutters are installed, do they include overflow outlets at each end? See Sections 6.8.1 and 7.7. | |
| **7.0** | **Landscaping** | |
| 7.1 | Have resilient tree species been selected and planted in accordance with the nominated wind region and approved landscape documentation? See Section 4.5. | |
| 7.2 | Have permeable surfaces and green spaces been installed in accordance with the approved landscape drawings? See Sections 4.6 and 7.8. | |
| **8.0** | **Enhancing Construction Quality** | |
| 8.1 | Has the quality of the initial fixings (such as roof fixings) been inspected and random checks completed throughout the installation process? See Section 8.5. | |
| 8.2 | As some climate change associated risk treatments will require a different approach on site to that currently undertaken by trade operatives, have checklists been developed, and used throughout the construction process, to focus on these risk treatment measures? See Section 8.5. | |
| **Remarks:** | | |

## Appendix 4: Risk Monitoring and Review

The following suggested actions aim to ensure that implemented risk treatment measures remain effective, relevant, and current over time. They are not exhaustive and client agencies are encouraged to consider these suggestions in the context of their own risk management processes.

| Ref | Suggested Action by Client Agency |
|---|---|
| **1.0** | **Monitoring risks and controls** |
| 1.1 | Regularly checking whether identified risks have changed (e.g. increased, decreased, or new risks emerging). |
| 1.2 | Verifying that control measures are being implemented as planned. |
| 1.3 | Observing operational activities, incident reports, near misses, audits, or performance data to detect warning signs. |
| **2.0** | **Reviewing effectiveness of controls** |
| 2.1 | Assessing whether existing controls are:<br>a) Working as intended.<br>b) Adequate for the level of risk.<br>c) Properly maintained and used. |
| 2.2 | Identifying control failures, gaps, or unintended consequences. |
| **3.0** | **Responding to change -** risk assessment should be reviewed whenever there is: |
| 3.1 | A change in processes, equipment, materials, or work practices. |
| 3.2 | New legislation or standards. |
| 3.3 | Organisational changes (staffing, structure, contractors). |
| 3.4 | An incident, near miss, or safety concern. |
| 3.5 | New information about hazards or risks. |
| **4.0** | **Periodic formal reviews** |
| 4.1 | Scheduled reviews (e.g. annually or project-based) even if no changes or incidents have occurred. |
| 4.2 | Ensures risks haven't been overlooked or become normalised. |
| **5.0** | **Continuous improvement** |
| 5.1 | Updating risk ratings, controls, and action plans based on findings. |

| Ref | Suggested Action by Client Agency |
|---|---|
| 5.2 | Implementing corrective actions and tracking them to completion. |
| 5.3 | Feeding lessons learned back into future risk assessments. |
| **6.0** | **Documentation and communication** |
| 6.1 | Monitoring and recording results, reviewing outcomes and decisions. |
| 6.2 | Communicating changes to relevant workers and stakeholders. |
| 6.3 | Ensuring updated risk assessments are accessible and understood. |

# Appendix 5: Glossary and Abbreviations

## Glossary - Definitions and key terms

| Term | Definition |
|---|---|
| Acceptable | Risks that do not need further treatment. The expression acceptable level of risk refers to the level at which it is decided that further restricting or otherwise altering the activity is not worthwhile.<br>E.g. additional effort will not result in significant reductions in risk levels. |
| Adaptive capacity | The ability of a system to adjust to climate change, moderate potential damages, take advantage of opportunities, or cope with the consequences. In the built environment, this includes the capacity of buildings and infrastructure to respond effectively to climate-related stresses. |
| Climate adaptation | The process of adjusting to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In building design, this involves integrating strategies that enhance resilience to climate hazards. |
| Climate change | A long-term alteration in the state of the climate, typically persisting for decades or longer, resulting from natural processes or human activities, particularly the emission of greenhouse gases. |
| Climate projections | Simulations of future climate conditions based on different scenarios of greenhouse gas emissions, land-use changes, and socio-economic development. These projections are generated using climate models and help inform long-term planning and risk assessments. |
| Climate resilience | The ability of a system—such as a building or community—to withstand, adapt to, and recover from climate-related shocks and stresses, while maintaining essential functions and thriving in a changing climate. |
| Climate risk | The potential for adverse consequences to human or ecological systems due to climate change. Risks may arise from direct climate impacts (e.g., extreme weather) or from human responses to climate change, and are shaped by exposure, vulnerability, and adaptive capacity. |
| Climate variables | Key factors that define and influence climate conditions, including temperature, rainfall, humidity, wind speed and direction, and atmospheric pressure. Changes in these variables can lead to climate hazards such as heatwaves, storms, or droughts. |
| Consequence | The outcome of an event affecting objectives. For example, the consequence of an extreme wind event may be penetration of a building envelope by debris, increasing internal pressure and leading to structural damage from uplift forces acting on tie-down systems. |
| Design Team | Comprises the Lead Consultant and specialist subconsultants engaged for the project. |
| Exposure | The presence of buildings, infrastructure, or assets in locations that could be adversely affected by climate hazards. |
| Extreme weather event | A weather event that is rare for a particular location and time of year. Examples include heatwaves, intense rainfall, and cyclones. The definition of "extreme" varies by region and context. |
| Hazard (climate hazard) | A potentially damaging physical event, trend, or impact—natural or human-induced—that may cause loss of life, injury, property damage, disruption of services, or environmental degradation. |
| Likelihood | The probability or chance of a specific event occurring, often expressed qualitatively or quantitatively in risk assessments. |
| Project Team | Comprises the Client Agency Representative, the DHW Project Manager, the Design Team and the Contractor, where appointed. |

| Term | Definition |
|---|---|
| Representative Concentration Pathways (RCPs) | Scenarios used in the IPCC Fifth Assessment Report (AR5) that describe different greenhouse gas concentration trajectories. Each RCP is defined by its level of radiative forcing (additional heat in the atmosphere) by the end of the 21st century. |
| Risk Treatment | Process to modify risk. |
| Shared Socioeconomic Pathways (SSPs) | The latest IPCC Assessment Report 6 (AR6) identified Shared Socioeconomic Pathways (SSPs). SSPs provide baseline narrative scenarios that identify socio-economic and geopolitical assumptions, and economic and technological trends. |
| Storm surge | Increase in water level at the shoreline due to the forcing of winds (wind-setup) and atmospheric pressure. |
| Vulnerability | The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change. Vulnerability includes sensitivity to harm and limitations in adaptive capacity. |

## Abbreviations

| Abbreviation | Definition |
|---|---|
| ABCB | Australian Building Codes Board |
| AEP | Annual Exceedance Probability |
| AIRAH | Australian Institute of Refrigeration, Air-conditioning and Heating |
| ARR | Australia Rainfall and Runoff |
| B&C | DHW's Buildings & Contracts Division |
| BOM | Bureau of Meteorology |
| BTS | B&C's Buildings & Technical Services Team |
| CAS | Climate Adaptation Strategy |
| CD | Construction Document |
| CMIP | Coupled Model Intercomparison Project |
| CSIRO | Commonwealth Scientific and Industrial Research Organization |
| DD | Design development |
| DHW | Department of Housing and Works |
| DTF | Department of Treasury and Finance |
| DWER | Department of Water and Environmental Regulation |
| ESD | Environmentally Sustainable Design |
| GBCA | Green Building Council of Australia |
| GHG | Green House Gas |
| HVAC | Heating, Ventilation and Air Conditioning |
| IL | Importance Level |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| MEP | Mechanical, Electrical, and Plumbing |
| NCC | National Construction Code |
| PDP | Project Definition Planning |
| RCP | Representative Concentration Pathway |
| SAMF | Department of Treasury & Finance's Strategic Asset Management Framework |
| SD | Schematic Design |
| SSP | Shared Socioeconomic Pathway |
| TG | Technical Guide |
| TMY | Typical Meteorological Year |
| XMY | Extreme Meteorological Year |

# Appendix 6: References & Useful Resources

## Standards

**(Refer to the latest version if listed standard is superseded)**

| Reference Number | Title |
|---|---|
| AS/NZS 1170.2: 2021 | Structural design actions, Part 2: Wind actions. |
| AS 1562.1:2018 | Design and installation of sheet roof and wall cladding, Part 1: Metal. |
| AS1668.2:2024 | The use of ventilation and air-conditioning in buildings, Part 2: Mechanical ventilation in buildings. |
| AS 2047:2014 | Windows and external glazed doors in buildings. |
| AS 2050:2018 | Installation of Roof Tiles. |
| AS/NZS 3500.3:2025 | Plumbing and drainage, Part 3: Stormwater drainage. |
| AS 4055:2024 | Wind loads on housing. |
| AS/NZS 4505:2017 | Garage doors and other large access doors. |
| AS 4685.1:2021 | Playground equipment and surfacing, Part 1 General safety requirements. |
| AS 5334:2013 | Climate change adaptation for settlements and infrastructure – a risk-based approach. |
| ISO 13732-1:2006 | Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces, Part 1: Hot surfaces. |
| ISO 14090:2019 | Adaptation to climate change: principles, requirements and guidelines. |
| ISO 14091:2021 | Adaptation to climate change: guidelines on vulnerability, impacts and risk assessments. |
| ISO 31000:2018 | Risk management: guidelines. |
| ISO 28803:2012 | Ergonomics of the Physical Environment — Application of International Standards to People with Special Requirements. |
| ISO 13732-1:2006 | Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces. Part 1: Hot surfaces. |

## Useful data sources

| Reference | Link |
|---|---|
| Australian Government/ Geoscience Australia: | Australian Rainfall and Runoff Guidelines |
| ABCB - NCC (2022) National Construction Code – Volume 1 | https://ncc.abcb.gov.au/editions/ncc-2022 |
| ABCB - Construction of Buildings in Flood Hazard Areas - Standard | ABCB - Construction of Buildings in Flood Hazard Areas - Standard |
| ABCB - Construction of Buildings in Flood Hazard Areas - Handbook | ABCB - Construction of Buildings in Flood Hazard Areas - Handbook |
| AIRAH DA09 - Air Conditioning Load Estimation and Psychrometrics (Extracts) | AIRAH DA09 - Air Conditioning Load Estimation and Psychrometrics (Extracts) |
| Bureau of Meteorology | https://www.bom.gov.au/climate/data/ |
| CoastAdapt | Home \| CoastAdapt |
| CSIRO & Bureau of Meteorology - Climate Futures Exploration Tool | CSIRO & Bureau of Meteorology - Climate Futures Exploration Tool |
| CSIRO - Typical Meteorological Year (TMY) Data for Building Energy Modelling | CSIRO - Typical Meteorological Year (TMY) Data for Building Energy Modelling |
| CSIRO - Projected Weather Files for Building Energy Modelling | CSIRO - Projected Weather Files for Building Energy Modelling |
| DHW - Technical Guideline TG040 | DHW - Technical Guideline TG040 - Environmentally Sustainable Design for Non-Residential Government Buildings |
| DHW - Consultant's Guidance and Forms | DHW - Consultant's Guidance and Forms |
| DPLH - Western Australian State Planning Policies | Western Australian State Planning Policies |
| DWER. (2023a). Climate Adaptation Strategy: Building WA's climate resilient future | Climate Adaptation Strategy |
| DWER. (2023b). Floodplain Mapping Tool | Floodplain mapping tool \| Western Australian Government |
| DWER - Western Australian Climate Change Risk Management Guide (Interim) | DWER - Western Australian Climate Change Risk Management Guide (Interim) |
| DWER - Western Australian Climate risk assessment tool | DWER - Western Australian Climate risk assessment tool |
| DWER - Water Sensitive Urban Design (WSUD) | DWER - Water Sensitive Urban Design (WSUD) |
| DOT. (2025) Dataset. Western Australia Coastal erosion hotspots | WA Coastal Erosion Hotspot - Dataset - Data.gov.au |
| GBCA's Green Star Building Submission Guideline | Green Building Council of Australia's Green Star Building Submission Guideline |
| NATSPEC | NATSPEC |
| Queensland Flood Resilient Building Guidance for Queensland Homes | Queensland Flood Resilient Building Guidance for Queensland Homes |