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IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

Annual report 2019-2020

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Cover: Damage due to Cyclone Debbie. Source: Cyclone Testing Station

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EXECUTIVE SUMMARY

This BNHCRC project titled: *Improving the resilience of existing housing to severe wind events* prescribes practical structural retrofits that will make improvements to the performance of Pre-80s (Legacy) houses in windstorms as well as measures to reduce damage and loss to modern homes.

The major activity carried out in 2019-20 by the CTS-JCU and GA has been refining the VAWS software package using detailed wind loading and structural response test data and conducting a benefit-cost analysis for a range of retrofit or mitigation options:

- Ten house types common to regions around Australia were selected and analysed using the VAWS package. The structural response (i.e. damage progression) with increasing wind speed has been modelled and compared with house damage states collected during damage investigations. Costing modules for these house types have also been incorporated in VAWS.
- A significant effort was put into developing the water ingress and associated damage and cost modules in VAWS.

The retrofit options for the ten selected house types are also being provided as guideline in a website that is being produced. In line with the project timeline, an alpha version of this tool will be presented to Stakeholders in the next Quarter with the intention of having the final version released at the end of the project.

This project continues to give advice to the Queensland Government Household Resilience Program which provides funding to low income eligible home owners to improve the resilience of their homes against cyclones. This program managed by the Queensland Department of Housing & Public Works (QDHPW) commenced in late 2018 and has been extended through 2020. Eligible home owners can apply to receive a Queensland Government grant of 75% of the cost of improvements (up to a maximum of $11,250 including GST. About 1700 houses have been retrofitted so far.

END-USER PROJECT IMPACT STATEMENT

Leesa Carson, *Geoscience Australia, ACT*

The project is progressing towards its final outputs. The cost-benefit analyses has provided important evidence base to inform stakeholders to take appropriate actions to mitigate based on actionable risk information, which aligns with the aims of the National Disaster Risk Reduction Framework. The analysis has highlighted areas where further research can be conducted in the future to further enhance understanding of the benefits of retrofit work. The relevance of this project's outputs continues to be highlighted via the stakeholder workshop and the two journal papers published this year. This project continues to have strong stakeholder engagement ensuring the project outputs will be of practical use for end-users. In particular the website for which the design has commenced will facilitate the utilisation of the project's research. The COVID-19 pandemic precluded a face to face stakeholder workshop to gain feedback on the intent and functionality of the alpha version of the website. The research team took a flexible approach to this hurdle and will hold a slightly delayed workshop via a series of online focus groups with stakeholder organisations.

PRODUCT USER TESTIMONIALS

John Galloway, *Chair - Cyclone Testing Station Advisory Board*

Discussions with a range of stakeholders indicate that the retrofitting guidelines being developed as a part of the BNH-CRC project 'Improving the resilience of existing housing under severe wind events' are a useful tool for use by Industry. A second stakeholder workshop was held during the Cyclone Testing Station's Advisory Board, consisting of individuals in key positions from ABCB, Qld State and Local Government, the Insurance industry, the Building industry, and Product manufacturers on 9 October 2019.

The aim of the workshop was to provide details of the format and proposed technical content of the guidelines being developed (including web based) and obtain feedback. Attendees were presented with an overview of the current CRC project including the other research tasks such as the development of the VAWS vulnerability modelling software and the benefit - cost analyses of retrofitting houses. A mock-up of a website was presented to provide a preview of the content and functionality of the site. Finally, a series of questions were posed to the attendees to guide the discussion and obtain feedback on key aspects of the presentation of the guidelines.

Important discussion points included the communication of the levels of performance the different types of retrofits may provide and regulatory aspects of having works performed. Additionally, the importance of considering engagement with community and feedback from industry in order improve the utilization of the guidelines was highlighted. Overall, the CTS Advisory Board was supportive of the proposed guidelines and further work may include working with organisations to promote incentive schemes and sources of funding for retrofitting programs.

INTRODUCTION

Post windstorm damage investigations carried out by the Cyclone Testing Station (CTS) have shown that Pre-80s houses across Australia are vulnerable to wind damage. The damage is caused by design and construction faults, poor connection details (i.e. batten/rafter, rafter/top plate). These studies also show that wind driven rainwater ingress related damage at low to moderate wind speeds are common across all (including Post-80s contemporary) house types.

This project prescribes practical structural retrofit solutions for improving the performance of house types common across Australia. Considering the prevalence of roofing failures due to unsatisfactory fixings in some house types, this project aims to widely disseminate guidelines on the benefits of good retrofitting measures. Additional benefits to home owners (i.e. reduction in insurance premiums) will also be highlighted to encourage take-up of these upgrading provisions. The VAWS software package forms an integral part of developing these cost effective retrofit measures.

BACKGROUND

This project examines the benefit-cost of retrofitting the legacy housing stock to improve its performance when exposed to severe winds. Table 1 shows the distribution of legacy (here defined as pre-1982) houses and modern houses in the Australian building stock. In the non-cyclonic regions legacy houses represent approximately 42% of the housing stock whilst in cyclonic regions, legacy houses comprise approximately 45% of the housing stock. Hence there is a significant proportion of the Australian housing stock built prior to the introduction of modern standards that may benefit from retrofit against severe wind hazard.

Wind regions	Pre 1982 (legacy)	1982+ (modern)
A and B	2,977,295	4,121,781
C and D	164,432	204,317

TABLE 1. NUMBERS OF HOUSES IN AUSTRALIA BY AGE AND WIND REGION EXTRACTED FROM NEXIS [1]

To calculate the benefit-cost of a specific retrofit scenario to a specific house type, the project must calculate the cost of retrofit and the benefit accrued through reduced loss in future storms. Previous reports have described:

- Source data for costing repair of north Queensland houses [2]
- Source data for costing repair of southern Australian houses [3]
- Descriptions and details of the retrofit options that the project is considering [4]
- Source data for the cost to install retrofit work [4]
- The software tool, VAWS, developed by the project to estimate the vulnerability of house types both before and after retrofit [5]
- The method that the project uses to calculate benefits [6].

RESEARCH APPROACH

Initial work this financial year on the VAWS vulnerability modelling software included incorporating feedback and suggestions from the Stakeholder meeting held in Sydney in 2019. Additionally, refinements to the program logic to simplify inputs required for more complex roof geometries was implemented.

Cost-benefit analyses of several retrofitting scenarios for the ten selected representative house types were performed. Analyses used the VAWS software in conjunction with calculations of the average annual loss to determine the present value of benefit for a 30 year period. Initial results were presented in the BNHCRC Report 3.2.1. Further work was also undertaken to improve modelling of the failure of hip roofed houses, wall collapse and the failure behaviour of tiled roofs.

GENERIC HOUSE TYPES

There is a large variety of house types across Australia. The project has selected ten generic house types of simple geometry based on surveys from different parts of Australia, interviews and exposure databases. The selected house types are intended to broadly reflect the variety of houses found in the Australian building stock. Table 2 lists the ten generic house types together with some descriptive attributes.

Generic house type	Vintage	Wall construction	Roof material	Roof shape
1	Legacy	Fibro (high set)	Metal sheeting	Gable, low pitch
2	Modern	Reinforced block	Metal sheeting	Gable, medium pitch
3	Legacy	Double brick	Metal sheeting	Gable, medium pitch
4	Legacy	Double brick	Tile	Gable, medium pitch
5	Legacy	Double brick	Metal sheeting	Hip, medium pitch
6	Legacy	Double brick	Tile	Hip, medium pitch
7	Legacy	Brick veneer	Metal sheeting	Gable, medium pitch
8	Legacy	Brick veneer	Tile	Gable, medium pitch
9	Legacy	Brick veneer	Metal sheeting	Hip, medium pitch
10	Legacy	Brick veneer	Tile	Hip, medium pitch

TABLE 2. PROJECT GENERIC HOUSE TYPES

VULNERABILITY ANALYSIS: HOUSE VULNERABILITY ASSESSMENT PROCESS

Each generic house type was modelled in the VAWS software tool [5]. The types of structural components and connections modelled varied by house type, and all modelled house types accommodated water ingress, debris damage to vertical wall elements and pressure-induced failure of windows and doors.

The output of VAWS is a series of coordinates defining a graph of damage index versus gust wind speed at the house. Each house was modelled in its base or unmitigated condition. In addition, each specified practical retrofit scenario for each house type was modelled separately by changing the strength properties for upgraded components and connections.

COMPONENT STRENGTHS

The assessment of vulnerability relies on many inputs. However, perhaps one of the most important is the assessment of connection strengths for both the existing, unretrofitted connections in legacy houses and retrofitted or strengthened connections. Report 3.2.1 presents the strengths and coefficients of variation adopted for the ten generic house types considered in this study [6]. This report also describes the mitigation work modelled to various connections in the generic house types and the strengths adopted for each upgraded connection type.

RETROFIT SCENARIOS

For each of the generic house types, a number of practical retrofit scenarios were modelled to explore the benefit-cost of these retrofit measures. Each scenario involved the retrofit of a specific component of the house type (e.g. addition of window protection screens).

COSTS OF MITIGATION IMPLEMENTATION

Estimates of the cost of retrofit were determined via a contract with a professional quantity surveyor [2]. The estimates included sufficient data to establish a full cost estimate for a retrofit scenario. Apart from the work of installing the actual retrofit, costs were also provided that cover access, removal and replacement of linings and fittings for access to install retrofit, builders' preliminaries and profit. Programs such as the Queensland Household Resilience Program, also provide data on the cost of retrofit that will be used to validate the quantity surveyor sourced cost estimates. The costs assume a builder is retrofitting a single house. Experience from the Queensland Household Resilience Program has indicated that widespread retrofit programs can lead to significantly reduced retrofit costs.

UNMITIGATED AND MITIGATED BUILDING VULNERABILITIES

The vulnerability curves for the base, or unmitigated, house together with outcomes from each retrofit scenario (such as the installation of window protection followed by enhanced batten to rafter tie down etc.) are derived for each house type. It can be seen that each retrofit option generally provides enhanced resilience.

SUMMARY OF BENEFIT COST ANALYSIS RESULTS

Whilst the repair of building fabric is perhaps the most obvious cost incurred due to wind-induced damage there are other costs which should be considered. This section discusses the non-building fabric costs that the project incorporated into the benefit-cost calculations. No allowance has been made for demand surge following a large storm such as a cyclone.

In the modern Australian environment, casualties from the actions of severe wind on buildings are thankfully rare. Thus, for this project, estimation of casualties arising from wind induced building damage and reduction in casualty numbers afforded by retrofit was not undertaken.

Wind-induced damage to the house envelope and structure together with water ingress will also damage contents within the house. The reduction in contents damage due to retrofit of the house is a benefit that is accounted for by the project.

Even if a house incurs minor damage during a storm it is likely that the occupants will require temporary accommodation while the damage is assessed, a builder found to undertake the repairs and the repair work executed. This cost is included in the analysis. However, no allowance has been made for the cost to the community of disruption from dislocation of members of the community due to having to find available accommodation etc.

The economic advantage of retrofitting is expressed as a benefit-cost ratio where the cost is the cost of installing the retrofit and the benefit is the reduction in average annual loss over the remaining life of the building plus any reduction in indirect costs such as temporary housing required whilst repairs are carried out following wind damage. A ratio greater than one indicates a positive economic advantage of undertaking retrofit.

The method used by the project to calculate benefit-cost is described in [6] and summarised below.

CALCULATION OF BENEFIT

The calculation of benefit is important for calculating a benefit-cost ratio.

The present value of benefit is taken as:

$$\sum_i \left((AAL_{bi} - AAL_{ri}) \times \left(\frac{1}{(1+r)^i} \right) \right)$$

where:

- AAL_{bi} is the average annual loss of the unmitigated house at year *i*
- AAL_{ri} is the average annual loss of the retrofitted house at year *i*

- *i* is the year number from current year varying from 1 to the remaining number of years in the house's lifespan
- *r* is the interest rate.

The average annual loss is calculated as the area under the loss-probability curve for the particular house for a particular retrofit scenario. The assessment of average annual loss is undertaken at each year as this enables the vulnerability curves (both unmitigated and retrofitted) to be adjusted if required to account for effects such as change in hazard, dilapidation and retrofit in future years (as opposed to retrofit at present time).

The loss-probability curve is determined by transforming the vulnerability curve for the house whether mitigated or retrofitted. For this project, the vulnerability curve, a plot of damage index versus the 0.2s, 10m gust wind speed at the house of interest, is output from the project-developed VAWS software [5].

FINDINGS

The efficacy of a range of retrofitting options for 10 representative Australian houses (an example is shown in Figure 1) were analysed using the VAWS wind vulnerability modelling software and benefit cost ratios were calculated based on the annual average loss over a 30 year period.

The development of the VAWS vulnerability modelling software has been a major part of this BNHCRC project. The program simulates structural, debris and water ingress damage of a house based on input data from wind tunnel studies and testing of structural elements. Using a Monte Carlo approach, a damage index as a function of wind speed can be calculated for a range of retrofitting scenarios, shown in Figure 2 and Figure 3 which show vulnerability functions for a metal roofed house and a tile roofed house of similar geometry.

Benefit-Cost ratios were calculated based on cost information from a professional quantity surveyor and the net benefit of retrofitting calculated based on the annual average loss derived from the damage index functions.

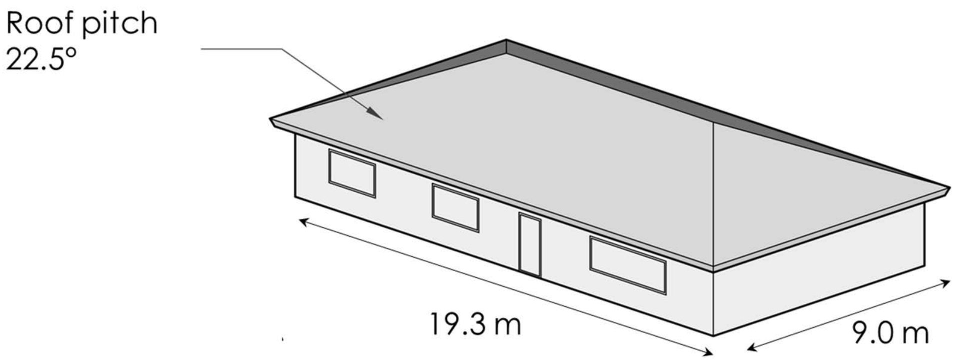


FIGURE 1. OVERALL DIMENSIONS OF THE HIPPED ROOF GENERIC HOUSE TYPES

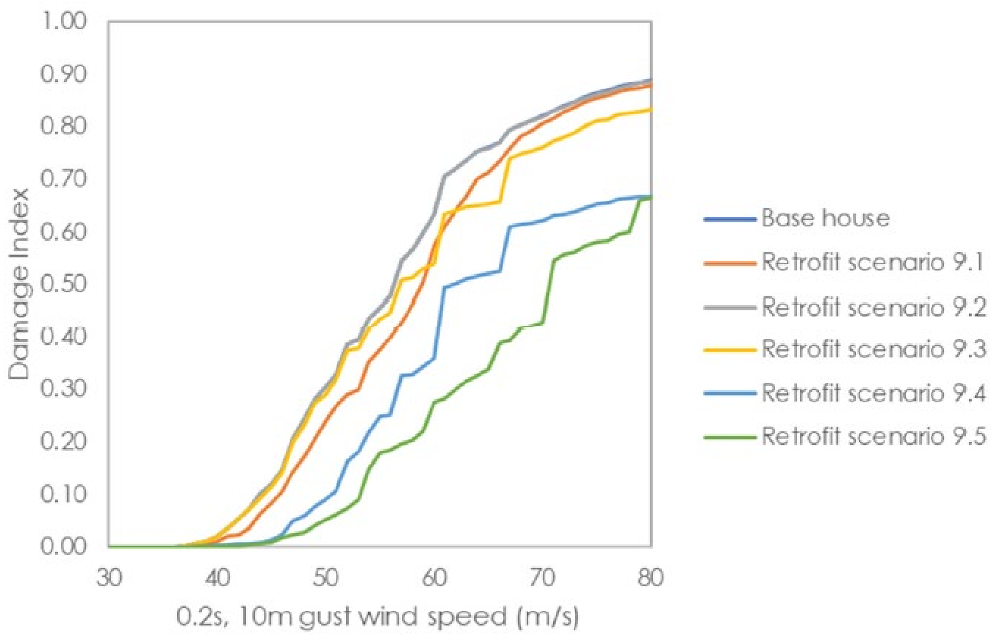


FIGURE 2. VULNERABILITY FUNCTIONS FOR HOUSE TYPE 9 – BRICK VENEER + METAL ROOF CLADDING

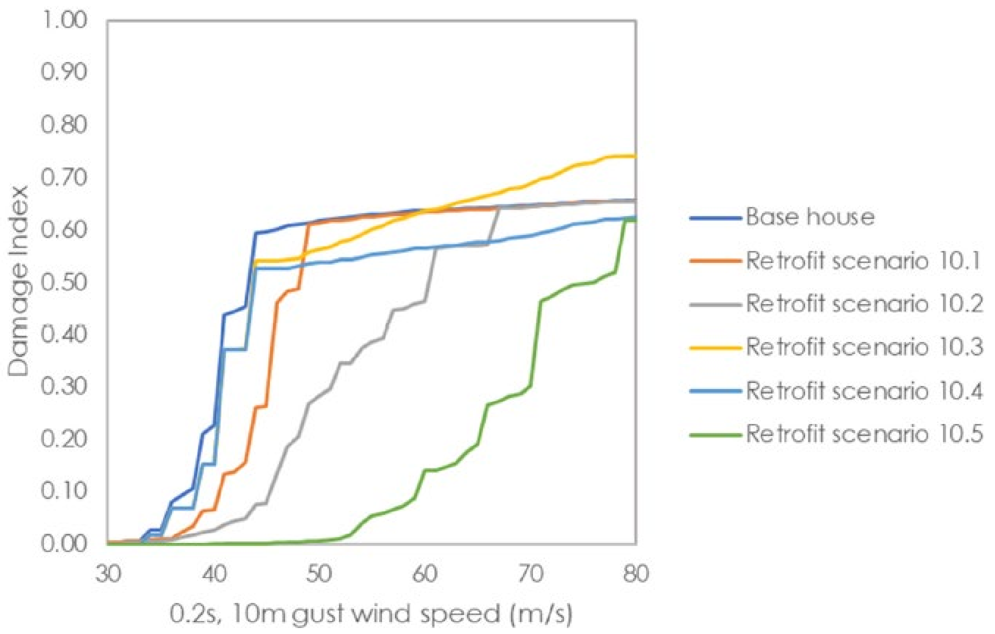


FIGURE 3. VULNERABILITY FUNCTIONS FOR HOUSE TYPE 10 – BRICK VENEER + TILE ROOF CLADDING

The benefit cost ratios, shown in Table 3 account for the probabilities of wind damage occurring through the annual average loss calculations for the different wind regions. As such, there is generally no benefit of retrofitting the representative house types in the non-cyclonic wind regions A. On the other hand, benefit cost ratios close to and exceeding 1.0 were obtained for certain retrofitting scenarios in the cyclonic wind region C.

Additionally, it was found that tile roof houses greatly benefit from certain retrofitting scenarios, mainly due to the reduction of water ingress damage at lower and more frequently occurring wind speeds.

Generic House Type	Retrofit Scenario	Retrofit Description	Benefit/Cost Ratio Region A	Benefit/Cost Ratio Region C
House Type 9	9.1	Window protection and door upgrade	0.00	0.94
-Brick Veneer	9.2	Roof sheeting upgrade	0.00	0.00
-Metal Sheet	9.3	Roof sheeting and batten connection upgrades	0.00	0.03
-Hip	9.4	Roof sheeting, batten connection and roof structure upgrade	0.00	0.56
	9.5	All upgrades 9.1 to 9.4	0.00	0.53
House Type 10	10.1	Window protection and door upgrade	0.06	9.03
-Brick Veneer	10.2	Additon of Sarking	0.02	4.75
-Tile	10.3	Addition of tile clips + batten connection upgrades	0.01	0.68
-Hip	10.4	Addition tile clips + batten connections and roof structure upgrade	0.01	0.58
	10.5	All upgrades 10.1 to 10.4	0.02	3.60

TABLE 3. B ENEFIT COST RATIOS FOR A RANGE OF RETROFITTING SCENARIOS FOR HOUSE TYPES 9 AND 10

The current benefit cost analyses only account for cost related to the damage of the house. Accounting for costs related to the disruption of economic activity in the community and mental health impacts of the event on citizens and other intangible costs would improve the benefit to cost of retrofitting older houses. However, this level of analysis is outside the scope of the current BNHCRC Project.

Further reductions in costs can occur when there is increased demand in the market for retrofitting. For example, the average costs of a full roof upgrade (scenario 9.4) during the Queensland Household Resilience Program were significantly lower than those calculated by the quantity surveyor, yielding a B/C ratio of approx. 2 for a full roof upgrade on house type 9 in Region C as opposed to the 0.53 from Table 3. Additional benefits that are not accounted for in this study are potential reductions in insurance premiums that may be offered to customers for implementing retrofitting measures.

KEY MILESTONES

Several Milestones were achieved in 2019-20 as listed in Table 4. These Milestones have enabled the project to progress satisfactorily and to commence development of the final project outputs that will available to Homeowners as well as Building and Insurance Industries.

The VAWS software package has been calibrated and validated for ten house types since its preliminary version was demonstrated by the team at a Stakeholder Meeting in Sydney, in 2019. Input data for all house types have been added and the package finalized. VAWS is used for assessing practical, cost-effective structural retrofit options for these house types. The proposed retrofit options will be presented in the final report and also as easy to use web guidelines at the end of the project.

Milestone	Description	Due Date
3.1.1	Draft report on proposed retrofitting methods and incentive schemes for stakeholder comments (not public release)	*30/09/2019*
3.1.2	Stakeholder workshop on retrofitting measures cost benefit outcomes (U2.6.3)	*30/09/2019*
3.1.3	Poster for BNHCRC Conference	*30/09/2019*
3.1.4	Quarterly Report	*30/09/2019*
3.2.1	Retrofitting methods with cost benefit analysis. Assessment of retrofit measures for mitigating wind driven rain water ingress damage	31/12/2019
3.2.2	Quarterly Report	31/12/2019
3.3.1	Journal paper on vulnerability assessment incorporating cost benefit analysis (CM 2.5.24)	*31/03/2020*
3.3.2	Quarterly Report	*31/03/2020*
3.4.1	Alpha version – Content for web based Guidelines for retrofitting and improving home resilience to severe storms	*30/06/2020*
3.4.2	Quarterly Report, Annual Report, Self-Assessment Matrix, Adjust utilisation Road Map if needed	*30/06/2020*

TABLE 4. MILESTONES FOR FINANCIAL YEAR 2019/20

UTILISATION AND IMPACT

SUMMARY

The project has had three important Utilisations and Impacts.

1. The Queensland Government Household Resilience Program (HRP)
2. Vulnerability and Adaption to Wind Simulation (VAWS)
3. Easy to use web based guidelines
4. Queensland Reconstruction Authority Cyclone and Storm Tide Resilient Building Guidelines

THE QUEENSLAND GOVERNMENT HOUSEHOLD RESILIENCE PROGRAM

The Queensland Government Household Resilience Program (HRP) provides funding to help eligible homeowners improve the resilience of their homes against cyclones. This program developed with advice from the Cyclone Testing Station is managed by the Queensland Department of Housing & Public Works (QDPWH) and commenced in late 2018 and was completed toward the end of 2019. The project was recently restarted on 1 July 2020

Eligible homeowners can apply to receive a Queensland Government grant of 75% of the cost of improvements (up to a maximum of $11,250 including GST).

Eligibility criteria require that the homeowner:

- live in a recognized cyclone risk area (in the area from Bundaberg to the Queensland/Northern Territory border within 50km of the coast)
- own or be the mortgagor of a house built before 1984
- live in the home (primary place of residence)
- meet certain income eligibility requirements.

Approved applicants are required to make a minimum 25% co-contribution towards the approved program works undertaken and may be able to arrange a loan to fund all or part of this co-contribution.

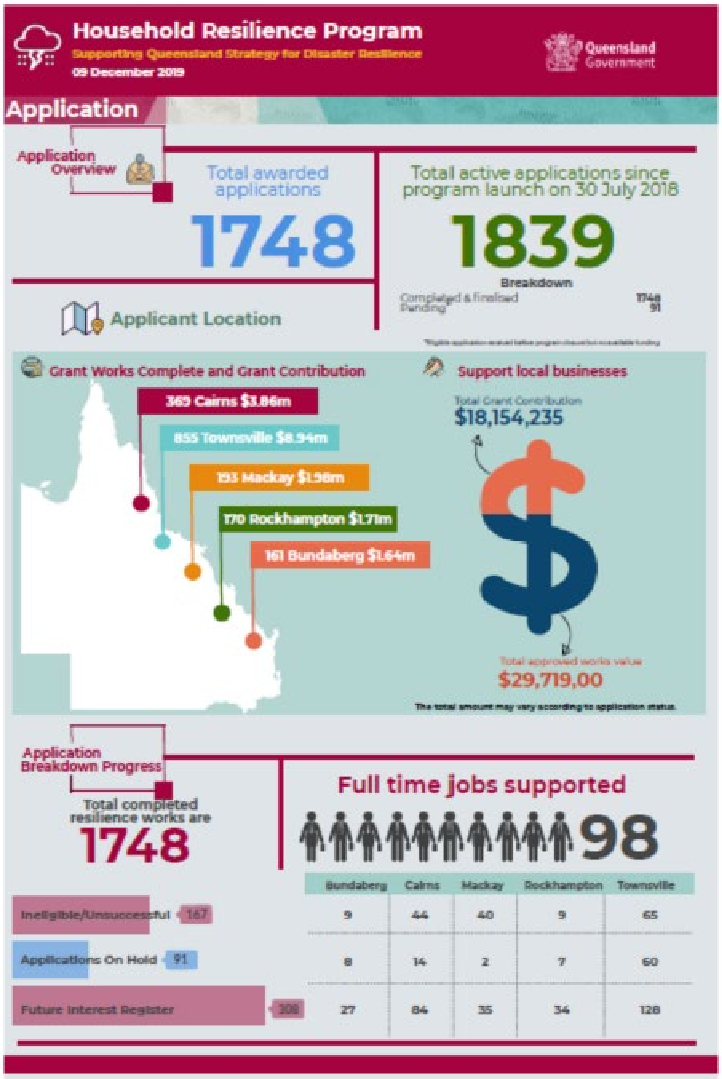
Improvements covered under the program, include:

- roof replacement including upgrade to roof tie-down
- roof structure tie-down upgrades using an external over-batten system
- replacement of garage doors and frames
- window protection including cyclone shutters or screens
- tie downs of external structures (e.g. sheds)
- replacement of external hollow core doors with solid core external grade doors.

Extent of Use, Utilisation & Impact

In December 2019, the Department of Housing and Public Works indicated that approximately 1800 applications have been received to date of which about 1700 valued at $18.1M have been approved. The total works value of this is $29.7M. These works resulted in reductions in insurance premiums averaging about 8%. Summary statistics provided in reports from the Department of Housing and Public Works, an extract is shown in Figure 4.

Utilisation and Impact Evidence



	Bundaberg	Cairns	Mackay	Rockhampton	Townsville
Ineligible/Unsuccessful 167	9	44	40	9	65
Applications On Hold 91	8	14	2	7	60
Future Interest Register 308	27	84	35	34	128

FIGURE 4. SUMMARY STATISTICS OF THE QLD HOUSING RESILIENCE PROGRAM IN MARCH 2019. SOURCE: QLD GOVERNMENT DEPT OF HOUSING AND PUBLIC WORKS

VULNERABILITY AND ADAPTION TO WIND SIMULATION (VAWS)

Modelling the vulnerability of houses in windstorms is important for insurance pricing, policy-making, and emergency management. Models for Australian house types have been developed since the 1970s, and have ranged from empirical insurance to reliability based structural engineering models, which provide estimates of damage for a range of wind speeds of interest. However, outputs from these models are also frequently misinterpreted as the basis of these models including underlying assumptions aren't adequately understood by the user. The Vulnerability and Adaption to Wind Simulation (VAWS), which uses probability based reliability analysis and structural engineering for the loading and response coupled with an extensive test database and field damage assessments to calculate the damage experienced by selected Australian house types.

VAWS consists of probabilistic modules for the 1. Wind hazard – external and internal pressures generated by the atmospheric wind and 2. Structural response – related to the structural system and capacities of the components and connections, and load effects. VAWS consists of the main modules (i.e. the house type and structural system, external and internal pressure distribution, structural response, initiation and progression of damage, and other effects such as windborne debris impact and water ingress and cost of repair). VAWS has had its outputs validated against damage observed during past wind storms for the ten house types.

VAWS is able to accommodate a range of house types for which the structural system and their strengths and the external pressure distribution for wind exposure from directions around the compass are known. The critical structural components are probabilistically assigned their strengths and the wind loads are applied for winds approaching from a specified direction. Failure is initiated when the load exceeds the capacity of a critical component or connection as the wind loads are increased with increasing wind speed. When components fail, loads are redistributed through the structural system. The cost of repair is calculated for the given level of damage and the damage index = repair cost/ original cost is calculated at each wind speed increment.

For each house type, the cost of a specific retrofit option is calculated and the effect of this retrofit on the performance is ascertained via the vulnerability (i.e. damage index vs wind speed). The benefit of this retrofit is calculated by calculating the expected reduction in damage over a 30 year period, from which the benefit – cost for that retrofit is calculated. This process the applied to progressive retrofit options.

Extent of Use, Utilisation & Impact

Utilisation of any technical information source such as the proposed guidelines requires stakeholder engagement during the development process. Therefore, a preliminary stakeholder workshop was held during the Cyclone Testing Station's Advisory Board meeting hosted at the Townsville Local Disaster Coordination Centre on the 9th of October. Attendees include individuals in key positions from a range of organisations from Government, the insurance industry, the building industry, Product manufacturers and local government, shown in Table 5.

Utilisation and Impact Evidence

Name	Organisation
Wayne Preedy	Townsville City Council
Karl Jones	Willis RE
Josh Kelland	Suncorp Insurance
Subo Gowripalan	Stramit
Elizabeth McIntyre	Roof Tile Association of Australia
Lindsay Walker	Queensland Department of Housing and Public Works
Craig Carpenter	Queensland Department of Housing and Public Works
Gary Stick	Queensland Building and Construction Commission
John Galloway	Chair of Board and representing Master Builders Association
Roger MacCallum	MacCallum Planning and Architecture representing the Royal Australian Institute of Architects
George Walker	JCU
Mark Leplastrier	IAG Insurance
Adrian Gabrielli	Gabrielli Constructions representing Master Builders
Karen Messer	Northern Consulting Engineering representing Engineers Australia
Daniel Smith	CTS
David Henderson	CTS
Debbie Falck	CTS
Geoffrey Boughton	CTS
John Doolan	CTS
John Ginger	CTS
Korah Parackal	CTS
Simon Ingham	CTS

TABLE 5. ATTENDEES OF THE STAKEHOLDER MEETING

The aim of the workshop was to raise awareness of the project to these organisations and gain feedback on the proposed content and purpose of the guidelines. Attendees were presented with an overview of the current CRC project including the other research tasks such as the development of the VAWS vulnerability modelling software and the cost benefit analyses of retrofitting houses. Additionally, a mock-up of a website was presented to provide a preview of the content and functionality of the site. Finally, a series of questions were posed to the attendees to guide the discussion and obtain feedback on key aspects of the presentation of the guidelines.

Questions presented in the workshop included:

- **Are different levels of mitigation appropriate? E.g. 60%, 100% of current design criteria**
- **How should we communicate the different levels of mitigation?**
    - How to show relative performance compared to current code compliant houses?
    - Should we even do it?
    - Methods:
        - Infographics

        - Bronze, silver, gold
        - Star rating
        - Loads in kN

- **How do we maximise utilisation?**
    - What are the existing platforms that homeowners and builders use to get information?
        - Can these resources direct people to the guidelines?
    - Seek funding for marketing and running workshops?
        - Target: equivalents of QBCC, AIBS, Master builders, Homeowners
- **Additional comments and discussion:**
    - Development of maintenance schedule?

Additional important discussion points included the communication of the levels of performance different types of retrofits and regulatory aspects of having works performed. Additionally, the importance of considering behavioural science and market research in order to improve the utilization of the guidelines was highlighted. Overall, the stakeholders were supportive of the proposed guidelines and further work may include working with organisations to promote incentive schemes and sources of funding for retrofitting of programs. Discussion points raised during this stakeholder meeting will shape the questions and agenda included in future stakeholder engagement activities.

EASY TO USE WEB BASED GUIDELINES

Communicating the importance and the process of retrofitting houses is a crucial part of improving the resilience of older housing stock. Currently, retrofitting guidelines that are easy to use, and openly accessible to building professionals and homeowners for Australian houses is lacking. Several documents and websites are available regarding retrofitting of houses in other countries, mainly the United States. However, technical details of the retrofits and graphical explanations of key parts of the structures are usually not available. As such, the development of a set of online guidelines is a key this BNHCRC project.

The guidelines will provide information on general principles and technical details of retrofitting older houses for windstorms. Content is aimed at anyone with an interest in home-improvement/ renovations / DIY projects. Not necessarily with formal engineering or construction qualifications. The guidelines will contain range of retrofitting measures for selected common Australian house types as well as basic background information on wind loading and house construction. Additionally, the importance of maintenance for both old and new house types, as well as the benefits of window and door protection for new houses is highlighted

Retrofitting options for typical scenarios that are applicable to most houses are presented in the form of illustrations and drawings where descriptions are provided in both general and technical terms. For other scenarios of retrofitting that may require additional technical requirements, reference is made to existing codes and standards and handbooks for use by building professionals and engineers. A unique feature of these guidelines is that the effectiveness of retrofits are quantified using the VAWS vulnerability modelling software developed through the BNHCRC project.

General Approach

The guidelines are presented in a modern website format that is compatible with desktop and mobile devices. The user experience has been designed to guide users of the website through a process of selecting an appropriate level of retrofitting for their particular house type. Different levels of mitigation are presented such as maintenance requirements, window and door protection, and roof retrofitting.

Retrofitting details are then presented in the form of interactive info graphics with additional information on the science of wind loading easily accessible throughout the site, as shown in Figure 5

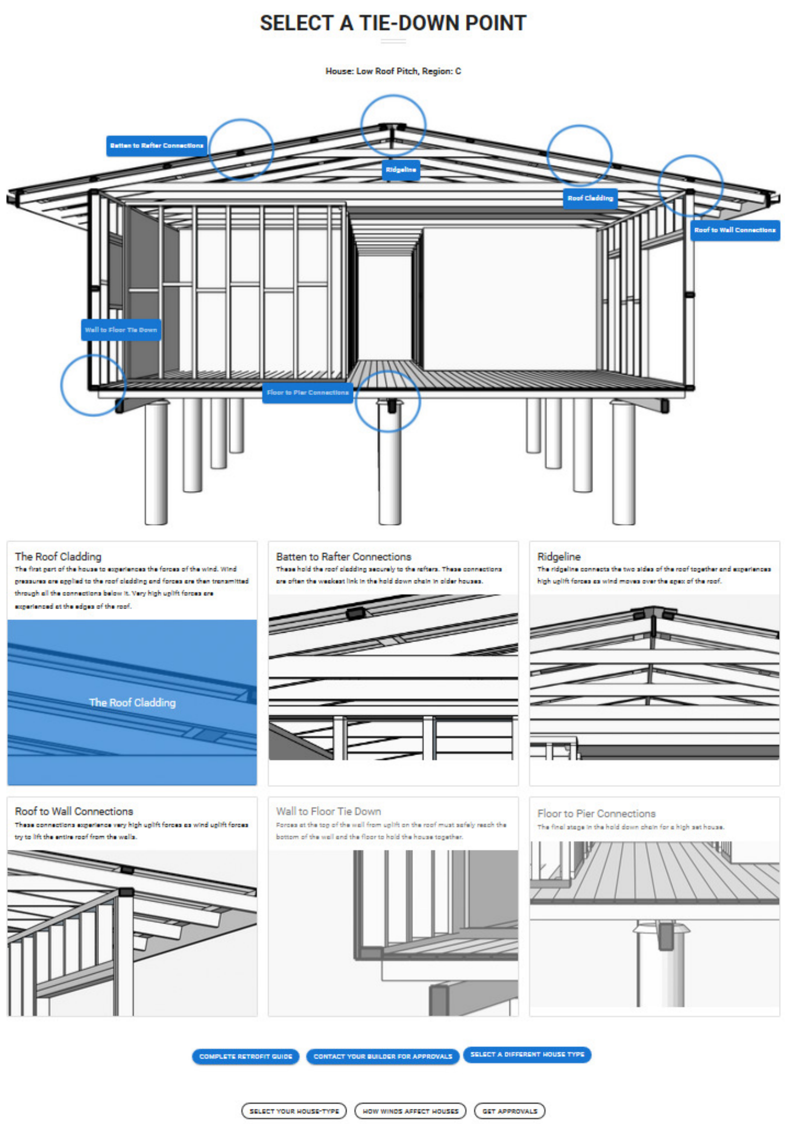


FIGURE 5 AN EXAMPLE OF THE INTERACTIVE INFOGRAPHICS FOR HIGHSET, LOW ROOF PITCH HOUSE TYPE

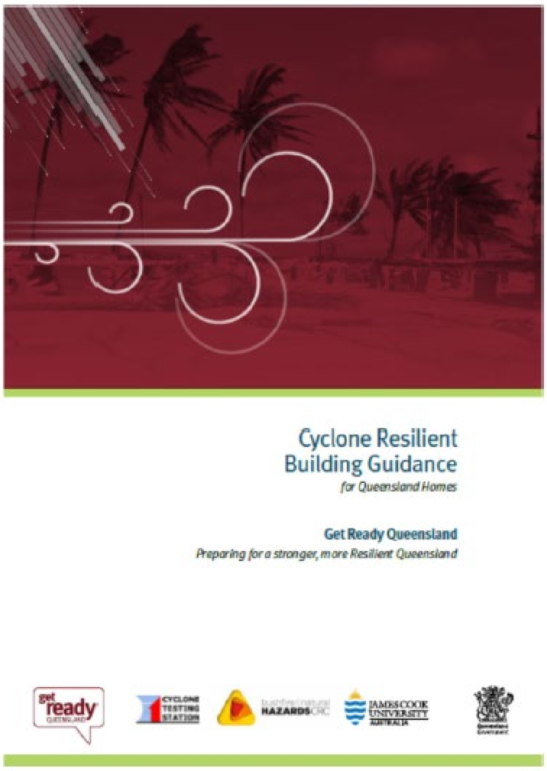
Stakeholder feedback and engagement is important for the development of quality set of guidelines as well as the usability of the site. The alpha version of this site that has been developed this financial year will be tested and critiqued by a range of stakeholders including government regulators, insurance agencies, builders and engineers. Due to the current COVID-19 restrictions these stakeholder workshops will be in the form of online focus groups consisting of individuals and key members of organisations.

QUEENSLAND RECONSTRUCTION AUTHORITY CYCLONE AND STORM TIDE RESILIENCE BUILDING GUIDELINES

The Queensland Reconstruction Authority has recently released two sets of guidelines for cyclone and storm tide resilient buildings (Figure 6). These are comprehensive documents that were developed in collaboration with the Cyclone Testing Station with support from the BNHCRC, with the storm tide guide also being created in collaboration with Systems Engineering Australia Pty. Ltd.

The cyclone resilient guide provides information on the risks of tropical cyclones including general information on the science and meteorology of these weather systems. Additionally, the guidelines provide significant amounts of information on resilient design principles, constructing new cyclone resilient homes and strengthening existing homes, as well has information on rebuilding after a cyclone.

Following a similar structure, the storm tide guidelines also outline the impacts and risks of storm tides and provide details on design principles for new houses, recommendations for existing houses and information on rebuilding after storm tide damage.



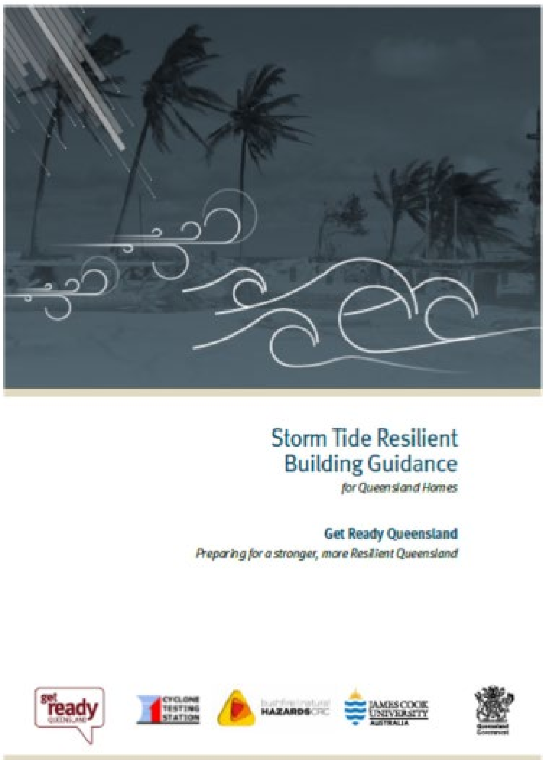


FIGURE 6. COVER PAGES OF THE CYCLONE AND STORM TIDE RESILIENCE BUILDING GUIDES

NEXT STEPS

UPCOMING MILESTONES IN 2020/21

The first quarter of the next financial year represents the final stages of this BNHCRC project. Key activities will include the preparation for the public release of the VAWS vulnerability modelling software, compilation and analysis of results from the completed cost benefit analyses and the finalisation of the web-based retrofitting guidelines.

Continued stakeholder engagement will be a valuable part of the development of the online retrofitting guidelines. Due to the current COVID-19 restrictions to travel, the originally intended stakeholder workshops will now be conducted as series of online focus groups with individuals and organisations. A list of the upcoming milestones for next financial year are presented in Table 6.

Milestone	Description	Due Date
4.1.1	Stakeholder engagement with web content (not-public) trials for retrofitting methods and resilience implementation	30/09/2020
4.1.2	Quarterly Report	30/09/2020
4.2.1	Web based Guidelines for retrofitting and improvinghome resilience to severe storms (U2.6.4)	31/12/2020
4.2.2	Synthesis Report summarising all project activities	31/12/2020
4.2.3	Quarterly Report, Closure Report, Self-Assessment Matrix, Adjust Utilisation Road Map if needed	31/12/2020

TABLE 6. MILESTONES FOR FINANCIAL YEAR 2020/21

PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

Navaratnam, S., Ginger, J., Humphreys, M., Henderson, D., Wang, C.H., Nguyen, K.T. and Mendis, P., 2020. Comparison of wind uplift load sharing for Australian truss-and pitch-framed roof structures. Journal of Wind Engineering and Industrial Aerodynamics, 204, p.104246.

Parackal, K.I., Ginger, J.D. and Henderson, D.J., 2020. Progressive failures of batten to rafter connections under fluctuating wind loads. Engineering Structures, 215, p.110684.

Smith, D.J., Edwards, M., Parackal, K., Ginger, J., Henderson, D., Ryu, H. and Wehner, M., 2020. Modelling vulnerability of Australian housing to severe wind events: past and present. Australian Journal of Structural Engineering, pp.1-18.

Scovell, M., McShane, C., Swinbourne, A. and Smith, D., 2020. How fringe cyclone experience affects predictions of damage severity. Disaster Prevention and Management: An International Journal.

Parackal, K., Wehner, M., Ryu, H., Ginger, J., Smith, D., Henderson, D. and Edwards, M., 2019. Modelling the vulnerability of a high-set house roof structure to windstorms using VAWS. Australian Journal of Emergency Management, 4, pp.51-63.

CONFERENCE PAPERS

Henderson, D., Buckley, B., Dyer, A., Stone, G., Leplastrier, M., 2020, Wind and Rain – systemic failures resulting in loss of functionality of residences and commercial properties during severe weather, AMOS Conference, Australian Meteorological and Oceanographic Society, Perth

Henderson, D., Smith, D., Boughton, G., Ginger, J. 2019. Damage and Loss from Wind-driven Rain Ingress to Australian Buildings. In the Proceedings of the 15th International Conference on Wind Engineering (ICWE15), 2019 Beijing, China.

Humphreys, M., Ginger, J., Henderson, D. 2019. Effect of Opening Area on Full-scale Internal Pressure Measurements. In the Proceedings of the 15th International Conference on Wind Engineering (ICWE15), 2019 Beijing, China.

Parackal, K., Ginger, J., Henderson, D., 2019. Progressive Failures of Light Framed Timber Roofs. In the Proceedings of the 15th International Conference on Wind Engineering (ICWE15), 2019 Beijing, China.

Smith, D., Morrison, M. 2019. Full-scale Wind Tunnel Testing of North American and Australian Roofing Tile Systems. In the Proceedings of the 15th International Conference on Wind Engineering (ICWE15), 2019 Beijing, China.

POSTERS

Parackal, K., Wehner, M., Ryu, H, Ginger, J., Henderson, D., Edwards, E., 2019. VAWS – Vulnerability and Adaptation to Wind Simulation. Poster presented at the 2019 BNHCRC and AFAC Conference, Melbourne

Humphreys, M., Ginger, J., Henderson, H., 2019. Mitigating Wind Damage Caused by Internal Pressures. Poster presented at the 2019 BNHCRC and AFAC Conference, Melbourne

COMMUNITY PRESENTATIONS

Parackal, K. 2020, Engineering Houses to Resist Cyclones, Public Lecture at the Museum of Tropical Queensland, Townsville.

Parackal, K. 2020, Engineering Houses to Resist Cyclones, Public Lecture Townsville City Council's Disaster Ready Sunday.

THESES

Humphreys, M., 2020 Characteristics of wind-induced internal pressures in industrial buildings with wall openings, PhD Thesis Submitted to the Graduate Research School, James Cook University.

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END-USERS

Geoscience Australia

Suncorp

Queensland Government

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1 Nadimpalli, K., M. Edwards, and D. Mullaly. National Exposure Information System (NEXIS) for Australia: Risk assessment opportunities. in MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December. 2007.

2 Turner-&-Townsend and Rawlinsons, Wind damage cost module development for north Queensland building types. 2006, Report to Geoscience Australia, 4 volumes.

3 Turner-&-Townsend, Repair and replacement costs for eight southern Australian house types. 2019, Report to Geoscience Australia.

4 K, P., et al., Design details of retrofitting measures of legacy housing. 2019, Report to the BNHCRC.

5 Parackal, K., et al., Model for assessing the vulnerability of Australian Housing to Windstorms – VAWS. 2019, Report to the BNHCRC.

6 Wehner, M., et al., Evaluating the economic benefit of retrofit. 2019, Report to the BNHCRC.