CYCLONE TESTING STATION

FOR A SAFER STATE

TC Zelia, East Pilbara, WA
Damage to Structures

CTS Technical Report No 69

Cyclone Testing Station
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TC Zelia, East Pilbara, WA
Damage to structures

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TC Zelia, East Pilbara, WA – Damage to structures
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LIMITATIONS OF THE REPORT

Executive Summary

TC Zelia crossed the East Pilbara coast near the De Grey River as a Category 4 event. It caused Category 1 wind speeds in Port Hedland and wind speeds that ranged from Category 4 near the coast to Category 1 wind speeds near Marble Bar as it progressed inland.

In the Port Hedland area including Wedgefield and South Hedland, there was damage to trees but little structural damage due to wind loads alone. Some buildings reported minor water ingress through window systems at wind speeds well below the serviceability wind speed.

Structural damage was only observed where the wind speeds were higher than 76% of the design wind speed.

- At around 65 m/s peak gust wind speeds, the failures were caused by deterioration of structural members.
- At around 75 m/s peak gust wind speeds there was damage due to combinations of actions in the SHS top chord of trusses and some examples of damage to both roof-mounted and ground mounted solar panels.

Acknowledgements

The authors thank the residents of the affected East Pilbara communities who generously assisted with this study by volunteering information and inviting the authors onto their properties, and to the staff of SES and DFES stationed in Port Hedland for arranging logistics that facilitated the investigation.

During this investigation, the CTS team worked closely with Building and Energy, and the Department of Fire and Emergency Services (DFES) WA. The collaboration between the three organisations enabled a coordinated, efficient, and effective approach to the investigation that increased the amount of data and information gathered. The authors particularly acknowledge the support given by:

- **Building and Energy** – particularly Craig Middleton, Paul Da Costa and Allan Shiell.
- **DFES** – particularly Matt Zanini, Adrian Brannigan, Peter Cameron and David Cowdell.
- **The Bureau of Meteorology** – especially Joe Courtney and Andrew Burton for providing feedback and the BoM summary information.

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1. Introduction

This report covers damage to structures from Severe Tropical Cyclone Zelia that crossed the Pilbara coast over the De Grey river delta in the early afternoon of 14th February, 2025 as a Category 4 tropical cyclone.

The path of TC Zelia was very difficult to predict due to complicated steering factors in the atmosphere at the time. Even 24 hours out from landfall, the range of likely tracks of the cyclone centre (the grey region) included most of the Pilbara coast. This made it difficult for communities in the Pilbara to prepare or evacuate to a safe location. The actual path was very close to the northern boundary of the error bands shown in Figure 1-1.

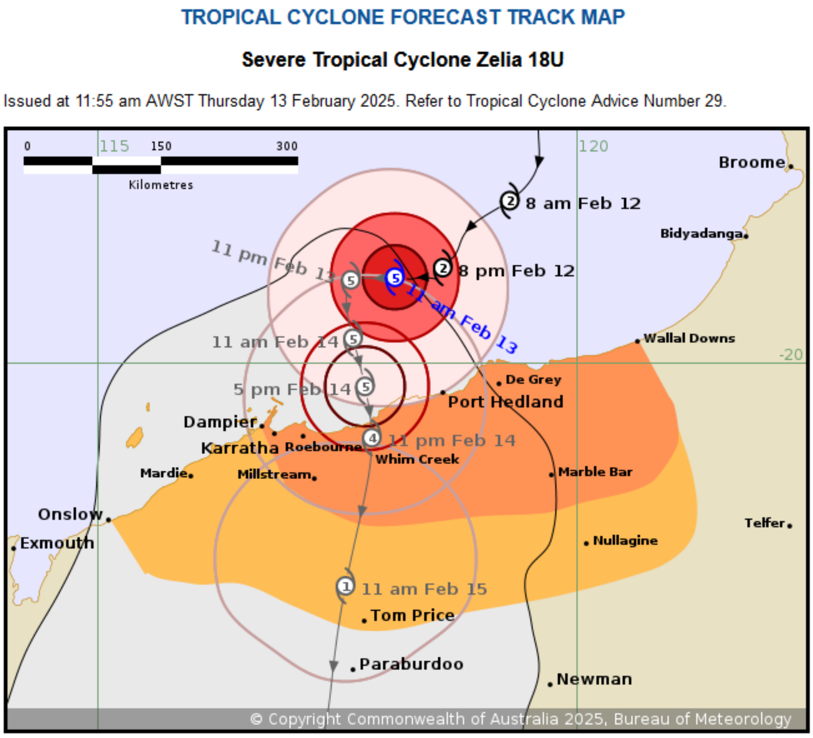

Figure 1-1 Prediction around 24 hours before landfall (Bureau of Meteorology, 2025)

1.1. Meteorological overview of TC Zelia

The following information was provided from the Bureau of Meteorology from preliminary information on their web page: http://www.bom.gov.au/cyclone/history/zelia2025.shtml. It is used with permission. The web page also contained the preliminary track map shown in this report as Figure 1-2 and information on weekly rainfall shown as Figure 1-3.

> *Severe Tropical Cyclone Zelia was a small but very intense cyclone, notable for its rapid development to category 5 off the Pilbara coast of Western Australia. Zelia crossed the coast at category 4 strength near the De Grey River mouth northeast of Port Hedland on 14 February.*
>
> *A tropical low (18U) was first tracked on 8 February just off the north Kimberley coast. The low remained weak and moved west-southwest for several days, before turning more southwest late on 10 February. On 11 February the environment became more conducive to development, and the winds around 18U strengthened to*

gale force. It was named Tropical Cyclone Zelia at 2 am WST 12 February, about 280 kilometres west of Broome.

On the evening of 12 February, Zelia slowed down and became near stationary about 130 kilometres north-northwest of Port Hedland. The ocean in this area was experiencing a marine heatwave and sea surface temperatures were extremely high (31-32°C). Zelia underwent a period of extremely rapid intensification, strengthening to category 5 by around midday WST on 13 February. Zelia spent another day moving slowly and erratically at category 5 strength. Then on the morning of 14 February, it turned southeast and moved towards the coast.

The cyclone weakened slightly as it approached land, but was still a high-end category 4 cyclone when it crossed near the De Grey River mouth at 12:30 pm AWST on 14 February. It retained severe tropical cyclone strength through the afternoon as it moved inland, with a discernible eye persisting on radar. During the evening, however, it weakened very rapidly. It was downgraded to a tropical low at 2am WST 15 February near Marble Bar.

The very destructive core of the cyclone did not directly impact any towns. Port Hedland experienced damaging winds in the periphery of the cyclone for about seven hours on 14 February as Zelia approached landfall (maximum gust 120 km/h). Marble Bar experienced gusts up to 109 km/h during the evening as the weakening cyclone tracked 15 kilometres to the west.

Rainfall and flooding caused significant impacts. The event produced record 3-day rainfall totals at De Grey and Pardoo stations, each receiving over 500mm. Numerous other sites in the Pilbara received over 200mm. Record flooding occurred on the De Grey River. The most notable record was observed at Marble Bar where the river peaked at 10.23 m on the morning of 15 February, around 2 metres above the previous record of 8.3 m from 1998. The Great Northern Highway was cut at Coolenar Pool for an extended period of time, isolating Pilbara and Kimberley communities from southern Western Australia. Evacuations from remote communities Warralong and Gooda Binya were conducted during the rising flood. Many secondary roads throughout the inland areas of the Pilbara were affected with many communities isolated as a result.

The closures of ports at Port Hedland (three days), Cape Lambert and Dampier disrupted shipping and combined with disruptions to offshore oil and gas operations resulted in significant economic costs to industry.

Severe Tropical Cyclone Zelia was the fifth tropical cyclone in the Australian region for the 2024/25 season, and the first to make landfall.

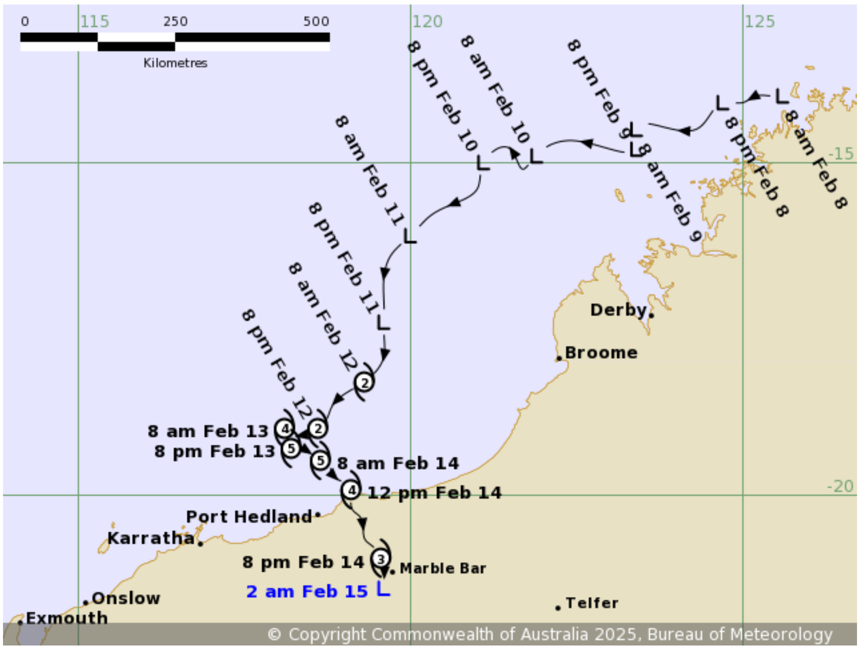

Figure 1-2 Preliminary track map (Bureau of Meteorology, 2025)

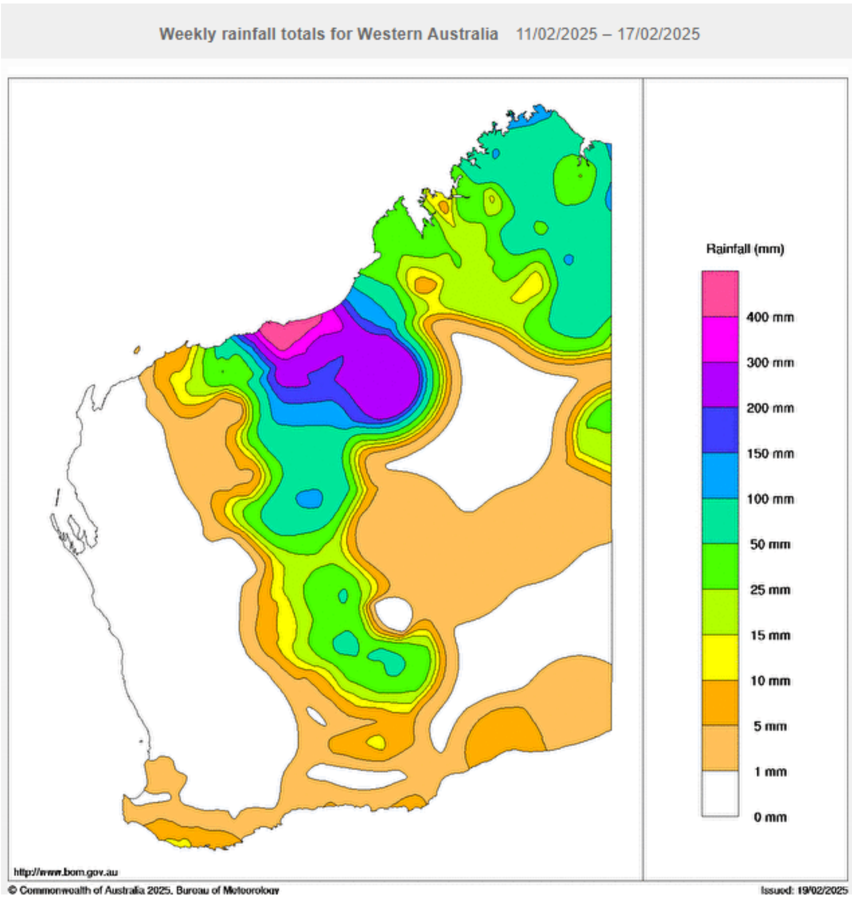

Figure 1-3 Preliminary weekly rainfall data for the week covering the passage of TC Zelia (Bureau of Meteorology, 2025)

1.2. Purpose of the report

This report presents the outcomes of the joint Cyclone Testing Station (CTS), the Department of Energy, Mines, Industry Regulation and Safety, Building and Energy Division (Building and Energy), and the WA Department of Fire and Emergency Services (DFES) field investigations. The aim of the investigations was to learn from damage to structures in the affected area and to estimate the wind speeds at locations in which structures were examined.

1.3. Investigations

The field study commenced on Sunday, 16 February 2025 and was completed on Thursday 20, February 2025. For that period, the team was based in Port Hedland WA and travelled to affected areas alongside teams from DFES.

Figure 1-4 shows the focus of the investigation superimposed on location of road signs measured and the location of structures that were visited as part of the study and used to estimate wind speeds during TC Zelia. (The Marble Bar road was impassable at the Shaw River and the Great Northern Highway at the flood plain East of the De Grey River which limited the eastward extent of road signs that could be used to estimate wind speeds.)

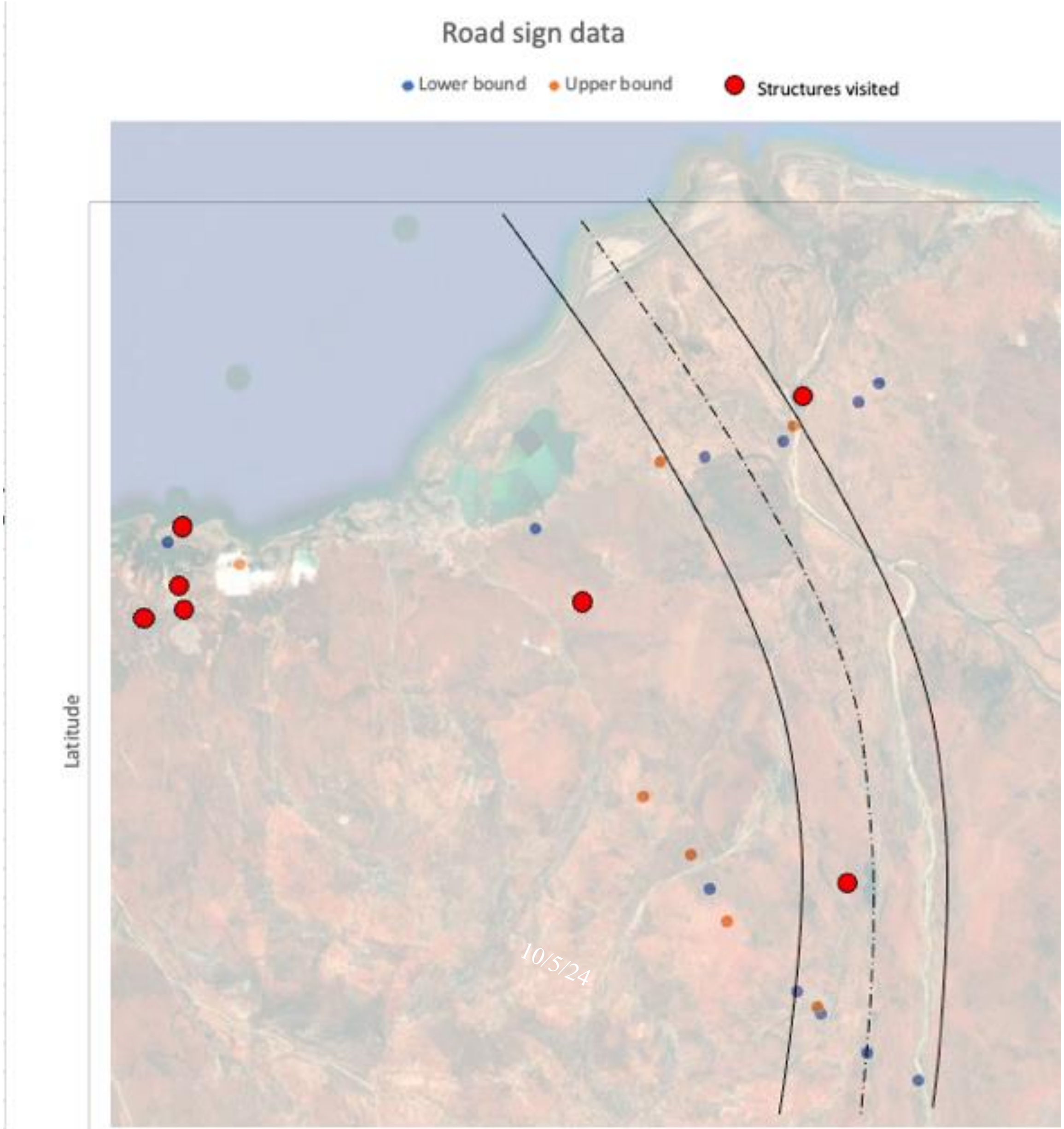

Figure 1-4 Localities visited in the investigation and our estimation of the path of the cyclone and the extent of its eye.

2. Wind speeds in TC Zelia

2.1. Meteorological data

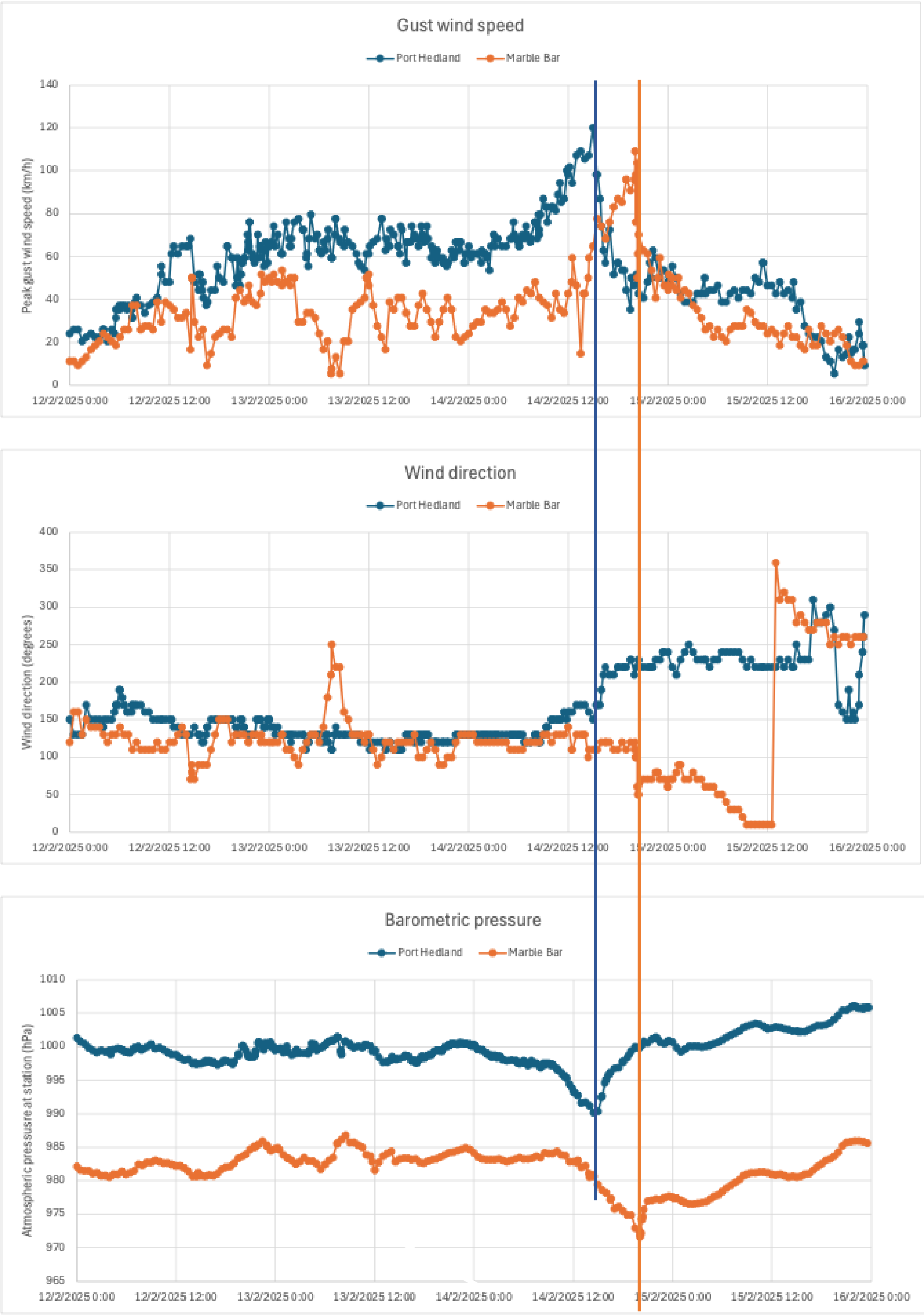

Figure 2-1 Meteorological records at Port Hedland airport and Marble Bar (Bureau of Meteorology)

Figure 1-2 shows that TC Zelia crossed the WA coast 54 km to the NE of the anemometer at Port Hedland. It also passed to the East of another anemometer at Marble Bar which is off the bottom of Figure 1-4. The record of peak gust speed, wind direction and barometric pressure at the stations is shown in Figure 2-1. (The station at Marble Bar is at higher elevation than that at Port Hedland airport which is why the barometric pressure at Marble Bar is uniformly lower than that at Port Hedland.)

The vertical lines in Figure 2-1 represent the time at which the barometric pressure was lowest at Port Hedland (dark blue) and Marble Bar (orange). These times coincide with the time of the peak gusts and the start of a change in wind direction.

2.2. Estimation of cyclone track

Observations of the direction of tree fall, damage to lighter vegetation and erosion of termite mounds were made to estimate the direction of maximum winds. These were noted on a map and where the predominant wind direction was easterly or westerly, this point was marked as the point at which the eye of the north to south moving cyclone crossed the road on which we were travelling. Observations of people who were sheltering at different communities were used to estimate the size of the eye shown in Figure 1-4. (Some of these people gave information by phone as we were not able to visit them due to closed roads.)

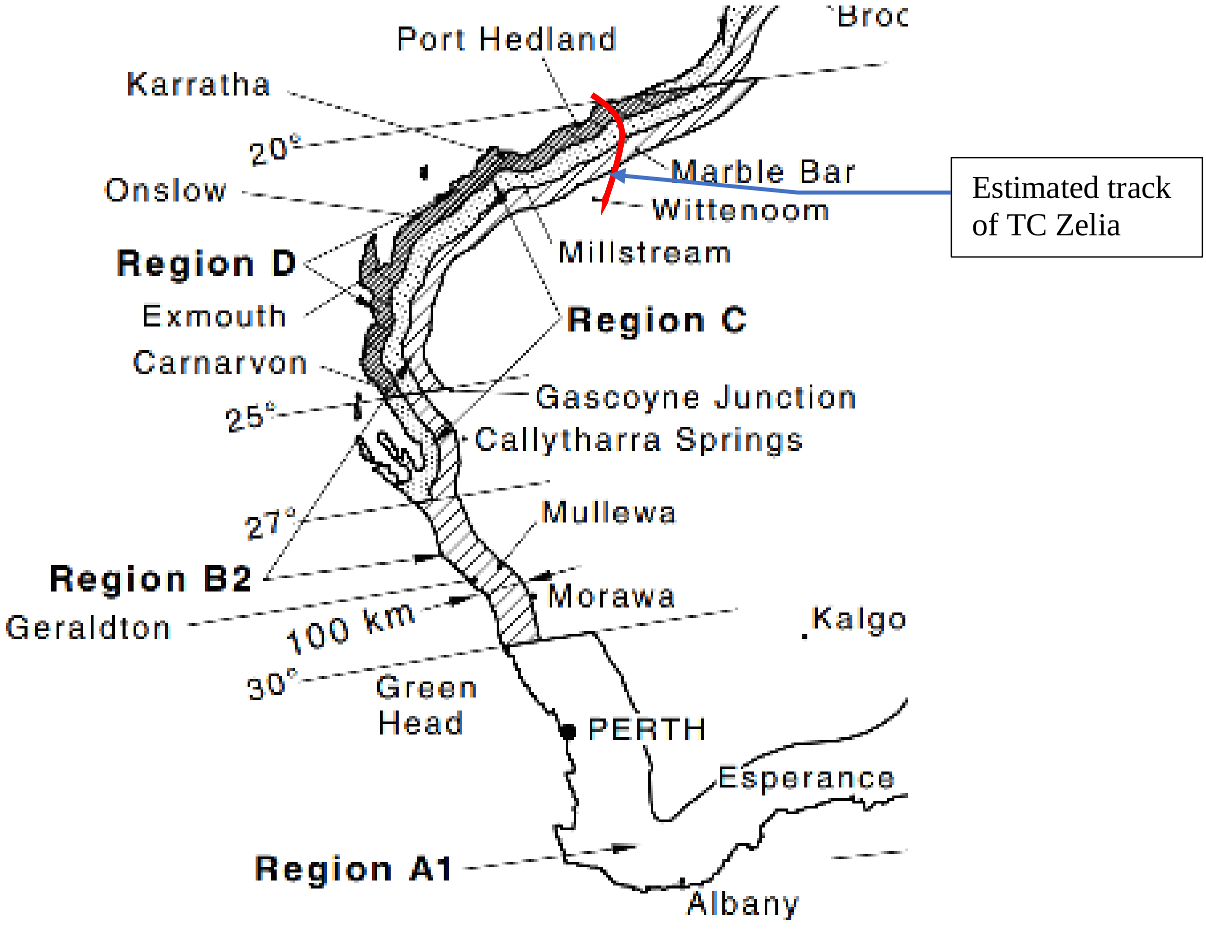

Figure 2-2 Wind regions (from AS/NZS 1170.2:2021)

2.3. Estimation of wind speed

The wind speed recorded at Port Hedland was recorded by the anemometer as shown in Figure 2-1with a peak 3 second gust of 120.2 km/h. This was the equivalent of a high Category 1 gust wind speed. In the context of AS/NZS 1170.2, this gust wind speed was equivalent to a 0.2 second gust of 38 m/s or around 45% of V_{1000}, the ultimate design wind speed for the Pilbara coast (region D) for importance level 2 buildings in NCC 2022.

The estimated path of TC Zelia crossed the coast into region D near De Grey, then passed into region C near Carlindi, then into region B near Marble Bar. This is shown in Figure 2-2 which is taken from AS/NZS 1170.2:2021. This map has been essentially unchanged in this area for decades, though in 2024, the northern boundary of region D was extended northwards by 1 degree latitude. All structures viewed as part of the investigation would have been designed using this map or its very similar predecessors.

There were no anemometers along the line of the path of the cyclone as estimated in Figure 1-4, so in order to estimate wind speeds during TC Zelia, 20 road signs were measured as 'windicators'.

Figure 2-3 shows two of the road signs that was used to estimate the wind speeds associated with the tropical cyclone. The left photo shows a sign that was still vertical. The wind forces had not been enough to cause a plastic hinge in the pole, so by calculating the speed required to cause a hinge, an upper bound of the wind at the location could be found. The right photo shows a sign that had developed a plastic hinge in the pole, so the same calculations on this sign gave a lower bound of the wind speed at the location.

Figure 2-3 Road sign used to estimate wind speed.

Twenty signs at different locations were measured as upper and lower bound signs as shown in Figure 1-4. By comparing upper and lower bound wind speeds for similar locations, it was possible to estimate wind speeds at critical positions.

- Signs quite close to Port Hedland indicated that the 0.2 s wind gust speed was 40 m/s. These signs were around 8 km closer to the cyclone track than the anemometer at Port Hedland airport so it was compatible with the measured gust equivalent to a 0.2 second gust of 38 m/s at the airport and gave confidence in the use of 'windicators' to estimate wind speeds elsewhere in this investigation. The regional design wind speed for importance level 2 buildings in wind region D is 85 m/s (0.2 s gust).
- The peak 0.2 s gust on the Great Northern Highway near the De Grey River was estimated by the 'windicators' at 73 m/s. This is equivalent to a 3 sec gust of 232 km/h – a category 4 cyclone wind speed. The regional design wind speed for importance level 2 buildings in wind region D is 85 m/s (0.2 s gust)
- The peak 0.2 s gust on the Marble Bar road near Carlindi Creek was estimated by the 'windicators' at 63 m/s. This is equivalent to a 3 sec gust of 201 km/h – a gust wind speed equivalent to a category 3 tropical cyclone. It was appropriate for a category 4 tropical cyclone at the coast that had weakened after 75 km of overland travel. The regional design wind speed for importance level 2 buildings in wind region C is 66 m/s (0.2 s gust)

In each case, the estimated peak gust wind speeds were less than the design wind speed for importance level 2 buildings. In Port Hedland, the measured wind speeds were less than 50% of the regional design wind speed for importance level 2 buildings.

3. Observations of wind damage

3.1. Port Hedland area including South Hedland

As indicated in Section 2.3, recorded wind speeds in the Port Hedland area were significantly lower than the regional design wind speed for importance level 2 structures in wind region D. Figure 3-1 shows a large tree that had been blown over in Port Hedland and a fence that had been blown over in South Hedland. (The photo of the tree was taken after it had been cut up by SES.)

Figure 3-1 Minor damage in Port Hedland area.

Some occupiers had reported wind driven rain entering their premises and Figure 3-2 shows some water damaged carpet and a gap in a window seal at the corner of the window that allowed water to enter the building.

Figure 3-2 Water ingress through windows.

The wind speed in Port Hedland was lower than the serviceability wind speed for structures but higher than a speed that would give the water penetration test pressure for windows.

> *Recommendation*
> Check and maintain seals on windows to minimise the chance of water penetration during even low winds associated with storms or nearby tropical cyclones.

At the wind speeds experienced in the Port Hedland area, both ground-mounted and roof mounted solar panels performed well, as shown in the photos in Figure 3-3. This was expected as the wind speed was 45% of the design wind speed in the port Hedland area. As the wind pressures are calculated from the square of the wind velocity, this meant that the wind loads were around 20% of the wind loads for which the facilities had been designed.

Figure 3-3 Good performance of solar panels in the Port Hedland area.

The fixing systems varied. In the lower photo in Figure 3-3 each panel was clamped to four rails using a total of 8 clamps per panel, whereas in the top left photo in Figure 3-3 each panel was clamped to only two rails using a total of 4 clamps per panel. Likewise in the roof-mounted systems, some rails were supported on L-foot brackets at around 160 mm centres in the roof cladding as shown in the upper photo in Figure 3-4 and others at around 900 mm centres as shown in the lower photo of Figure 3-4. In this case, the winds were not strong enough to cause damage to the systems that had fewer rails or lower frequency of L-foot brackets. In previous investigations in this area and in locations that experienced wind speeds in excess of 73 m/s, there were cases in which the L-foot brackets had pulled screws out of metal battens or purlins where their spacing was high and the tributary area per L-foot bracket was large.

Figure 3-4 Varying frequency of L-foot brackets in roof-mounted solar panel systems.

3.2. Damage in areas that experienced 0.2 s gust wind speeds around 65 m/s

There was some damage to a number of structures in areas that experienced 0.2 sec wind gusts of around 65 m/s. In region D, this represents 76% of the regional design wind speed for importance level 2 buildings and in region C, it represents nearly 100 % of the regional design wind speed for importance level 2 buildings.

3.2.1. Veranda failure on a house

A veranda on a house failed under wind uplift. In this case, the failure was in the footings. Footings were removed still attached to the base of the veranda posts as shown in Figure 3-5. The edge of the concrete slab of the veranda was used as the footings for the post and each post was bolted to the slab edge with three bolts. Figure 3-5 presents a photo taken on the roof of a nearby building where part of the veranda had been deposited by the wind.

- The slab edge is shown in the centre of the photo in Figure 3-5. The base of the veranda post is still attached and two of the masonry anchors at the base of the post are visible. (The third is under the concrete but was also intact.)
- The veranda post had broken about 200 mm above the base plate after the post had been lifted to its current location. The upper part of the post remained attached to part of the veranda and blew further away. There had been some corrosion inside the post that facilitated the break once the column had been removed, but the corrosion was not a contributor to the original failure of the footing.
- The roofing above the base of the veranda post is part of the veranda roof. The blue battens visible in the upper half of the photo are battens from the veranda.

Figure 3-5 Footings still attached to the base of the veranda post after failure.

Once the veranda shown in Figure 3-5 had failed it exposed the roof edge to which the veranda had been attached to wind-driven rain. This allowed rain into the roof space and caused damage to linings and contents throughout the house as shown in Figure 3-6.

The veranda had been added to the house relatively recently, and while many aspects of the veranda were able to carry the wind loads, the footing had not been upgraded at the time of the veranda construction. The consequential water damage meant that the house had to be emptied of contents and could no longer be used as a house. This case study underlines the potential for premature failure of a structure attached to a house to render the house unfit for habitation. In order for additional structures not to be a liability for the main house, they must be designed and constructed to the same design criteria as the main house.

Recommendation
Ensure that structures attached to houses and other buildings are built to the same design criteria as the main building.

Figure 3-6 Water damage as a consequence of veranda loss.

3.2.2. Damage to a shed

A shed was significantly damaged and caused damage to the contents of the shed which included some farm equipment and expensive vehicles. The first failure was at the base of the posts. In this case, corrosion in the cold-formed steel posts where they had been cast into concrete had caused the posts to break at the surface of the concrete slab as shown in Figure 3-7. This figure shows the base of the shed post on the left and the footing with the rusted shed post cast in on the right.

Once the post at the front of the shed was no longer connected to the slab, if allowed the wall to lift off the slab and allowed the sliding doors on the front of the shed to blow in and the roof with walls attached to fold back. As there was an accommodation block behind the shed, the roof and part of the walls became wrapped around the accommodation and compromised its use as well. In Figure 3-8 the original position of the shed was on the right side of the photo, and the roof of the shed can be seen wrapped over a mobile accommodation block (donga) on the left of the photo. The panel at the bottom of the photo is a side wall that rotated about the back post of the shed after the front posts had failed.

Figure 3-7 Corrosion at the base of the steel posts.

Figure 3-8 Roof of shed over accommodation block.

The damage to this structure highlights the importance of specifying details that minimise the effects of deterioration in important structural members. It is particularly necessary to regularly inspect and maintain thin steel structural members to ensure that they have not been compromised by corrosion.

Recommendation
Use details that minimise the effects of corrosion in the design and construction of all buildings. Check and maintain buildings to minimise the effects of deterioration.

3.2.3. Damage to ground mounted solar panels

The 0.2 sec wind speed at the location of some ground-mounted solar panels shown in Figure 3-9, was estimated at around 65 m/s – around 76% of the regional design velocity for this location. A few panels had failed by detachment of the panel chassis at the clips that held them to the rails. Some panels at this facility had experienced very similar failures in a previous cyclone that caused around the same wind speed at this location (Boughton et al, 2023).

Figure 3-9 shows a missing panel from one array of panels. There were four arrays at this location and each had at least one panel missing. The wind direction at this location was from behind the array. (The photo is taken looking into the wind direction that caused this damage.)

Figure 3-9 Failure of anchorage on ground mounted solar panels.

The panels had clamps bolted to the back of the chassis that tightened onto a ridge on the rails under the panel. The metal of the chassis had torn around the bolt to the clamp. It is likely that low cycle fatigue may have contributed to the failure. The fatigue failures in the chasses may have been affected by the prior cycling in the previous tropical cyclone.

The left photo in Figure 3-10 shows an anchorage clip on a panel that had not failed adjacent to the panel that had failed. The chassis of the panel is coloured black, and the clamp was bolted directly to it with the bolt visible on the underside of the clamp. The right photo shows the tear in the back of the chassis of the panel that became separated. The torn failure surface can be seen in the photo, and it appeared to involve progressive tearing.

Figure 3-10 Detail of the chassis failure.

> *Recommendation*
> Clamping and bolting systems that secure solar panels in tropical cyclone areas should be tested to ensure that they have the capacity to resist the appropriate loads applied using a repeated loading sequence similar to the NCC low-high-low test for metal cladding.

3.3. Damage in areas that experienced 0.2 s gust wind speeds around 75 m/s

Areas close to the coastal crossing of TC Zelia experienced 0.2 sec gust wind speeds estimated at around 75 m/s. This wind speed corresponds to around 88% of the regional design wind speed for importance level 2 buildings in wind region D. The latitude of the crossing point was 20º 02'S, so it was very close to the previous boundary for wind region D in AS/NZS 1170.2:2021 (20ºS), but well within region D in the second amendment of that standard released in 2024 (21ºS).

The wind speeds estimated in this investigation were compatible with the change of the wind region D boundary in the second amendment to AS/NZS 1170.2:2021.

3.3.1. Damage to a shed

A shed that was around a year old was significantly damaged. The shed was an open shed with one whole side open. The failure occurred when the wind was blowing towards the opening. There was no evidence of failures of cladding separating from the purlins or of purlins failing under wind uplift which indicates that the shed had been appropriately designed for internal pressure.

Figure 3-11 shows a view of the shed which lost approximately ¾ of its roof, one end wall and nearly all of the back wall. The parts of the shed that remained were badly twisted and the contents of the shed (mainly vehicles) had been damaged in the collapse.

- In the right foreground of Figure 3-11 is a part of the roof with the ridge line on the left of the panel. This panel was the downwind section of roof at the time of the shed failure
- Lying on top of that panel is the badly damaged end wall.
- The very left of the photo shows the back or leeward wall of the shed protruding from under the end wall.
- The top of the photo shows the half of the upwind roof panel that remained attached, having collapsed on the contents of the shed. The truck in the top right of the photo has not been moved since the cyclone, and was stored completely within the shed.

Some security video footage showed that the roof failure started at the ridge of the shed near the end wall shown in Figure 3-11. The roof panel in the foreground was the part of the roof close to the failure point. It showed that the roof truss had fractured at the ridge.

Figure 3-11 Failure of a recently constructed shed.

The top chord of the truss was a Square Hollow Section (SHS) in tension during the wind uplift during TC Zelia. Examination of the length of the truss showed that some of the cleat plates had torn the top face of the top chord at the weld of the purlin cleat as shown in Figure 3-12. This type of tear in the top chord changed the stress distribution in the top chord as the top face could not carry tension through the tear. The resulting higher stresses on the other three sides of the SHS caused it to fail at the weld with the bolted ridge plates.

Once the top chord of the end truss had failed at the ridge, the wind could lift the end of the roof, progressively failing each truss at the ridge. The back half of the roof would have been lifted off the building which would have enabled the back wall of the shed to be folded out of the building by the lateral wind pressure. Likewise the top of the end wall was also unsupported and was blown out of the building.

Recommendation
Truss members in structures should be sized so that the cross section can resist local stresses near welds under all actions associated with wind uplift. This includes the combination of stresses at weld cleats and cleats for bracing members combined with tension in the truss chords.

Figure 3-12 Torn SHS top chord at cleat plates.

3.3.2. Roof mounted solar panels

A number of buildings in this area had roof-mounted solar panels. On one building, the forces on the L-foot brackets removed the roof screws from the purlins. Panels, clamps and rails were lifted from the roof by the wind forces on the solar panels. In parts of the roof, sheeting was lost because of the missing screws. Figure 3-13 shows the building with no rails left. The screws that were removed were roofing screws that were holding down the L-foot brackets and the roofing.

In the centre part of the roof, the missing screws also led to the loss of some roof sheeting. Depending on the spacing of the L-foot brackets, the loads on the individual screws can be increased substantially by the wind actions on the panel itself. (Where there are only two rails per panel and one L-foot bracket on a rail under each panel, the tributary area of each L-foot bracket is around half the area of the panel – considerably higher than the tributary area of roofing for each screw before the panels were installed.

Loads on roofing screws can be reduced by using more L-foot brackets on each rail as shown in the upper photo in Figure 3-4.

Figure 3-13 Forces on L-foot brackets removed roofing screws and rails from roof.

Figure 3-14 shows a building with some panels that are missing because clamps failed or moved. The photo also shows that there were several panels in this roof that had sustained debris damage. The panels that were released became wind borne debris that may have impacted other buildings. Some wind-borne panels were captured on security cameras though few of them were found.

Figure 3-15 shows panels on a roof where debris had damaged a number of panels, but they hadn't become detached from the roof. Some panels on this roof had moved under the clamps, but none had become detached.

Recommendation
Solar panels mounted on buildings should have all components in their fastening system rated for wind actions calculated for the location using an importance level appropriate for the buildings on which they are located.

Figure 3-14 Missing roof-mounted panels due to clamp failure.

Figure 3-15 Debris damage to roof-mounted solar panels.

3.3.3. Ground-mounted solar panels

A number of arrays of tracking ground mounted panels were observed in the area that experienced winds estimated at 0.2 s gusts around 75 m/s. As the tracking systems had stopped working a number of years ago, the tracking mechanism had been locked in position so that each panel was horizontal. Each array consisted of 5 panels and there were 16 arrays installed in two rows. Most arrays had been damaged, either by loss of panels, failure of the framing or by debris impact. Figure 3-16 shows a selection of photos illustrating the damage to these systems.

- These panels had been directly screwed to the framing rather than utilising a clamp, but the principle was the same, it relied on friction between the panel and the frame to hold it in position and sliding of some panels indicated that this mechanism was not sufficient.
- Some panels had concentric fracture rings consistent with debris impact damage, and others had uniformly crazed cracking across the whole panel, more consistent with glass failure under pressure loads.
- Most panels had moved from an inclination of around 0^{o} (horizontal) to the range of the mechanism (near vertical). The final angle was not consistent.

Figure 3-16 Damaged ground-mounted solar panels.

3.3.4. Large access doors

There were no roller doors in buildings that experienced 0.2 s wind gusts near 75 m/s. However in a previous event in 2007, roller doors on a large shed had been damaged and had been replaced with tilting doors that transferred load directly to the building frame when closed. These doors were not commercially produced but were built on-site. They had not been tested to AS/NZS 4505:2012 but performed well at loads well in excess of the serviceability level.

3.3.5. Fold-down debris screens

A number of residential buildings in the area that sustained the maximum winds had fold-down debris screens that were normally suspended from a veranda outside windows, but could be folded down and bolted into brackets connected to the frame to offer debris protection to the window.

The screens used roofing sheets screwed to a light steel frame and had a bolted hinge at the top and bolts near the bottom to secure them. They are illustrated in Figure 3-17.

These systems had not been tested using simulated wind-borne debris projected with the energy defined in AS/NZS 1170.2, but there were no cases of windows breaking where they had been protected by the screens. On one building, two of the screens had been blown away by wind actions.

Figure 3-17 Fold-down debris screens.

4. Potential changes to Codes and Standards

4.1. Wind regions

TC Zelia crossed the Pilbara coast within 50 km of the eastern boundary of wind region D as defined in AS/NZS 1170.2 up to 2024. Changes to the eastern boundary of wind region D in the amendment to the standard in 2024 shifted it around 230 km to the ENE. This places this Category 4 event comfortably within wind region D.

- Estimates of the peak gust (0.2 s) wind speed in wind region D were 88% of the importance level 2 regional design wind speed.
- Estimates of the peak gust (0.2 s) wind speed in wind region C were 100% of the importance level 2 regional design wind speed.
- It was not possible to estimate the wind speed as the tropical cyclone crossed into wind region B as roads had been closed by floods.

4.2. Wind actions

The investigation noted some damage to ground-mounted solar panel installations and to roof-mounted solar panel installations. The information collected on panel performance during the investigation will be taken into account by research projects on wind actions on solar panels that are currently in place and aim to recommend changes to Appendix B6 (wind actions on solar panels) in AS/NZS 1170.2:2021.

There were no other recommendations for changes to codes and standards.

5. Conclusions

TC Zelia crossed the East Pilbara coast near the De Grey River as a Category 4 event. It caused Category 1 wind speeds in Port Hedland and wind speeds that ranged from Category 4 near the coast to Category 1 wind speeds near Marble Bar as it progressed inland.

In the Port Hedland area including Wedgefield and South Hedland, there was damage to trees but little structural damage to buildings due to wind loads alone. Some buildings reported minor water ingress through window systems at wind speeds below the serviceability wind speed.

Structural damage was only observed where the wind speeds were higher than 76% of the design wind speed.

- At locations that experienced around 65 m/s 0.2 s gusts, the failures were caused by deterioration of structural members.
- At locations that experienced around 75 m/s 0.2 s gusts, there was damage due to combinations of actions in the SHS top chord of trusses and some examples of damage to both roof-mounted and ground mounted solar panels.

6. Recommendations

The following recommendations were made in this report:

- Check and maintain seals on windows to minimise the chance of water penetration during even low winds associated with storms or tropical cyclones.
- Ensure that structures attached to houses and other buildings are built to the same design criteria as the main building.
- Use details that minimise the effects of corrosion in the design and construction of all buildings. Check and maintain buildings to minimise the effects of deterioration.
- Clamping and bolting systems that secure solar panels in tropical cyclone areas should be tested to ensure that they have the capacity to resist the appropriate loads applied using a repeated loading sequence similar to a low-high-low test for metal cladding.
- Truss members in structures should be sized so that plates can resist local stresses near welds under all actions associated with wind uplift. This includes the combination of stresses at weld cleats and cleats for bracing members combined with tension in the truss chords.
- Solar panels mounted on buildings should have all components in their fastening system rated for wind actions calculated for the location using an importance level appropriate for the buildings on which they are located.

7. References

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