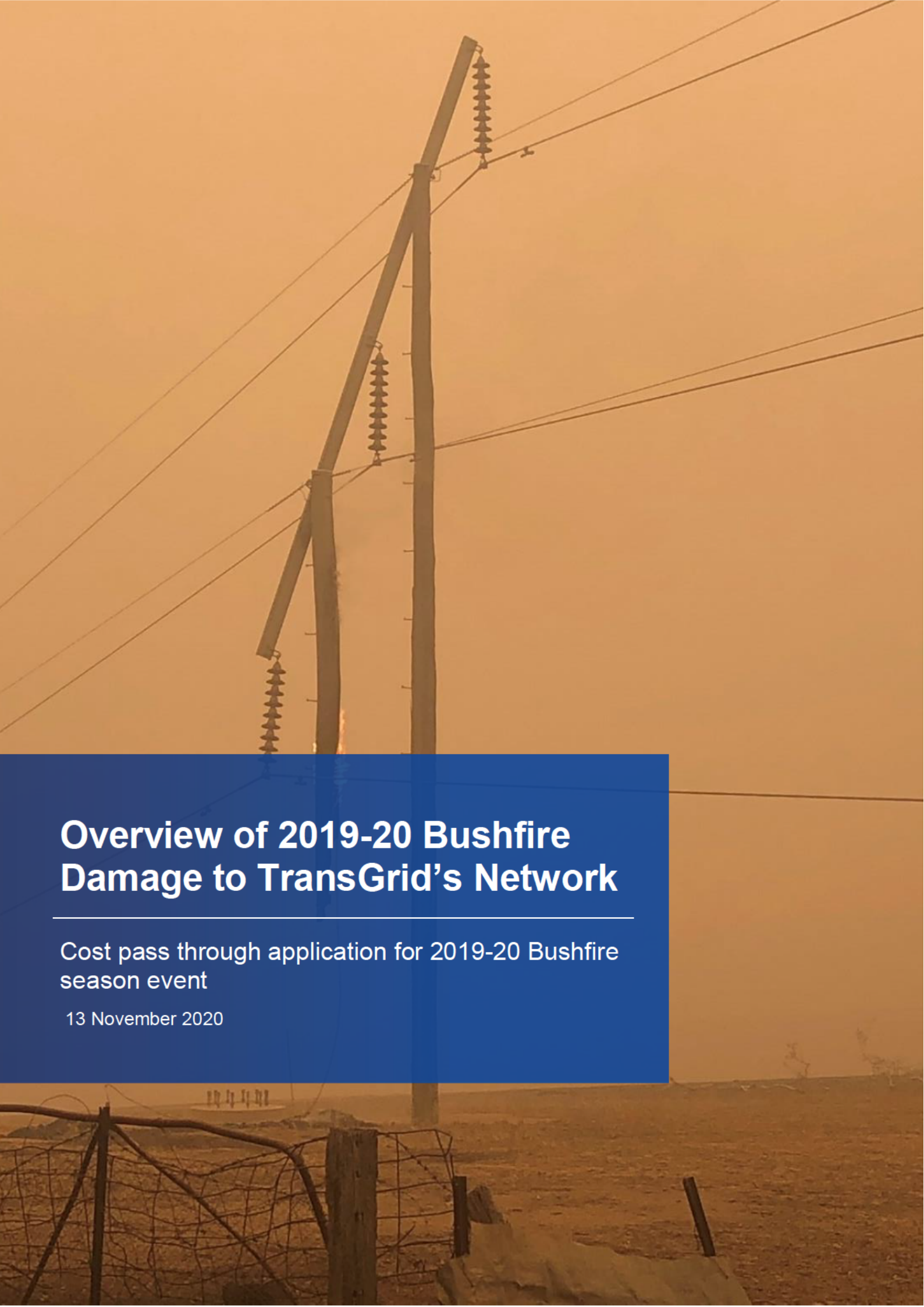

Overview of 2019-20 Bushfire Damage to TransGrid's Network

Cost pass through application for 2019-20 Bushfire season event

13 November 2020

Approvals

Author	[redacted]	Asset Strategist
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Date	13 November 2020	

Change history

Revision	Date	Amendment
0	13/11/2020	First issue

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1. Executive Summary

The summer of 2019/2020 was the scene of a historically destructive bushfire season in Australia and NSW with burnt areas greater than the burnt areas of the 2009 Black Saturday and 1983 Ash Wednesday combined. The final report of the NSW Bushfire Inquiry concluded that the 2019/20 bushfire season was 'extreme' and 'challenged conventional assumptions', however, the season could have been worse still. Over the next six years the risk will increase and return to or exceed pre-2019/20 levels[1].

The bushfire season first impacted TransGrid's network on 6 September 2019 when the first network fault outage occurred and finished on 2 March 2020 when the NSW RFS declared that there were no longer any active fires. TransGrid assets were within the active fire zones until this day. No bushfires in the 2019/20 bushfire danger period were initiated by the TransGrid network.

Key impacts of the 2019/20 bushfire season (August 2019 – March 2020) on TransGrid's network were:

- 999 km of transmission line route length (comprising 9,000km of conductor and earthwire), or 9% of TransGrid transmission line network, was within the bushfire-impacted zones.
- 2,681 transmission line structures were within the bushfire-impacted zones.
- 249 transmission line fault and forced outages caused by bushfires, 20 times higher than past seasons.
- 65% more fault outages than the 10-year average for the same period. This included 275 forced outages in January 2020, more than 200% higher than the January average over the last 10 years.
- Two NEM regional separation events, one involving the NSW to Victorian interconnection and the other involving the NSW to Queensland interconnection, compared to zero separation events in 2018/19.

Transmission line assets form the vast majority of damaged infrastructure given their proximity and exposure to bushfires across the state of NSW. Emergency repairs have already been completed. For the remainder of the damage, detailed damage assessments have been performed and remediation plans formulated and underway for damage which requires remediation in the short term. Damage which has been deemed non-urgent will continue to be monitored by TransGrid.

[1] https://www.dpc.nsw.gov.au/assets/dpc-nsw-gov-au/publications/NSW-Bushfire-Inquiry-1630/Final-Report-of-the-NSW-Bushfire-Inquiry.pdf

2. Acronyms

Term	Explanation/Comments
AAAC	All Aluminium Alloy Conductor
ACSR/GZ	Aluminium Conductor Steel Reinforced / Galvanised
AC	Alternating Current
AEMO	Australian Energy Market Operator
AFP	After Fire Patrol
ALARP	As Low As Reasonably Practicable
CB	Circuit Breaker
CT	Current Transformer
CVT	Capacitive Voltage Transformer
DPIE	Department of Planning, Industry and Environment
DST	Daylight Savings Time. Note that NSW daylight savings time in one hour ahead of National Electricity Market time.
ENS	Energy Not Supplied
ENSMS	Electricity Network Safety Management System
EUSFAC	Energy Utilities Functional Area Coordinator
kV	Kilovolt
LME	Liquid Metal Embrittlement
MW	Megawatt
IPART	Independent Pricing and Regulatory Tribunal
LiDAR	Light Detection and Ranging
LOR	Lack of Reserve
NEM	National Electricity Market
NiCad	Nickel-Cadmium
OPGW	OPtical Ground Wire
OTDR	Optical Time-Domain Reflectometer
PVC	Poly Vinyl Chloride

Term	Explanation/Comments
QNI	Queensland – NSW Interconnector
RFS	NSW Rural Fire Service
RIT-T	Regulatory Investment Test for Transmission
RRS	Radio Repeater Site
SAIP	Smart Aerial Image Processing
SEOC	State Emergency Operations Centre
STPIS	Service target Performance Incentive Scheme
TL	Transmission Line
VESDA	Very Early Smoke Detection Apparatus
VHF	Very High Frequency
VLRA	Valve Regulated Lead–Acid
VNI	Victoria – NSW Interconnector
WO	Work Order

3. The 2019/20 Bushfire Season

The summer of 2019/2020 was the scene of a historically destructive bushfire season in Australia and NSW with burnt areas greater than the burnt areas of the 2009 Black Saturday and 1983 Ash Wednesday combined (Australia as a whole)[2].

The final report of the NSW Bushfire Inquiry concluded that the 2019/20 bushfire season was 'extreme' and 'challenged conventional assumptions', however, the season could have been worse still. Overall, the evidence indicates that extreme fires and fire seasons will likely be seen again and more frequently. It was noted that the reductions in future bushfire risk due to the size of the 2019/20 fire season is partial and temporary only. Over the next six years the risk will increase and return to or exceed pre-2019/20 levels[3].

The bushfire season first impacted TransGrid's network on 6 September 2019 when the first network fault outage occurred and finished on 2 March 2020 when the NSW RFS declared that there were no longer any active fires[4]. TransGrid assets were within the active fire zones until this day.

The fires traversed many NSW national parks over a period of several weeks. Figure 1[5] shows the geographic extent of the fires. Approximately 9% of TransGrid's network route length is within 2019/20 NSW bushfire-impacted zones. TransGrid's transmission line network within the burn area includes 1,822 steel lattice tower and pole structures, 596 wood poles structures, 263 concrete structures, and 999 km route length of transmission line conductors and earth wires. Three TransGrid substations had fire up to the buffer zone and/or fence and 32 substations were impacted by smoke and soot.

TransGrid's annual bushfire preparedness activities include mitigations for externally caused bushfires passing through or near TransGrid's assets, however the unprecedented scale and intensity of the 2019/20 bushfires has had a significant impact on TransGrid's transmission network and the condition of the assets.

[2] https://www.csiro.au/en/Research/Environment/Extreme-Events/Bushfire/preparing-for-climate-change/2019-20-bushfires-explainer

[3] https://www.dpc.nsw.gov.au/assets/dpc-nsw-gov-au/publications/NSW-Bushfire-Inquiry-1630/Final-Report-of-the-NSW-Bushfire-Inquiry.pdf

[4] NSW RFS Twitter Feed 02/03/2020 05:10PM, https://twitter.com/nswrfs/status/1234360507919822849?lang=en

[5] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/factsheet-google-earth-engine-burnt-area-map-200063.pdf

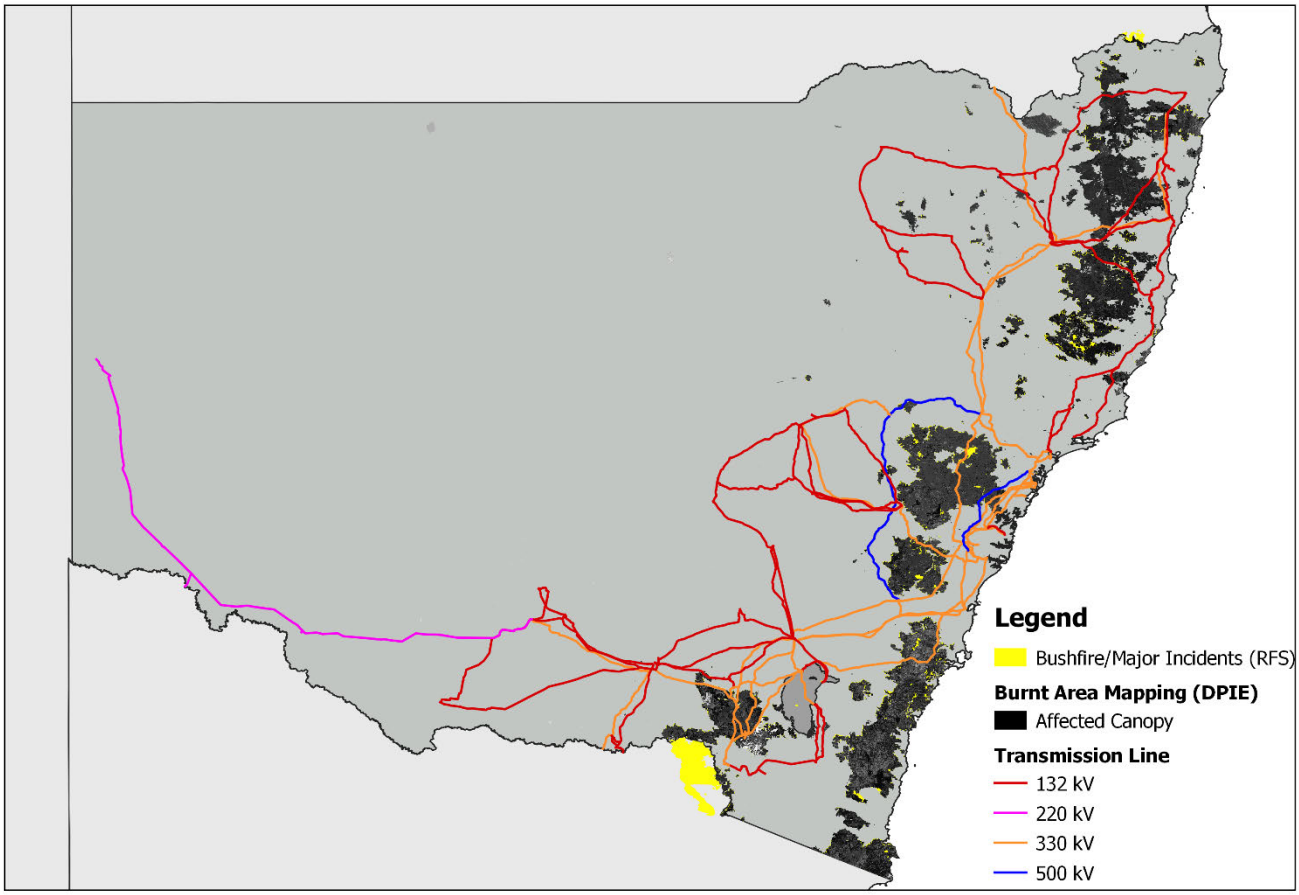

Figure 1 - Map of 2019/20 bushfire burnt area within NSW and the TransGrid network (source: NSW Department of Planning, Industry and Environment and Rural Fire Service)

For TransGrid's Network, the bushfire season can be broken into three distinct locations described below.

3.1 Northern NSW

During October and early November 2019, the fires were mainly in the north of the state with TransGrid's 132 kV wood pole assets in the area most affected. The fires extended from Lismore down the east coast past Taree and inland as far as Armidale. During this period the network experienced approximately 30 bushfire-triggered outages, on 330 kV and 132 kV assets. The most significant damage occurred to line numbers 963, 964, 965, 966, and 967. During this period nine wood pole structures were destroyed and a significant portion of the north coast was being fed radially and with a constant risk of tripping whilst emergency repairs were being carried out.

A concurrent trip of lines 967 and 89 occurred on 8th October 2019. These lines run parallel to each other and were impacted by the same fire front. These outages led to an Energy Not Supplied (ENS) event at Lismore that lasted 22 minutes and has been calculated to be a total of 30.25 MWh of unsupplied energy, equating to 0.123 system minutes.

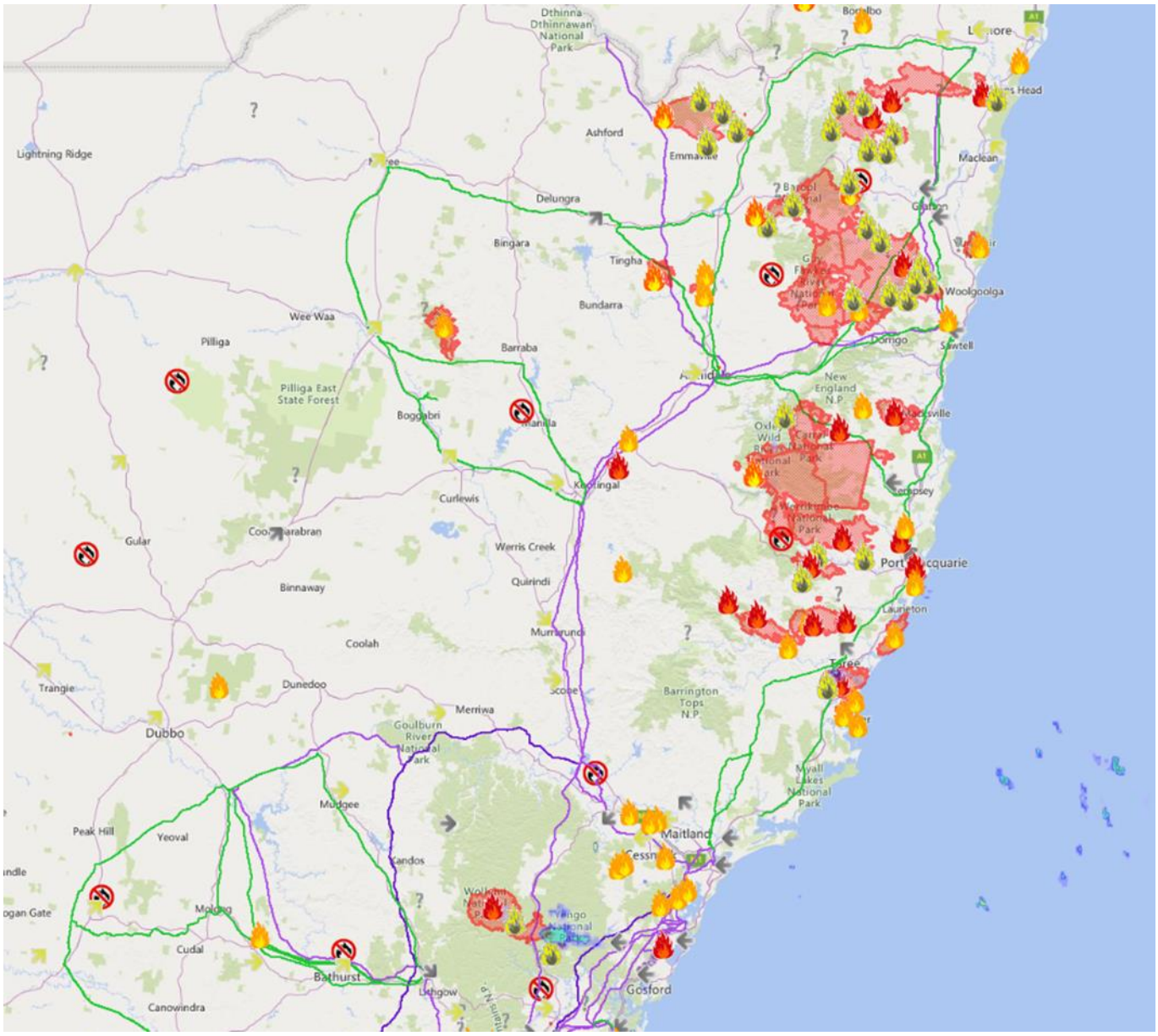

Figure 2 – Northern NSW Fires on 13/11/2019 (source: TransGrid Indji)

3.2 Central NSW

From mid-November to the end of January, a number of significant fires were impacting TransGrid's Assets. Fires on the Central Coast were interrupting supplies from the Hunter and Central Coast power stations, the Gospers Mountain fire near Lithgow was causing outages on TransGrid's 500 kV and 330 kV assets, and the northern parts of the Shoalhaven fires were causing outages on TransGrid's assets in and around Kangaroo Valley. These last fires also caused a loss of supply to the network communications services to Kangaroo Valley Switching Station resulting in urgent dispatch of staff and diesel generators to the impacted sites.

In total there were 12 trips of 500 kV transmission lines. This is significant as these are not only part of the main backbone of TransGrid's network but are also the tallest and largest structures on the network. The fact that so many trips occurred on these assets indicates the magnitude of the severity of the fires and the volume of smoke being produced at the time.

As well as trips to TransGrid's 500 kV network there were also 129 outages caused by bushfires on the 330 kV network. This is significant again due to the size of the transmission line structures that they were exposed to the fire and engulfed by the heavy smoke.

3.3 Southern NSW/ Snowy Mountains

In late December and Early January, the Snowy mountains fires took hold, resulting in 65 outages of 330 kV assets. Unfortunately on the 4th January, four of the 330 kV lines tripped within minutes of each other and caused the NEM regional separation of NSW from Victoria. This separation is the subject of a separate AEMO report.

One of the four lines out of service was the most damaged line within TransGrid's 330 kV network, line 2. This line had sufficiently damaged insulators on multiple structures such that it was impossible to re-energise the line. This line took a number of weeks to repair due to both the significance of the damage and the difficulty in assessing and clearing the access tracks to the site. The nearby U3 line was also damaged. This line had melted and annealed conductor, with one phase found on the ground. A section of U3 had to be re-strung with new conductor taking approximately 3 months to procure and install.

During January an ENS event occurred at Tumut 132 kV Substation. A fault (lightning strike) occurred on Line 970, and with line 993 out of service due to five wood poles being destroyed by fire, Tumut lost supply. TransGrid were able to restore the busbar within 20 minutes however, Essential Energy could not restore the Low Voltage Circuit Breakers immediately and Tumut town and surrounding area was blacked out for approximately 2 hours.

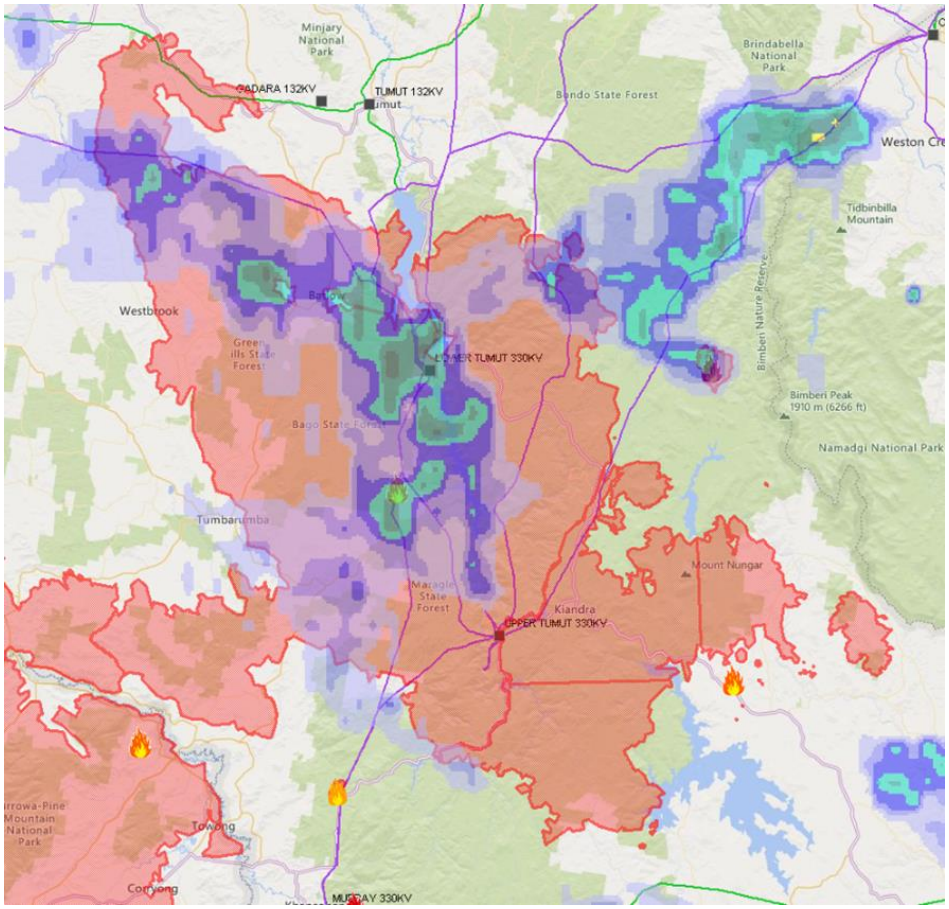

Figure 3 – Snowy Mountains NSW Fires on 15/01/2020 (source: TransGrid Indji)

3.4 Comparison to previous Seasons

The Bushfires over summer 2019/20 were the some of the worst fires experienced in NSW history. Operationally, the number of transmission line outages due to bushfires was far higher than previously experienced, as shown in Figure 4 and Figure 5. The actions taken by TransGrid helped to maintain the network and keep the assets in service to meet the electricity demands of NSW and the ACT.

During the Bushfire season (August 2019 – March 2020) the entire TransGrid network experienced 65% more forced outages than the 10-year average for the same period. This included 275 forced outages in January 2020, which was more than 200% higher than the January average over the last 10 years. And more than 100 outages above the next highest month of outages (January 2019).

The period between November to February was significantly higher than the long-term averages and the worst day on the network was 4th January 2020 where 85 forced outages were recorded. This one day on its own was greater than the 10-year average for the entire month of any month during the bushfire season.

Fault and forced outages on TransGrid's network cause by bushfires in 2019/20 were 20 times higher than in previous years due to the duration, scale and intensity of the fires as shown in Figure 2. This highlights the stress that the transmission network was placed under and the network impact of the damage caused by the fires.

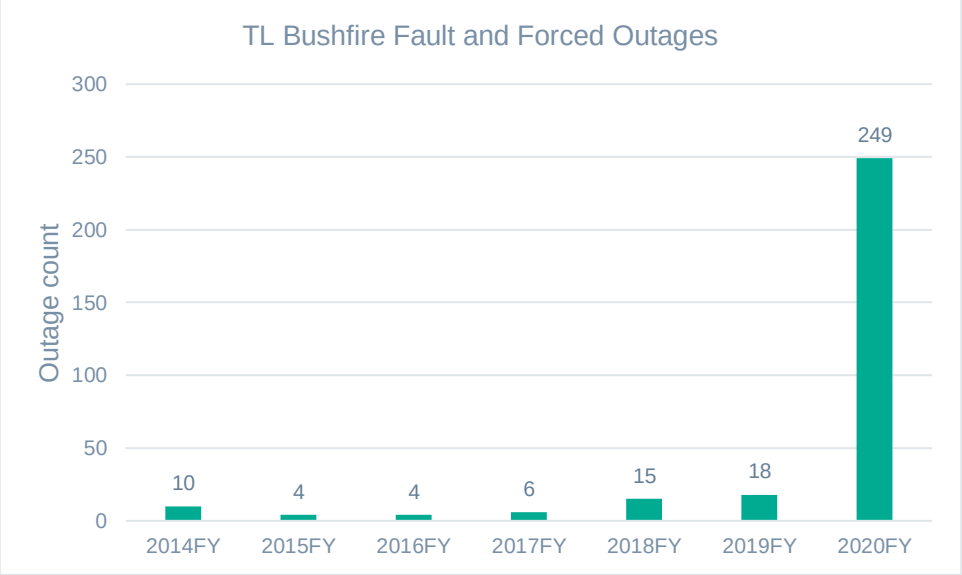

Figure 4 – Transmission line bushfire caused fault and forced outages

This chart illustrates the extreme severity of the 2019/20 bushfires by way of the significant impact it had on TransGrid's assets in the affected areas compared to recent years.

When all TransGrid equipment is considered, such as circuit breakers feeding distributor-owned lines, the quantity of fault and forced outages, were significantly above average. As shown in Figure 5, January 2020 had 231% greater unplanned outages than the long term average, with 275 events, surpassing the previous monthly maximum of 163 in January 2019. On the 4th of January alone there were 85 events, greater than the entire January monthly average of 83.

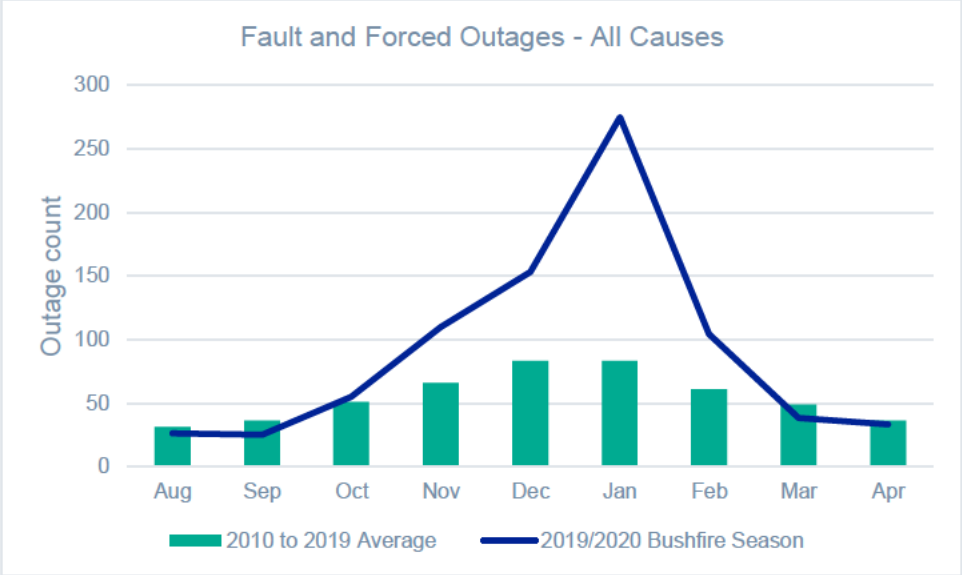

Figure 5 – Fault and forced outages, all causes, including CB to customer lines

4. Operational Response

During the whole bushfire period, TransGrid maintained contact with the NSW Rural Fire Service (RFS) Headquarters and the Energy Utilities Functional Area Coordinator (EUSFAC) who was stationed in the State Emergency Operations Centre (SEOC) with the RFS. The ESUFAC covers electricity supply, natural gas, liquid fuels, water supply and waste management. The 2019/20 bushfires were the first time the EUSFAC have been deployed 24/7 to the SEOC.

This allowed TransGrid access to current information on the fires and to assist in predicting when and where some of the fires may spread so that the network contingency plans can be arranged.

Figure 6 - Working with the RFS to access assets in the Snowy Mountains on 5th January 2020

4.1 Preparation of the Network

TransGrid manages the transmission network within forecast and prevailing weather and demand conditions as part of the normal day-to-day operation of the network. Lack of Reserve (LOR) market notices combined with predicted power flows identify areas of concern the day before, and plans are put in place to manage these occurrences. As a result of daily reviews, outages can be and are regularly suspended (or prevented from starting) in normal day-to-day activities but these become more numerous and more significant as extreme ambient temperatures, high demand and operating environment risks to assets become more likely.

In addition, the network configurations during Summer 2019/20 and the supply-demand balance within each state meant there was significant reliance on the Interconnectors as critical elements to support the network for the summer. As a result of the significant risks arising from the bushfires, a large amount of planned maintenance and project work was cancelled and deferred.

TransGrid also made the decision on several occasions to pre-emptively dispatch staff to critical interconnector sites to ensure that in the event of fire causing an interruption, that staff were on hand that could respond immediately to reduce any potential impacts. TransGrid also dispatched staff at other times to locations that were likely to be cut off by intervening bushfires. This again was to ensure that TransGrid could respond to faults, failures and outages without being cut off from accessing critical sites.

4.2 Transmission Line response

When it was safe to do so, an 'After Fault' patrol was organised and dispatched for each impacted line using both the Easements and Lines patrol teams. The Easements team ensure safe access and that any urgent hazard trees are identified and managed. The Lines patrol team inspect the transmission line assets for damage.

The patrols found the following urgent damage which required immediate remediation to restore the network to a safe and secure operating state.

4.2.1 Southern NSW and Snowy Mountains

The extent of fires on 4 January 2020 resulted in all transmission lines at Lower Tumut and Upper Tumut switching stations tripping out of service due to fire and smoke. This resulted in a NEM regional separation event of NSW from Victoria, with the separated regions required to operate islanded to maintain a stable power system. This event resulted in the loss of any potential generation from Snowy Hydro into NSW during the time of the separation.

While this caused disruption to the electricity market participants, there was only a minor loss of supply event which occurred at the time of separation between NSW and Victoria where approximately 36 MW of load was interrupted at Tumut and Gadara.

Reliability risk and Energy Not Supplied events were minimised because of the relatively lower electricity demand at the time, with the events occurring on a weekend.

The bushfires resulted in unprecedented damage to network assets due to the intensity of the fires, as shown in Figure 7, fire zones are shown in relation to TransGrid assets 330 kV transmission lines shown in purple and 132 kV transmission lines shown in green.

TransGrid responded in the short term with urgent repairs as well as damage inspections via helicopter on affected lines. By 29 January 2020 all impacted Snowy Mountains lines had been inspected by air.

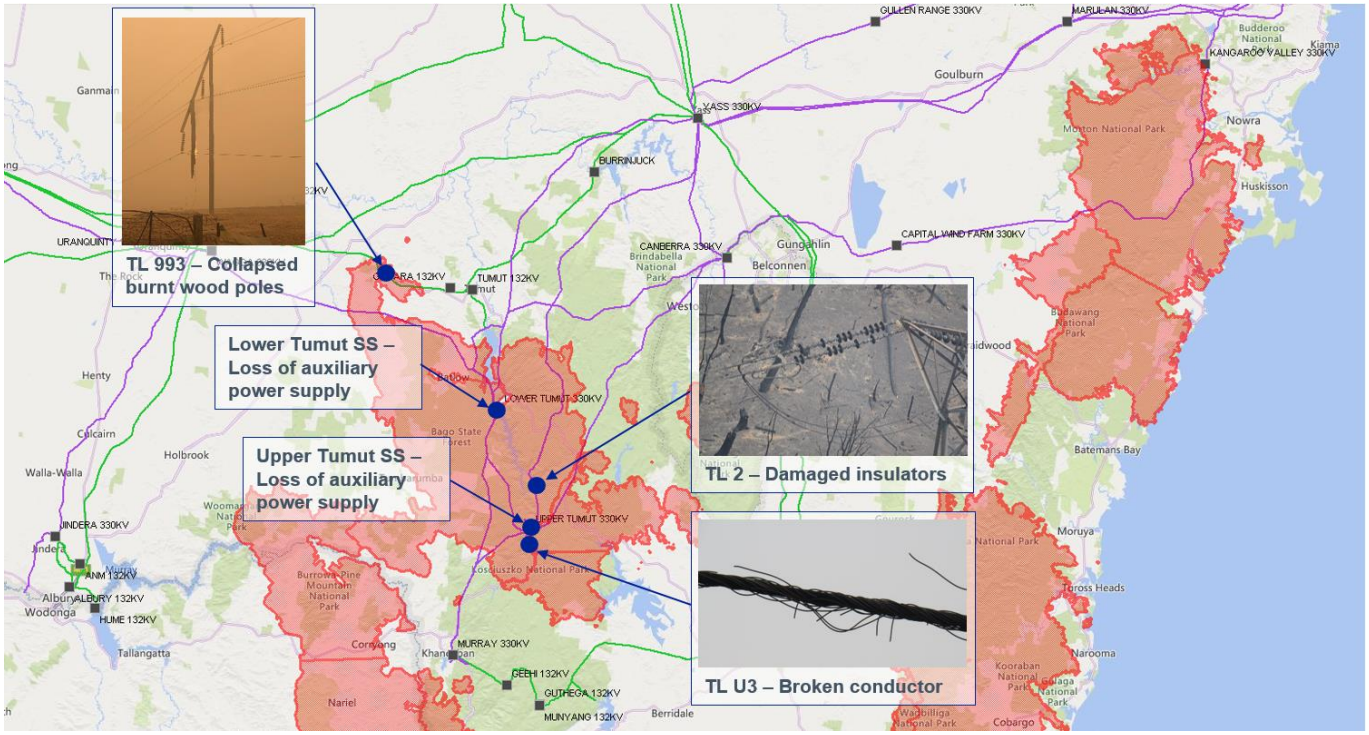

Figure 7 – Snowy Mountains Fires Initial Response Findings January 2020

4.2.1.1 Line U3 response

On 8 January 2020 TransGrid received advice from Snowy Hydro of dispatch problems and a possible line fault. A helicopter was dispatched and confirmed that conductors were down between structures 11 and 12 on 330 kV line U3. TransGrid's easement contractor worked throughout the day clearing safe access to the site. The site was accessed from the ground in the late afternoon to assess the extent of damage and prepare to make safe. Extensive damage to the aluminium conductor was found, with much of it melted and one phase with conductor separation.

Extensive access works were required to be able to perform the repair works. The conductor used on this transmission line is also a size and aluminium alloy which is no longer available from suppliers as a standard. A special order for the conductor size of a similar alloy was placed but had a significant lead time and as such a temporary conductor was strung to replace the damaged conductor and return the transmission line to service on 14 April 2020. The temporary conductor is a different size and alloy to what is required for the ongoing operation of the transmission line.

Figure 8 – Access track works on Line U3

Figure 9 – Line U3 Dropped conductor on ground

Figure 10 – Terrain on Line U3

4.2.1.2 Line 2 Response

330 kV Line 2 suffered multiple trips and lockouts from 4 January 2020 to 6 January 2020 after which the line was unable to be returned to service (would trip on energising).

Several structures (three tension, three suspension) were found to have multiple damaged and broken insulators.

The response required safety considerations including risk of falling trees due to heavy timber cover and side-slope, EWP access, climbing towers and added complexity of insulator replacement on tension structures. Restoration was restricted by heavy smoke, with stand-downs required for worker safety and access issues caused by rain. A “skidder” was kept on standby to clear debris and recover vehicles if needed. TransGrid’s vegetation management contractor worked during these repairs to clear the access tracks

The insulators were replaced and the line was returned to service on 26 January 2020.

Figure 11 – Line 2 Damaged Insulators

Figure 12 – Clearing bushfire-damaged trees for access to Line 2

4.2.1.3 Line 993 Response

On 4 January 2020 Line 993 faulted in the system separation event with Victoria. The line was unable to be restored during the restoration. The line was subsequently patrolled on 5 Janurary 2020 which found five structures were significantly damaged by the Dunns Road fire.

The damage at structure 85 resulted in downed lines over the Snowy Mountains Highway between Adelong and the Hume Highway. TransGrid undertook urgent temporary repairs to facilitate safe use of the highway being used by the RFS. These repairs included, cutting the conductor and moving away, earthing and making safe to enable the highway to reopen.

This line was undergoing a line rebuild in the lead up to the bushfires, where all wood pole structures were being replaced with steel poles and one of two earthwires being replaced with OPGW. The foundations for these structures had already been poured. The construction contractor was called to site to replace the remaining damaged structures with the steel poles planned in the project. Some incremental costs due to bushfire damage were incurred by TransGrid due to disruption to the planned project works.

The conductor was also damaged and broken with all there phases requiring restringing between structures 65 to 82, a route length of 5.5 km.

Figure 13 – Line 993 Wood Pole Damage

Figure 14 - Line 993 Failed Conductor on Ground

4.2.2 Northern NSW

4.2.2.1 Line 963 Tomago to Taree 132 kV Line

Line 963 was impacted by the Hillville fire. On 9 November 2019 a short notice outage was taken on Line 963 after an Essential Energy staff member reported a structure was on fire. The site preliminary scoping work was done by Essential Energy staff for plant access and discussed over the phone with TransGrid staff. A pole change was planned for next day.

On 10 and 11 November 2019, safe access to site was not possible so work to access was discontinued. On 12 November 2019, safe access to site was possible and one pole was changed on structure 446. The line was made available for service.

A ground inspection of the fire zone covering structures 435 to 475 was later conducted. One fire damaged urgent hazard tree was removed.

Figure 15 – Line 963 Wood Pole Damage

4.2.2.2 Line 966 Armidale to Koolkhan 132 kV Line

Line 966 was impacted by the Liberation Trail Fire. Multiple fault outages occurred on 8 November 2019. Six structures required replacement to restore the transmission line. Active fires prevented immediate access to all structures. Some access clearing and construction of equipment pads were required. The six structures were restored and the line returned to service on 17 November 2019.

Figure 16 – Line 966 NSW RFS Twitter 09/11/2019

Figure 17 – Line 966 Structures

4.2.2.3 Line 965 Armidale to Kempsey 132 kV Line

Line 965 was impacted by the Warm Crossing, Carrai Creek and Carri East fires. On 10 November 2019 TransGrid received notification that the base of one pole of a two-pole structure was 50% burned through. Due to all the other line outages and fires in the area, TransGrid decided to keep the line in service with auto reclose disabled. This pole was replaced on 18 November 2019.

Figure 18 – Aerial patrol Line 965

At the time of this replacement the next structure was found with fire damage and chunks taken out at ground line. It was replaced 31 January 2020.

4.2.3 Insulator Pollution

Three 330 kV transmission lines tripped in the early hours of 7 January 2020, namely:

> Line 83 – Liddell to Muswellbrook
> Line 84 – Liddell to Tamworth
> Line 17 – Avon to Macarthur

Line 83 tripped first and then locked out on re-close attempt. This was followed by Line 84 trip which then separated the NSW and QLD networks as both transmission lines are on the Queensland – New South Wales Interconnector path.

Pollution from recent bushfires, combined with lack of substantial rain, caused the asset performance issues identified above. Pollution build up is a known failure mode of insulators. Normally, pollution is not an issue as natural washing of transmission line insulators occurs with moderate rainfall. However the three months to end of December 2019 saw very much below average rainfall in the areas where the issues presented, combined with unprecedented bushfire activity in the vicinity of the transmission lines. This is supported by reports on other lines in the network of minor arcing of insulators on 330 kV line 3W by property owners, as well as trips and visual tracking on substation equipment at Munmorah, Vales Pt and Dapto at similar times in light rain, which are all indications of excess leakage current caused by pollution reducing the effectiveness of the insulation.

The early hours of 7 January 2020 saw light rainfall across much of the state, any in some locations the first rainfall since November 2019. It is well documented that wetting of insulators, particularly porcelain and glass, which have pollution build up can cause increased leakage current leading to arcing discharges and dry band formation progressing to flashover[6]. For this to occur, the pollution must generally include some particulate or

[6] https://www.inmr.com/pollution-flashover-insulators/

minerals with conductive elements. Bushfire ash can include these conductive elements including salts, iron, and copper in varying concentrations depending upon the temperature of the fire[7].

Transmission line insulators polluted with potentially conductive material are at risk of arcing and flashover until either:

(a) Natural washing of the insulators occurs with moderate to heavy rain, or

(b) Washing by high pressure cleaner.

Waiting for natural washing of the insulators presents the ongoing risk of potential flashover and line trips, particularly in unfavourable conditions such as high humidity, fog, mist, or light rain.

Washing of insulators involves a helicopter with high pressure washing equipment flying and hovering at each tower to wash the pollutants from each insulator string. It is not economic or practical to consider washing all insulators in or near fire zones due to the extent of this area, therefore washing must be prioritised by probability of failure and consequence of failure.

The most critical transmission lines were identified as those on the QNI and VNI transmission paths. In considering the likelihood of each of these transmission lines having pollution build up, the DPIE air quality readings for particulate matter were analysed. Figure 19 shows that particulate matter has been increasing substantially since September 2019, coinciding with the bushfires.

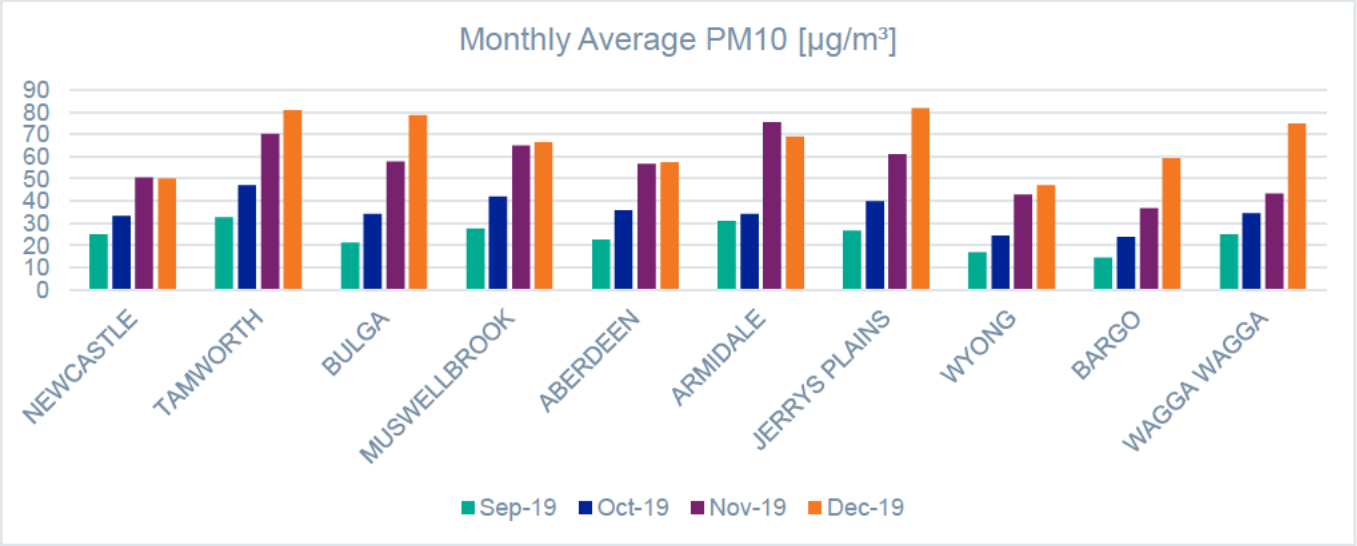

Figure 19 - Monthly Average Particulate Matter

Moderate rainfall observed in February 2020 was expected to wash the insulators naturally, and given the estimated cost of approximately $1.1 million to wash the QNI and VNI associated transmission lines, TransGrid decided not to perform the transmission line insulator washing works. This considered analysis applied to this and all other response activities have ensured that only necessary costs have been incurred.

4.2.4 Other Lines with bushfire damage not requiring emergency works

AEMO placed constraints on the transmission lines and Victoria – New South Wales interconnector due to the unknown condition of the assets potentially damaged by the bushfire events, during severe weather events[8]. Aerial patrols were initiated, and all Snowy Mountains region lines were inspected by air by 26th January 2020. AEMO were advised on 29th January 2020 that there was no damage identified to warrant continued

[7] Bodi, M., et.al., 2014, Wildland fire ash: Production, composition and eco-hydro-geomorphic effects, Earth-Science Reviews.

[8] AEMO Electricity Market Notice 72574

multi-circuit credible contingency constraints. The remainder of the transmission lines impacted by bushfires were also patrolled following inspection of the Snowy Mountains region. Summary of the findings are below.

- Line 01 – Upper Tumut Switching Station to Canberra – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - Two fault outages on 4 January 2020. The second outage failed to reclose successfully. Four unsuccessful attempts were made to reenergise the line. Fifth attempt was successful, just under four hours from failed auto-reclose.
  - After fire lines and easement patrols were conducted between Upper Tumut Switching Station and Structure 87 (25.3 km route length)
- Line 3 – Lower Tumut Switching Station to Yass – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - Four fault outages
  - After fire lines and easement patrols were conducted between Lower Tumut Switching Station and Structure 58 (19.4 km route length)
- Line 07 – Lower Tumut Switching Station to Canberra – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - Four fault outages
  - After fire lines and easement patrols were conducted between Lower Tumut Switching Station and Structure 37 (16.6 km route length)
- Line 64 – Lower Tumult Switching Station to Upper Tumut Switching Station – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - 11 Fault outages
  - After fire lines and easement patrols were conducted for the entire line length (40.6 km)
- Line 65 – Murray Switching Station to Upper Tumut Switching Station – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - Three fault outages
  - After fire lines and easement patrols were conducted from Upper Tumut Switching Station to Structure 35 (13.4 km route length)
- Line 66 – Murray Switching Station to Lower Tumut Switching Station – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - 18 fault outages
  - After fire lines and easement patrols were conducted from Structure 74 to Lower Tumut Switching Station (41.1 km route length)
- Line 051 – Lower Tumut Switching Station to Wagga Wagga – 330 kV steel tower line
  - Impacted by the Dunns Road Fire
  - Eight fault outages
  - After fire lines and easement patrols were conducted from Lower Tumut Switching Station to Structure 124 (57 km route length)
- Line 3W – Capital Wind Farm to Kangaroo Valley Switching Station – 330 kV steel tower line
  - Impacted by the Currowan 2 Fire
  - 36 fault outages
  - After fire lines and easement patrols were conducted between Structure 278 to KVSS (78.3 km route length)
- Line 22 – Vales Point to Sydney North – 330 kV steel tower line

- Impacted by the Arizona Road, Gospers Mountain and Three Mile Fires
- No fault outages
- After fire lines and easement patrols were conducted between Structure 17 to 18, and 114 to 135 (11.5 km route length)

> Line 2M – Munmorah to Tuggerah – 330 kV steel tower line
- Impacted by the Arizona Rd Fire
- No fault outages
- After fire lines and easement patrols were conducted between Structure 13 to 16 (1.2 km route length)

> Line 25/26 – Vineyard to Vales Point – 330 kV steel tower line
- Impacted by Gospers Mountain Fire
- One fault outage
- After fire lines and easement patrols were conducted between Structures 104 to 114, 122-123 and 126 to 168 (22.9 km route length).

> Line 31/32 – Bayswater to Regentville – 330 kV double circuit steel tower line
- Impacted by the Gospers Mountain Fire
- 41 fault outages
- After fire lines and easement patrols were conducted between Structures 103 to 472 (100.8 km route length).

> Line 39 – Bannaby to Sydney West – 330 kV steel tower line
- Impacted by the Green Wattle Creek Fire
- Two fault outages
- After fire lines and easement patrols were conducted between structures 353 to 355, and 369 to 405 (16.1 km route length).

> Line 5A1/5A2 – Eraring to Kemps Creek – 500 kV double circuit steel tower line
- Impacted by Three Mile, Watagan Rd and Charcoal Rd fires and Gospers Mountain fires from September 2019 to January 2020
- Six fault outages
- After fire lines and easement patrols were conducted between structures 93 and 151 (16.1 km route length).

> Line 5A3/5A4 – Bayswater to Wollar – 500 kV double circuit steel tower line
- Impacted by the Meads Creek West fire
- One fault outage
- After fire lines and easement patrols were conducted from structures 176 to 178, 181 to 186, 207 to 210, and 215 to 221 (8.4 km route length).

> Line 5A3/5A5 –Wollar to Mount Piper – 500 kV double circuit steel tower line
- Impacted by the Upper Turon Rd fire
- Four fault outages
- After fire lines and easement patrols were conducted between structures 429 and 442 (5.9 km route length).

> Line 5A6/5A7 – Mt Piper to Bannaby – 500 kV double circuit steel tower line
- Impacted by Green Wattle Creek fire
- one fault outage

  - After fire lines and easement patrols were conducted from structures 279 to 286, and 293 to 295 (5.4 km route length).
- Line 76/77 Wallerawang to Ingleburn
  - Impacted by Green Wattle Creek Fire
  - 47 fault outages
  - After fire lines and easement patrols were conducted from structure 106 to 220 (46.4 km route length).
- Line 87 – Armidale to Coffs Harbour – 330 kV steel tower line – 330 kV steel tower line
  - Impacted by Guyra Road, Bees nest and Eve Creek Rd fires
  - No fault outages
  - After fire lines and easement patrols were conducted from structures 116 to 152, 269 to 272 and 288 to 290 (20.4 km route length).
- Line 89 – Coffs Harbour to Lismore – 330 kV steel tower line – 330 kV steel tower line
  - Impacted by Liberation Trail, Busby Flat Road and Myall Creek Road Fires
  - Four fault outages on 08/10/2019, one on 12/11/2019
  - After fire lines and easement patrols were conducted from structures 338 to 399, and 549 to 643 (69.9 km route length).
- 8C/8E – Armidale to Sapphire – 330 kV steel tower line
  - Impacted by Guyra Rd fire.
  - One fault outage 08/11/2019.
  - After fire lines and easement patrols were conducted from structures 328 to 330, and 338 to 364 (11.6 km route length).
- 8C/8J –Sapphire to Dumaresq – 330 kV steel tower line
  - Impacted by Rocky Creek Road 2 fire
  - One fault outage
  - After fire lines and easement patrols were conducted from structures 169 to 175 (3.0 km route length)
- 967 – Koolkhan to Coffs Harbour – 132 kV concrete pole line
  - Impacted by Myall Creek Road fire and Busby Flat Road fires
  - Eight fault outages
  - After fire lines and easement patrols were conducted from structures 102 to 254 (39.2 km route length).

Figure 20 – Line 89 and 967 late October 2019 (three weeks after Busbys Flat Rd fire fire)

- 96C – Armidale to Coffs Harbour – 132 kV wood pole line
  - Impacted by Guyra Rd and Andersons Creek fires
  - No fault outages
  - After fire lines and easement patrols were conducted from structures 206 to 214, and 258 to 287 (10.5 km)
- 96L – Tenterfield to Lismore – 132 kV wood pole line
  - Impacted by Long Gully Road Fire and Bruxner Highway fires.
  - No fault outages.
  - After fire lines and easement patrols were conducted from structures 206 to 214, and 258 to 287 (10.5 km)
- 96R – Glenn Innes to Tenterfield – 132 kV wood pole line
  - Impacted by Mount Mckenzie Rd fire during September 2019
  - Fire impacted structure 316-330 (4.1 km route length)
  - One fault outage in (failed reclose) 9 September 2019. Returned to service 18 hours later after line patrolled.

Figure 21 – Line 96R Fire Impact

- 96H – Coffs Harbour to Koolkhan – 132 kV concrete pole line
  - Liberation Trail, Boundary Rd and Kangaroo Creek Rd fires
  - No fault outages
  - After fire lines and easement patrols were conducted from structures 68 to 91, 173 to 177, and 188 to 215 (12.05 km route length).
- 96N – Armidale to Inverell – 132
  - Impacted by Guyra Rd Fire.
  - One fault outage
  - After fire lines and easement patrols were conducted from structures 337 to 407, and 511 to 523 (16.9 km route length).
- 9W9/96G – Kempsey to Port Macquarie – 132 kV dual circuit concrete pole line
  - Impacted by Lindfield Park Road Fire
  - One fault outage
  - After fire lines and easement patrols were conducted from structures 207 to 215 (1.3 km route length).
- 978 – Williamsdale to Cooma – 132 kV wood pole line
  - Impacted by Clear Range Fire
  - No fault outages
  - After fire lines and easement patrols were conducted from structures 248 to 342 (18.7 km route length).
- 97D – Williamsdale to Cooma – 132 kV wood pole line
  - Impacted by Clear Range Fire
  - No fault outages
  - After fire lines and easement patrols were conducted from structures 251 to 296 (11.6 km route length).
- YY – Lower Tumut Switching Station to Field
  - Impacted by Dunns Road fire
  - After fire lines and easement patrol (2.3 km route length)

4.3 Easement and Access Tracks

Establishing safe access to the transmission lines involved clearing access tracks and removing hazard trees which were an immediate threat to the transmission line.

Numerous damaged trees outside of standard clearance zones also required trimming or removal to mitigate the risk of subsequent falls impacting the safety of response workers and to protect existing or newly replaced network assets from further damage.

Clearing fallen and hazardous trees was a high priority activity in our bushfire emergency response. Initial condition assessments were performed via aerial inspection to identify urgent trees to be managed. The following work involved clearing access tracks, providing safe access for crews and allow supply restoration and replacement work to take place. Once the initial fire period had abated, efforts turned to inspecting all impacted areas to identify the activities required to manage fire-affected hazard trees that had the potential to fail onto the electricity network assets as described in Section 5.

Figure 22 – Fire damaged hazard tree threatening transmission line

4.4 Substation Response

Bushfires affecting transmission lines resulted in numerous circuit breaker (CB) operations across the network which may also have resulted in some minor increased asset aging. Several CBs had greater than 10 fault operations from the event and these were associated with Lines 3W, 66, 64, 77, 76, 051 and 02. There are no CB replacements included in this pass-through application proposal, however these CBs may have to be included in future asset replacement strategies sooner than what otherwise would have occurred. The aging impact will not be known until the next maintenance testing of each asset. TransGrid performs line CB maintenance on a six-yearly frequency.

When safe access was available in January 2020, all substations in the Snowy Mountains were inspected, but no specific asset damage or pollution to equipment was identified. All Snowy Mountains substations were inspected by the end of January 2020.

4.4.1 Upper Tumut Switching Station

Severe damage to multiple 33 kV Essential Energy structures supplying Cabramurra resulted in loss of auxiliaries to Upper Tumut Switching Station.

Issues with the remote-end protection trip from Snowy Hydro prevented immediate supply from the backup diesel, so the site was running on batteries for a substantial duration.

Bushfires damage to Essential Energy and Snowy Hydro assets in the region caused loss of external AC auxiliary supply to Upper Tumut Switching Station and the Snowy Hydro control room, resulting in sites run on batteries and local backup diesel generation (which is as designed). Additional follow up inspections and testing are ongoing to confirm any further asset damage due to smoke or heat, but these are not expected to identify anything significant, apart from burnt-out access stairs which required replacement.

Figure 23 – Upper Tumut Switching Station – Fires burnt to boundary

4.4.2 Lower Tumut Switching Station

Lower Tumut Switching Station normally gets its auxiliary supply from Essential Energy's Talbingo 66/11 kV zone substation. That substation is fed radially by feeder 850 which was damaged and had conductors down.

Supplies had to be rearranged so that the switching station and the Talbingo town could be supplied from Tumut 3 power station until Essential Energy could install a diesel generator to restore supplies to the typical configuration.

There was a grass fire between the zone substation and the switching station. This may have caused some increased aging to the TransGrid-owned 11 kV supply cables buried in this location, but any minor aging

would not elevate the risk sufficiently to justify replacement of these cables within the current regulatory control period.

CB0512 experienced over 250 operations over three hours due to a protection fault. This would have resulted in some loss of life. Investigations of this CB's condition was included in diagnostic tests described in Section 5.3, so the costs have been included in this pass-through application, however even without this maloperation, the CB would have met the criteria due to the proximity of the fire to the substation boundary. Any subsequent repairs or replacements would not been included in this pass-through application unless caused by bushfire heat. Investigations of the protection system by technicians have not been included in this pass-through application.

4.4.3 Other Assets

Bushfire ash caused elevated discharge activity across TransGrid's network resulting in network asset trips at Tomago (Capacitor bank) and Vales Point (Capacitor bank & Busbar) on 7 January 2020. Lines 82 (Liddell – Tomago), 83 (Liddell – Tamworth) and 84 (Liddell – Muswellbrook) were impacted, in large part due to dust and bush fire debris and light rain settling on insulators and other substation equipment.

By the close of business on 7 January 2020, all other issues had been resolved for assets mentioned above with repairs continuing at Vales Point.

Site-wide visible arcing activity was observed at Dapto and Munmorah Substations (refer Figure 24). Ash was the reported cause of a CVT imbalance alarm at Dapto.

Insulator washing was considered and deemed not necessary. TransGrid nominated sites for inspections to determine the extent of pollution-related discharge activity while monitoring the impact of rain providing natural washing. Localised rain activity in January 2020 followed by extensive rainfall across the state in February 2020 resulted in sufficient washing of insulator pollution, with reports from site inspections identifying discharge activity was back at normal levels.

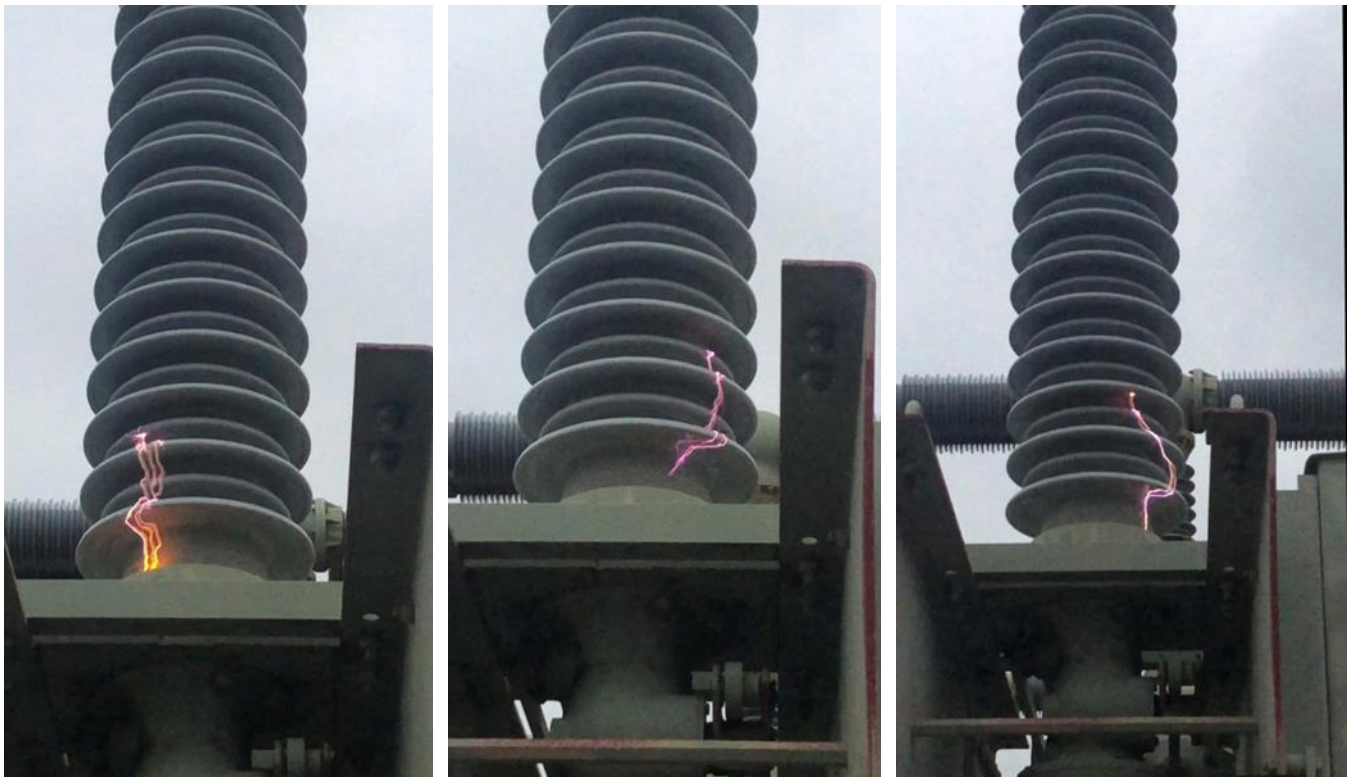

Figure 24 – Tracking on CB insulators at Munmorah Substation

4.5 Substation Property

4.5.1 Fire Protection Systems

Excessive smoke throughout the state resulted in numerous fire alarm events. To prevent nuisance alarms to the system operator the alarming functionality was disabled after checking that the site was not under threat. Sprinklers remained armed.

The rearming was completed during the next routine fire system inspection (no later than three months). In December 2019 to January 2020 a total of 32 sites were disarmed.

4.6 Digital Infrastructure response

A number of Digital Infrastructure assets were in close poximity to the fires and potentially susceptible to damage due to heat and ash. Two radio repeater sites lost 415 V supply which resulted in immediate investigations.

4.6.1 Snubba Radio Repeater Site

Snubba Radio Repeater Site (RRS) was impacted by the bushfires. The 415 V supply to the site was interrupted and damage to the air conditioning unit, building guttering and tower cable was evident. Several diesel generators were mobilised to Snubba RRS whilst Essential Energy repaired the mains supply.

Figure 25 - Snubba RRS damage

4.6.2 Clarks Hill Radio Repeater Site

Auxiliary supply was interrupted to Clarks Hill RRS with no significant services impacted. There was no damage to the Snowy Hydro building or TransGrid's VHF Repeater. There was no VHF Repeater covering

this area until mains power was restored however an assessed determined it was not necessary to install a mobile generator.

4.6.3 Protection Response

The “failed reclose” event that resulted in the seperation on Queensland and New South Wales was found to have operated as designed. The protection “timed out” before synchronism was reached.

The protection maloperation investigation noted in Section 4.4.2 has not been included in this pass-through application as it was a pre-existing hidden issue.

5. Damage Assessment

5.1 Transmission Line Assets

TransGrid initiated works to assess damage in two stages:

(i) Network integrity assessment[9]
Actions taken to assess the immediate integrity of the network in January 2020 and to inform the extension of removal of market constraints imposed by AEMO as described in Section 4.2.4.

(ii) Detailed inspections and assessment of damage[10]
Inspections and assessment to determine the extent of damage cause to the network.

5.1.1 Network Integrity Assessment

5.1.1.1 Detailed helicopter patrol

Detailed helicopter patrols of the fire-affected areas were conducted, starting in the Snowy Mountains region and moving north through each fire zone. The inspections included:

> inspecting each structure for component issues or defects;
> identifying obvious hazard trees at risk of immediate failure;
> gauging the intensity of the burn to inform prioritisation of future inspections; and
> taking photos or video if practical.

Only the areas noted in the RFS burn zones were inspected.

The inspections identified various asset and vegetation issues as described in Section 6.

5.1.1.2 Conductor and fitting metallurgical testing

Conductors and fittings that were damaged and replaced as part of the emergency response works were recovered and sent for metallurgical testing (where appropriate) to determine whether the asset components in the vicinity of the obvious damage were compromised due to the heat of the fires. Intense heat can permanently change the mechanical and electrical properties of the steel and aluminium components which can go unnoticed visually until failure occurs. Conductors from three 330kV transmission lines were tested – lines 993, U3 and 2.

The tests of Line 993 conductor included:

> Testing of failed conductor to determine the failure mode
> Tensile test of intact heat affected sample to determine breaking load and
> Metallurgical analysis of an intact heat-affected sample to assess any impacts on the conductor that may have changed its mechanical or electrical properties, or may have resulted in loss of remaining life (such as loss of grease and galvanising).

Testing of conductor samples from line 993 found that the failure of the conductor was due to exposure to elevated temperatures in the range of 420-660°C, with indication that the steel core has had a reduction in strength due to exposure to heat[11]. This heat led to the galvanising layer on the steel core melting, the molten

[9] Set out in Asset Management Instruction TLC-2020-002.
[10] Set out in Internal Works Request N2270 Rev 2.
[11] ALS Industrial Report TG-2987060-01, issued 24/01/2020.

zinc then penetrated cracks which formed within the steel core. This is known as Liquid Metal Embrittlement which has contributed to the failure of the conductor during the bushfire[12].

Line U3 span 11 (red phase) was found on the ground surrounded by melted metal. Several samples were taken from Line U3, including the two phases on the span which did not fall. The tests of Line U3 conductor included:

- Determine conductor-break failure mode through metallurgical inspection
- damaged but not broken conductor from each phase, and a sample of intact conductor from each phase: Tensile test of intact heat-affected sample to determine breaking load and metallurgical analysis of intact heat affected sample to assess any impacts on the conductor that may have changed its mechanical or electrical properties, or may result in loss of remaining life
- mid-span joint for testing
- a sample of intact conductor and dead-end for testing.

The analysis found that the microstructure of the aluminium had transformed due to the bushfire heat, resulting in a significant reduction in mechanical properties leading to failure of the aluminium strands. Even at a distance from the failure location, the conductor suffered a reduction in mechanical properties due to exposure to the heat from the bushfires[13]. Thus even minor visual damage to the aluminium strands indicates a reduction of strength of the conductor. This type of conductor is all aluminium alloy, and does not contain any steel core, relying only on the aluminium for its strength.

Line 2 was observed to have blackened conductor. The tests of Line 2 conductor were to include:

- Jumpers on outside phases at tension structures where insulator replacements are occurring
- Tensile test of sample to determine breaking load and metallurgical analysis of intact heat-affected sample to assess any impacts on the conductor that may have changed its mechanical or electrical properties, or may result in loss of remaining life

The results of the Line 2 analysis determined that the outer aluminium that was blackened, and also had some slight wire loosening, did suffer a reduction in tensile strength and breaking load[14]. The sample with no blackening had no reduction in strength. The impact overall was considered relatively minor with the overall conductor suitable, and therefore conductors with only minor damage and loose strands have not been included for remediation.

A jumper sample was also recovered from a bushfire affected area of Line 3. The sample had blackening and some very minor melting on aluminium. The testing found that the outer aluminium strands in the damaged regions had a slightly lower tensile strength than the non-damaged area of the sample[15]. Overall, it was not possible to draw any conclusions other than the blackening of the conductor did not appear to be related to mechanical degradation of the conductor. Thus conductors which only exhibit blackening have not been included for remediation.

A conductor sample was also taken from TL 966 bushfire zone. Reduction in the properties of the outer aluminium strands were noted, however not sufficient to compromise the overall conductor in the short term[16].

5.1.1.3 Insulator testing

Numerous insulators were significantly damaged by fires in the Snowy Mountains region, the integrity of the remaining insulators to perform their function required assessment. Recovered intact discs were tested as follows:

[12] ALS Industrial Report TG-2987060-02, issued 21/02/2020.

[13] ALS Industrial Report TG-PW123933-01, issued 30/06/2020.

[14] ALS Industrial Report TG-PW126274-02, issued 23/09/2020.

[15] ALS Industrial Report TG-PW122348-01, issued 25/06/2020.

[16] ALS Industrial Report TG-PW126274-01, issued 18/09/2020.

- Line 02 recovered intact insulator discs: tensile testing to determine failing load, compare to rated failing load and broken disc tested failing load
- Line U3 Structure 11 red-phase, a single disc: tensile testing to determine failing load, compare to rated failing load
- Insulator electrical testing.

Mechanical testing found that intact discs passed the tensile load tests. Discs which were damaged failed slightly below their rating[17]. Recovered intact and damaged insulators were also sent to the manufacturer (NGK Japan) for mechanical and electrical testing of the discs to the relevant IEC standards. No issues were identified for the remaining intact insulators on the network that are attributable to bushfire damage[18].

5.1.1.4 Tower metallurgical testing

Fire activity which has caused damage to conductors and insulators was potentially hot enough to change the metallurgical properties of tower steelwork, reducing the strength of the towers substantially. Some towers were noted as heavily blackened. It was unclear if they had been compromised. Some members were also bent. It was unclear if this was due to the fire.

A metallurgist was arranged to visit towers in the Snowy region to perform non-destructive testing and assess potential loss of steel strength and damage to galvanising for the following lines:

- Line 2 – Six accessible structures
- Line U3 – Three structures
- Line 993 – Steel poles that were exposed to fire.

Due to limited availability to safe access, the inspection covered eight structures on Line U3, four structures on Line 2, and two structures on Line 993. Among the structures inspected, slight deformation/bending was found in some members of structure No. 43 (Line 2), and one member in structure No. 11 (Line U3). None of these bent members were in the most heat-affected regions (Legs A/B), indicating that the fire was not the main factor for the deformation. No bent members have been included in the scope of this pass-through application.

The galvanised coating appeared to have blistering and surface runs in some areas of members. Among the inspected structure, one member in Line U3 structure 13 appeared to have a significant flaking defects which may be the result of exposure to recent fires.[19]. Overall, the inspection identified that the steelwork was not affected by the bushfires to the extent that structural integrity was at all compromised. The only issue attributable to the fires is the flaking galvanising, which does not require a short term response.

[17] ALS Industrial Report TG-2989187-07, issued 06/05/2020.

[18] NGK Japan Technical Note (Draft), issued 28/09/2020.

[19] ALS Industrial Report TG-2987388-01, issued 12/02/2020.

Figure 26 – Tower gusset plate with blackened appearance on Line 2

Figure 27 – Flaking of galvanising on the surface of a structure on Line U3

Figure 28 – Representative view of steel pole structure on Line 993

5.1.2 Detailed inspections

5.1.2.1 LiDAR inspections

TransGrid undertakes LiDAR annually to assess vegetation clearances. This inspection was brought forward for the bushfire zones and additional analysis undertaken to assess the condition of the transmission line conductor (sag-tension comparison of data from pre fires compared to post fires) and to assess for material changes in ground clearances. Only the incremental cost to bring forward the bushfire zone inspections and perform the condition analysis has been included in this application.

LiDAR findings

The condition assessment has identified 21 lines with material discrepancies in conductor tension indicating that the conductor could be heat affected for a long enough duration to cause annealing.

5.1.2.2 Multi-spectral aerial inspection

Aerial inspection of transmission lines in fire zones was undertaken with combined photographic, infrared (thermographic) and UV (corona) assessment. These inspections were undertaken to identify issues caused by the bushfires which are outside of the visual spectrum. TransGrid utilised a technology which allowed this to occur in a single flight rather than multiple flights.

Multi-spectral inspection findings

The inspections identified 201 issues across all spectrums. Examples of the inspection results are shown in the figures below.

Figure 29 - Example UV (corona) inspection results

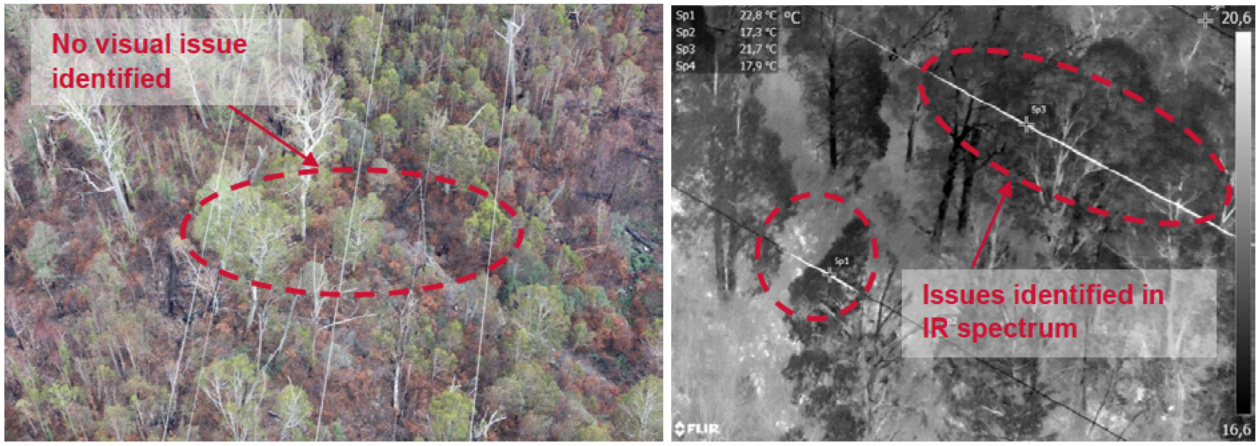

Figure 30 - Example IR (infrared) inspection results

5.1.2.3 Smart Aerial Image Processing (SAIP)

SAIP is an enhanced condition assessment technique that uses helicopter-mounted high-resolution cameras to capture a continuous stream of digital images of overhead conductors, which are processed and analysed using machine learning to detect and map defects. It is a very effective and efficient means of identifying defects which are hard to see unless close-up and most processing is done through the machine learning algorithms which identify anomalies.

TransGrid dispatched the SAIP inspections only in the Snowy Mountains region where the bushfires were most intense, and some conductor damage had already been reported. It was not dispatched to other bushfire regions as no conductor issues had been identified, avoiding unnecessary expenditure.

SAIP findings

The SAIP inspection was completed on 3 July 2020. There are 345 spans with defects and corresponding Work Orders logged against them due to bushfire damage from the 2019/20 bushfire season have been identified. Defects comprise of:

- OHEW damper damages
- Broken insulator discs
- Flashed insulators
- Blackened conductors.

SAIP was successful in identifying significant defects that were not picked up on the aerial inspections. No significant conductor damage was noted on [redacted] by the visual inspection from air; all bar [redacted] had defects identified in SAIP that require remediation in the short term.

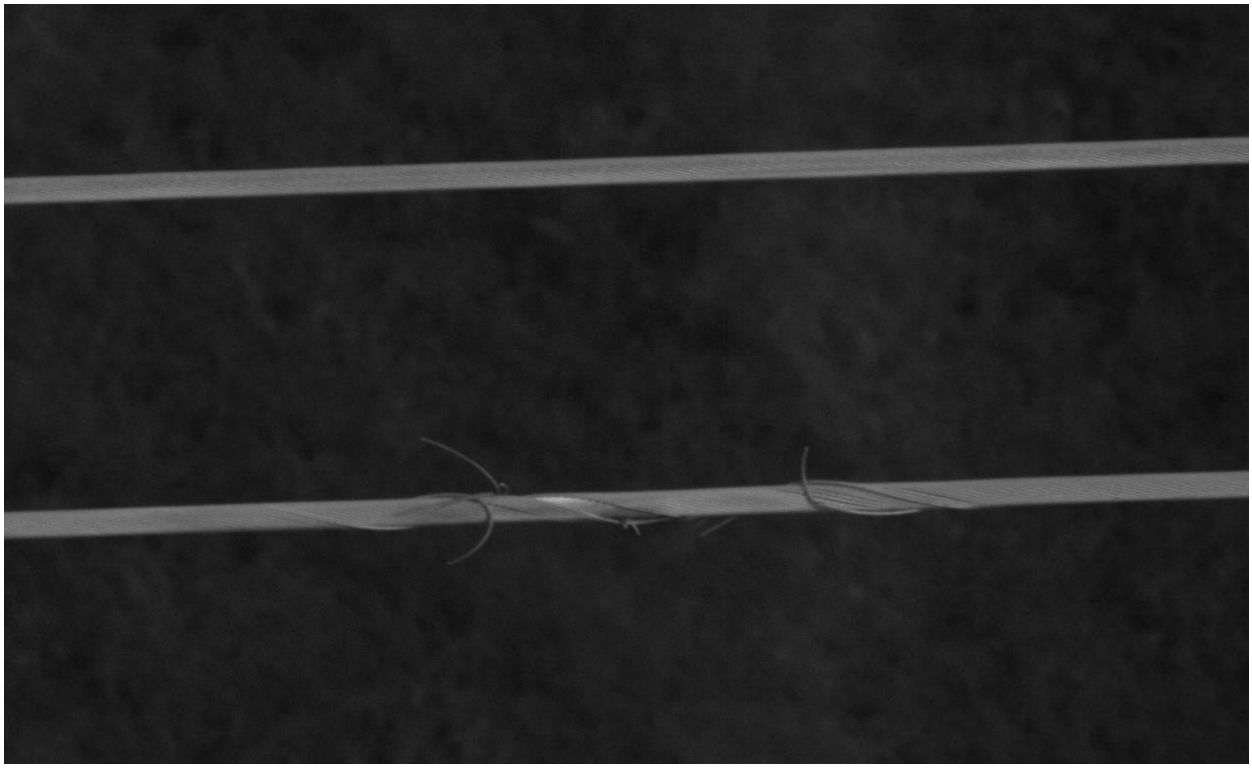

Figure 31 – SAIP Image on [redacted]. Initial visual inspection noted no significant conductor issues.

5.1.2.4 Conductor Sampling

The combined results of conductor sampling and testing are summarised in Section 5.1.1.2. Conductor that has visual damage to the aluminium is deemed to be compromised.

5.1.2.5 Porcelain Insulator testing

The combined results of insulator testing are summarised in Section 5.1.1.3. Only discs that are physically cracked or broken require replacement.

5.1.2.6 Wood pole inspections

After fire patrols and aerial inspections noted several wood pole structures with charred bases on Lines 933, 965, 96C, 96N and 96L, further assessment of the wood pole remaining capacity is required to determine if the charring has reduced the effective circumference of sound timber on the poles. The inspections to date indicate that the damage is not expected to require urgent intervention.

5.1.2.7 Composite insulator inspections

Drone inspections were taken on discoloured composite insulators on Line 967 burn zones. White discolouration (or chalking) is indicative of heat affecting the properties of the silicone. After consultation with manufacturers it was determined that there was no urgent damage. A sample of the insulators have been recovered to be sent for further testing to determine if there are any longer-term impacts or recommendations from the manufacturers.

5.2 Easements and Access Tracks

5.2.1 Hazard tree inspections

The bushfires burnt out many tall trees at the edges of transmission line corridors. These trees are now at risk of failure due to the fire damage and they could impact the transmission line if they fall. These trees are being inspected by qualified arborists and being identified for removal or management where their condition warrants[20].

The hazard tree inspection program is continuing.

Hazard tree inspection findings

Whilst it has been difficult to access heavily burnt areas, evidence of the trees assessed indicates fire had compromised their structural integrity. Trees were burnt beyond their capacity to remain structurally sound, with fire further hollowing major limbs, stems, structural roots, and live tissue, to the point that failure is likely.

The intense fires incinerated soil-protecting leaf litter, vegetative debris, live understory and tree canopy all of which protect and provide essential nutrients to the trees and soil biota. This will continue to impact on tree stability and structural integrity well into the future.

The fires followed by heavy, consistent rain events has resulted in significant access constraints, limiting the ability to conduct tree assessments. Also, due to on-going weather conditions and changes in growing environment, trees will continue to fail, presenting challenging situation and ongoing assessments. In response, a detailed reassessment is recommended during the management of the identified hazard trees.

Approximately 17,700 hazard trees were impacted by the bushfires and required inspection. By September 2020, 80% of impacted spans had been inspected. Approximately 14% of the impacted hazard trees require management to limit the risk to the TransGrid's electricity network, in addition to the quantity normally managed through TransGrid's routine hazard trees maintenance program.

5.2.2 Access tracks

Many access tracks were damaged or access cut-off due to changes to the landscape and debris as a result of the bushfires. The extensively changed environment continued to impact on access, resulting in significant soil erosion, tree failure, and in some instance exposing naturally occurring asbestos making the access tracks unsafe for operations.

Initial work involved, clearing fallen trees debris across, and hazard trees adjacent to access tracks, providing safe access for crews and allowing After Fire Patrol (AFP) inspections, infrastructure repairs and replacement work to take place. These initial access tracks clearance activities were performed against AFP inspections work orders. The majority of access restoration has been completed, however some outstanding work remains.

5.2.3 Routine vegetation maintenance

With much of the landscape burnt, sections of transmission line which have routine vegetation maintenance in 2019/20 and 2020/21 and overlap with these fire affected areas have avoided some maintenance costs, predominately in the Snowy Mountains region. Subsequent regrowth is unlikely to result in any further avoided costs. The pass-through application has been adjusted to take into account this avoided maintenance.

[20] Internal Works Request N2254

In some areas routine maintenance has seen an increase in cost as a result of the bushfires. This increase has not been included in the pass-through application.

5.3 Substations assets

An investigation scope was developed by TransGrid to verify the condition of assets that may be bushfire impacted. The following scope was issued:

> Substation sites with fire in close proximity – Lower Tumut and Upper Tumut.
  – Inspection of sites for heat and ash impact to HV equipment and local infrastructure.
  – Draft reports identify no significant impact to HV assets or infrastructure.
> Inspections have been dispatched for possible bushfire affected sites (Lower and Upper Tumut) to report on asset condition. Selected assets have been identified for diagnostic testing including some circuit breakers, oil filled CTs and VT unbalance schemes.
  – Initial feedback on diagnostic testing results identify no detectable condition issues with HV assets.
> Urgent inspections of substations deemed likely to be impacted by pollution were dispatched.
  – Draft reports indicate that substantial rainfall since the bushfire events seems to have washed most sites resulted in reduced/negligible pollution-induced discharge activity.

5.4 Network Property Assets

An internal works request was raised to investigate the potential damage, note condition and rectify issues.

5.4.1 Substations and Microwave Repeater Sites

The following was performed at Upper Tumut Switching Station, Lower Tumut Switching Station, Bugong Gap RRS, Snubba RRS, Wereboldera RRS and Banyabba RRS:

> Building gutters - blockages, damage and debris. Drain and clean if required.
> Building Air Conditioning – Inspect for heat damage. Record Condition. Clean or replace filters.
> Buffer zone - Inspect for debris and damage. Record condition.
> Fences - Steel Fence member to be inspected for heat damage to members and galvanising. Inspection should start at areas closest to the fire zone and work outwards based on findings. Assess condition of any above ground earthing arrangements. Record condition.
> Fire Systems - Check for blockages, contamination and damage to VESDA systems. Update VESDA configuration to include 30 second delay before alarming. Remediate small defects where practicable, otherwise record condition.
> CCTV - Check operability. Record Condition.

5.4.2 VHF Repeater Sites

The following was performed at Kurrajong RRS, Nerriga RRS, Boyne RRS, Putty RRS, High Range RRS:

> General Site Inspection - Inspect Site. Confirm operation of apparatus. Visually inspect towers, noting any signs of heat damage. Perform Battery health assessment. Carry out minor maintenance tasks if required (clearing gutters, cleaning filters, cleaning solar panels). Record condition.

5.5 Digital Infrastructure Assets

An internal works request was raised to investigate the potential damage, note condition and rectify issues.

Communications and protection systems incorporated the following:

5.5.1 Substation and Microwave Repeater Sites

The following was performed at Upper Tumut Switching Station, Lower Tumut Switching Station, Bugong Gap RRS, Snubba RRS, Wereboldera RRS and Banyabba RRS

> Battery banks - Perform Discharge Tests on NiCad banks. Inspect and resistance check VLRA banks. Determine current health compared to most recent results

> Low Voltage Cabling and Waveguides – Inspect exposed for heat damage, as well as any other fittings (i.e. cable ties, glands, etc). Inspection should start at areas closest to the fire zone and work outwards based on findings. Record condition.

5.5.2 OPGW

Perform OTDR (Optical Time-Domain Reflectometer) testing on OPGW for Lines 2M, 76/77, 051, 07, 64, 65, 967, 964, 9W9.

6. Remediation Assessment

6.1 Assessment Approach

TransGrid manages and mitigates network safety risk to ensure they are below risk tolerance levels or 'As Low As Reasonably Practicable' ('ALARP'), in accordance with TransGrid's obligations under the New South Wales Electricity Supply (Safety and Network Management) Regulation 2014 and TransGrid's Electricity Network Safety Management System (ENSMS).[21] The proposed remediation will enable TransGrid to continue to manage and operate this part of the network to a safety and risk mitigation level of ALARP.

TransGrid's maintenance plans[22] identify the damage that is considered a defect requiring remediation and contains priorities to undertake the remediation. These maintenance plans have been audited by an independent third party under the direction of TransGrid's technical regulator (IPART) as part of ENSMS audits which confirm that TransGrid is managing network safety risk to ALARP. The damage caused by the bushfires has been assessed against these maintenance plans and the appropriate priority assigned to each issue.

The required remediation to reduce risk to ALARP is described below. Only items that meet ALARP are included. For example, there were several transmission line spans which had minor damage and currently pose minimal risk. Remediating these to pre-bushfire condition would be considered disproportionate under ALARP. TransGrid will monitor these issues during routine inspections and re-assess the condition and risk.

6.2 Conductor Damage

Heat from bushfires can impact conductors through various mechanisms including; annealing of the aluminium strands, loss of conductor grease and the loss of the galvanizing layer from the inner steel strands of Aluminium Conductor Steel Reinforced/Galvanised (ACSR/GZ) type conductors. Annealing and melting of zinc galvanising causing leading to Liquid Metal Embrittlement (LME) have the potential to immediately impact conductor performance through a reduction in tensile strength. Loss of conductor grease or loss of the galvanizing layer impact performance over the longer term through reduced corrosion performance.

The extent of annealing is dependent upon the exposure temperature and duration. Aluminium loses approximately 10% of its tensile strength at 210°C and then anneals rapidly at temperatures exceeding 340°C until it reaches its melting point at approx. 645°C[23]. It is generally accepted that temperatures exceeding 300°C will result in permanent reduction of tensile strength[24]. The steel core for ACSR/GZ conductor itself is generally not affected at these temperatures, however LME may occur should the zinc galvanising melt at temperatures above 420°C.

The loss of conductor grease is dependent upon the type of grease applied, specifically its thermal drop point and the temperature it is exposed to. The grease type can generally be classified into two categories; pre-1970 and post-1970. Pre-1970 typically used bituminous compounds that tend to drop at temperatures exceeding 70°C, while post-1970 grease typically drops at temperatures exceeding 180ºC.

In ACSR/GZ conductors the loss of the grease layer results in galvanic action between the zinc and aluminium, increasing the rate of zinc loss, this in turn leads to corrosion of the aluminium when directly exposed to the steel core. With all aluminium alloy-type conductors the loss of grease allows the ingress of

[21] TransGrid's ENSMS follows the International Organization for Standardization's ISO31000 risk management framework which requires following hierarchy of hazard mitigation approach

[22] Maintenance Plan – Transmission Line Assets, Maintenance Plan – Easements & Access Tracks, and Corrective Maintenance Process

[23] AS/NZS 7000:2016, Appendix AA

[24] "*Effect of Elevated Temperature Operation on the Tensile Strength of Overhead Conductors*", IEEE Transactions on Power Delivery, Vol. 11, No. 1, January 1996, pp 345-352)

pollutants that can also initiate corrosion. One of the visual indicators of possible grease drop is discolouration on the surface of the outer strands.

As with annealing and grease drop, the loss of the galvanizing layer due to melting of the zinc, is dependent upon the temperature. This typically occurs at temperatures exceeding 420°C. The loss of the zinc leads to the same aluminium corrosion as described above.

70°C - 180°C	300°C	420°C	645°C
•Conductor greese migrates or drops •Loss of corrosion protection	•Aluminium starts to anneal •Loss of conductor strength	•Zinc (galvanising) melts •Can lead to LME and loss of conductor steel core strength •Loss of corrosion protection	•Aluminium melts •Major loss of conductor strength

Figure 32 - Conductor damage progression

Extensive conductor damage had been identified in the Snowy Mountains region where the bushfires were most intense. There is evidence of conductor temperatures exceeding 645°C, with extensive conductor damage observed and what was molten aluminium on the ground below the conductor.

Figure 33 - Extensive conductor damage with melted aluminium

All Aluminium Alloy Conductor (AAAC) conductors are more susceptible to fire damage and is installed on the Snowy Mountains transmission lines in the higher altitude sections. They contain no steel core and rely solely on the aluminium for their mechanical and electrical properties. Several samples were taken from Line U3 on the two phases from the span which did not fall. Even at a distance from the failure location, the conductor suffered a reduction in mechanical properties due to exposure to the heat from the bushfires as described in Section 5.1.1.2. Even minor visual damage indicates that the aluminium of the conductor has been compromised. AAAC conductor identified in the SAIP inspection as "Multiple loose strands" or worse are proposed to be remediated as they are at risk of failure. Even if they have not yet failed, they may still fail under ultimate loading and short-circuit scenarios. AAAC identified as "loose strand minor" will be monitored.

ACSR conductor has a steel core which provides strength even if the aluminium is damaged, however this does not mean that damaged conductor can be left in-situ, as the un-wrapping or bird caging of the aluminium can change the conductor heat generation and dissipation characteristics and lead to localised overheating on the conductor leading to failure of the steel core.

There are also many conductor defects identified that will only be monitored and not remediated in the short term and monitored, such as blackening or discolouration of the conductor, which may require longer term remediation. This is illustrated in Figure 34. The extent of damage has been assessed from visual, multispectral and SAIP inspections as described in Section 5.1.

Priorities for remediation have been allocated in line with the maintenance plan, however, the extent of damage and outage constraints on key power transfer paths between Victoria, Snowy and NSW regions means it will take multiple years to remediate the damage. Remediation will be prioritised based on extent of the damage and criticality, and the condition will be monitored. Operational controls are being implemented for summer 2020-21 to monitor conductor temperatures to prevent asset failure. Further mitigations, such as de-rating transmission lines until the damage is remediated, may be required to manage short term risk of failure.

Figure 34 – [redacted]

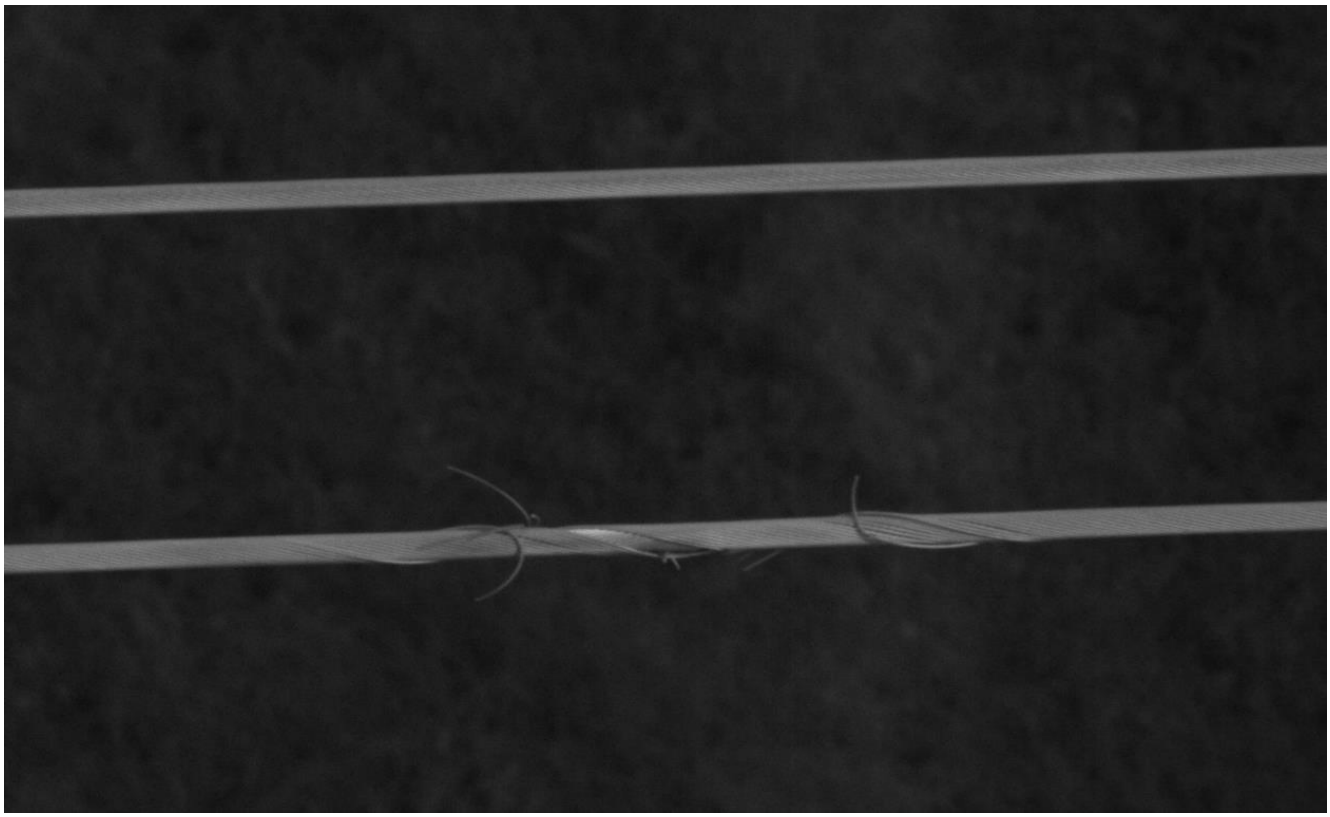

Figure 35 – Conductor damage example on ACSR conductor [redacted] identified in SAIP

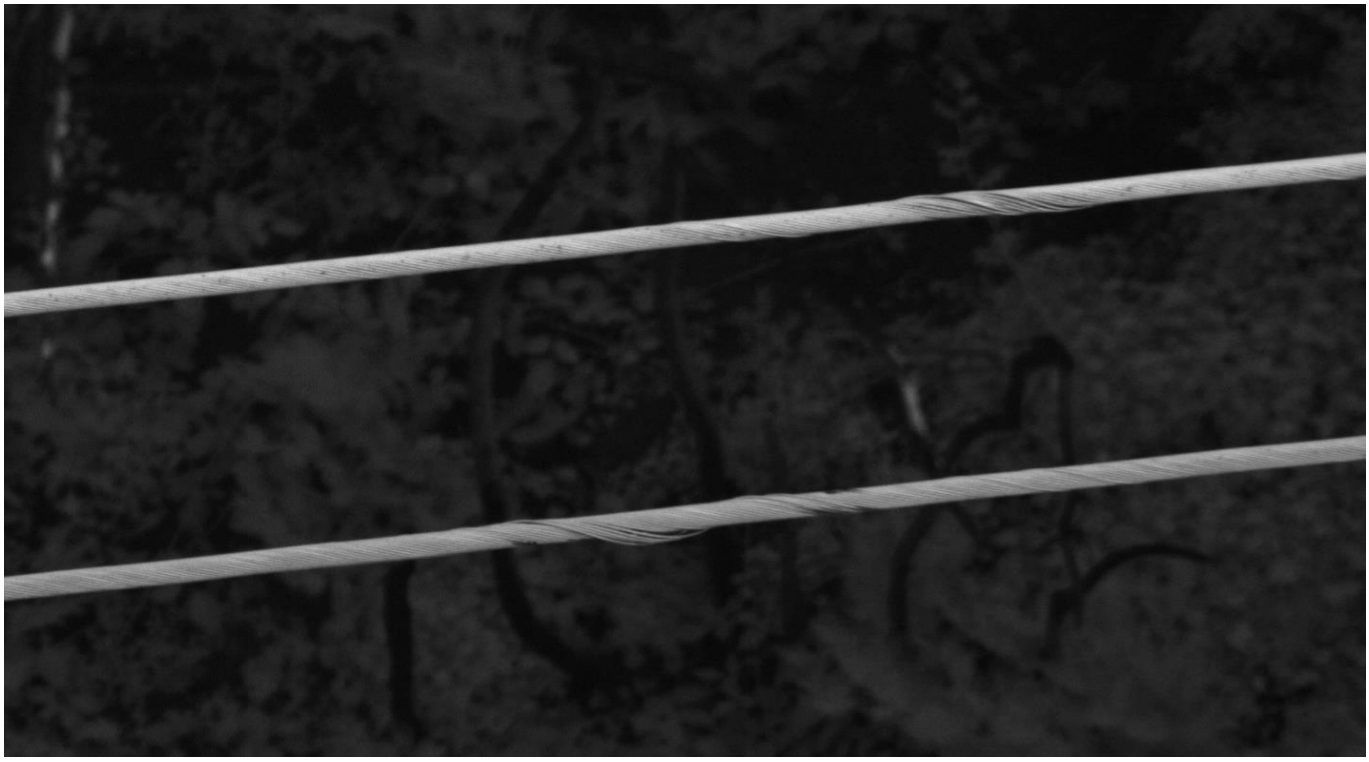

Figure 36 – Conductor damage example on ACSR conductor [redacted] identified in SAIP

Figure 37 – Conductor damage example on AAAC conductor [redacted] identified visually

Figure 38 - Conductor damage example of 'hot spots' [redacted] identified in multispectral (IR) inspection

6.2.1 Conductor Damage requiring remediation

In locations where the conductor did not mechanically fail inspections identified severe bird-caging, broken wires, loose and unwrapping of the outer strands, these are all visual indicators of possible annealing. These locations are summarised below.

It will not always be possible to just replace the damaged spans. Site constraints may require tension to tension restringing or additional spans either side of the damaged span.

6.2.1.1 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 2

Length of spans: 736.7 m

6.2.1.2 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 17 (24 equivalent, multiple phases damaged in some spans)

Length of spans: 7,364.9 m

6.2.1.3 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 14 (21 equivalent, multiple phases damaged in some spans)

Length of spans: 8,411.2 m

6.2.1.4 [redacted] 330 kV Line

Fires Name(s):

Number of spans: 4

Length of spans: 957 m

6.2.1.5 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 2

Length of spans: 763.6 m

6.2.1.6 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 5

Length of spans: 1912.1 m

6.2.1.7 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 1

Length of spans: 767.7 m

6.2.1.8 [redacted] 330 kV Line

Fires Name: Dunns Road

Number of spans: 1 Left and right conductors

Length of spans: 520.4 m

6.2.1.9 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 3

Length of spans: 819.3 m

6.2.1.10 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 2 (left and right phase conductors and EW in span 7)

Length of spans: 1113.7 m

6.2.2 Conductor Damage that TransGrid will monitor

As described above, the heat generated during bushfires can impact the longer-term performance of conductors, through the loss of tensile strength and reduced corrosion performance. The SAIP inspections identified locations where the conductor displayed individual loose strands and discolouration of the outer strands. These locations have been flagged for ongoing monitoring.

Locations with minor damage are not proposed to be monitored during routine inspections. As example of loose strands can be seen is Figure 39 and conductor discolouration in Figure 40.

Figure 39 – ASCR conductor damage – loose strands

Figure 40 – ASCR conductor damage – discolouration

6.2.2.1 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 7 (8 equivalent)

6.2.2.2 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 31 (33 equivalent)

6.2.2.3 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 5

6.2.2.4 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 1

6.2.2.5 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 2

6.2.2.6 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 7 (9 equivalent)

6.2.2.7 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 5 (6 equivalent)

6.2.2.8 [redacted] 330 kV Line

Fires Name(s): Dunns Road

Number of spans: 3

6.2.2.9 [redacted] kV Line

Fires Name(s): Dunns Road

Number of spans: 2

6.2.3 Conductors requiring further investigation

LiDAR inspections described in Section 5.1.2.1 have been used to compare the conductor tension before and after the bushfires as an efficient means of assessing conductor condition across the various bushfire impacted assets. In addition to the transmission line identified above, [redacted] have had material changes in conductor tension compared to pre-bushfires.

While there was no visible damaged reported which is likely from intense heat, annealing is a cumulative effect so it is possible that lower temperatures present for a longer duration may have changed the conductor

metallurgical properties without visible damage. These lines will need further investigation to determine if there is indeed any damage and the extent of it. No allowance has been forecast for conductor investigations or remediation in the pass-through application on these lines.

6.3 Wood Pole Damage

Timber poles being combustible are susceptible to fires. TransGrid uses hardwood poles, which require more energy to burn out compared to soft wood poles. There is no evidence to suggest that pole damage is exacerbated by fuel loads. TransGrid history of pole failures caused by fire is often in grass fields. The extent of wood pole damage is shown in Figure 41.

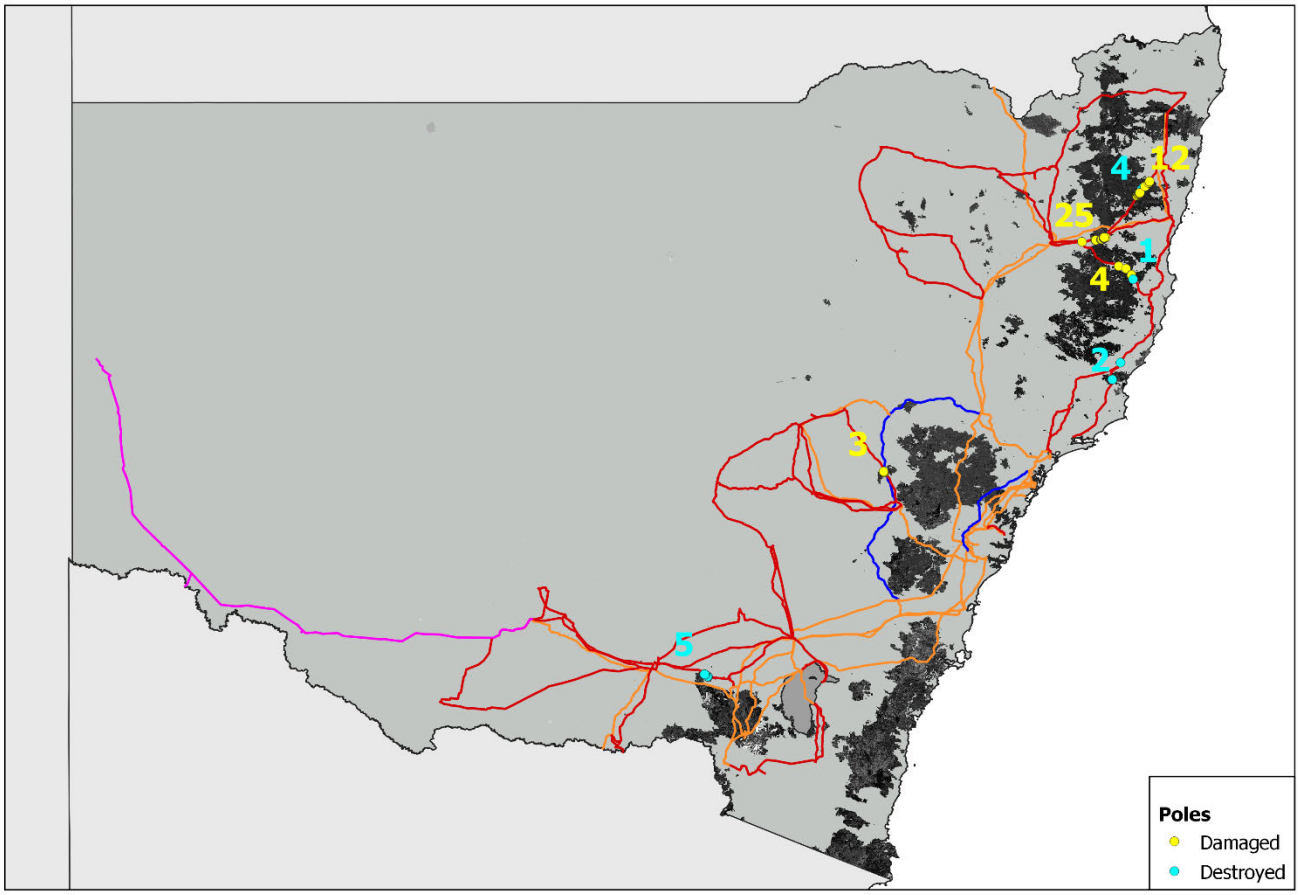

Figure 41 - Wood pole damage

6.3.1 Line 966 – Armidale to Koolkhan 132 kV

Fires Name: Guyra Rd, Andersons Creek, Liberation Trail Fire

As noted in Section 4.2.2.2 six wood pole structures required pole replacements in order to make the line serviceable.

A further 11 structures have been noted as “base of structure burnt” for detailed inspections to determine long term serviceability.

6.3.2 Line 963 – Tomago to Taree 132 kV

Fires Name(s): Hillville fire

As noted in Section 4.2.2.1 one wood pole structures required pole replacements in order to make the line serviceable.

A further 8 structures have been noted as “base of structure burnt” for detailed inspections to determine long term serviceability.

Figure 42 - Example burnt wood poles

6.3.3 Line 965 – Armidale to Kempsey 132 kV

Fires Name(s): Warm Crossing, Carrai Creek and Carri East

As noted in Section 4.2.2.3, one structure required pole replacement as a high priority after the event. Further inspections from air identified 21 structures noted as “base of structure burnt”.

6.3.4 Line 96C – Armidale – Coffs Harbour

Fires Name(s): Guyra Rd, Andersons Creek

20 structures have been noted as “base of structure burnt” for detailed inspections to determine long term serviceability.

6.3.5 Line 96N – Armidale – Inverell

Fires Name(s): Guyra Rd

Four structures have been noted as “base of structure burnt” for detailed inspections to determine long term serviceability.

6.3.6 Line 96L – Tenterfield – Lismore

Fires Name(s): Long Gully Road Fire and Bruxner Highway

Six structures have been noted as “base of structure burnt” for detailed inspections to determine long term serviceability.

6.4 Melted Spiral Vibration Dampers

Spiral vibration dampers are made of PVC. They are installed on earthwires and OPGW with a diameter less than 19 mm. Vibration dampers reduce Aeolian vibration. Aeolian vibration can lead to fatigue wear on fittings and failure of the earthwire.

Figure 43 – Spiral vibration dampers – good condition

The melting point of PVC vibration dampers is approximately 100 °C to 150 °C, depending on mixture of the material. This can make them especially prone to bushfires. Damage to these vibration dampers were widespread.

For defects on earthwire dampers TransGrid states a one-year (P4) remediation and three months (P3) in the case of OPGW, due to the potential for fibre damage. The extent of damage for spiral dampers was widespread.

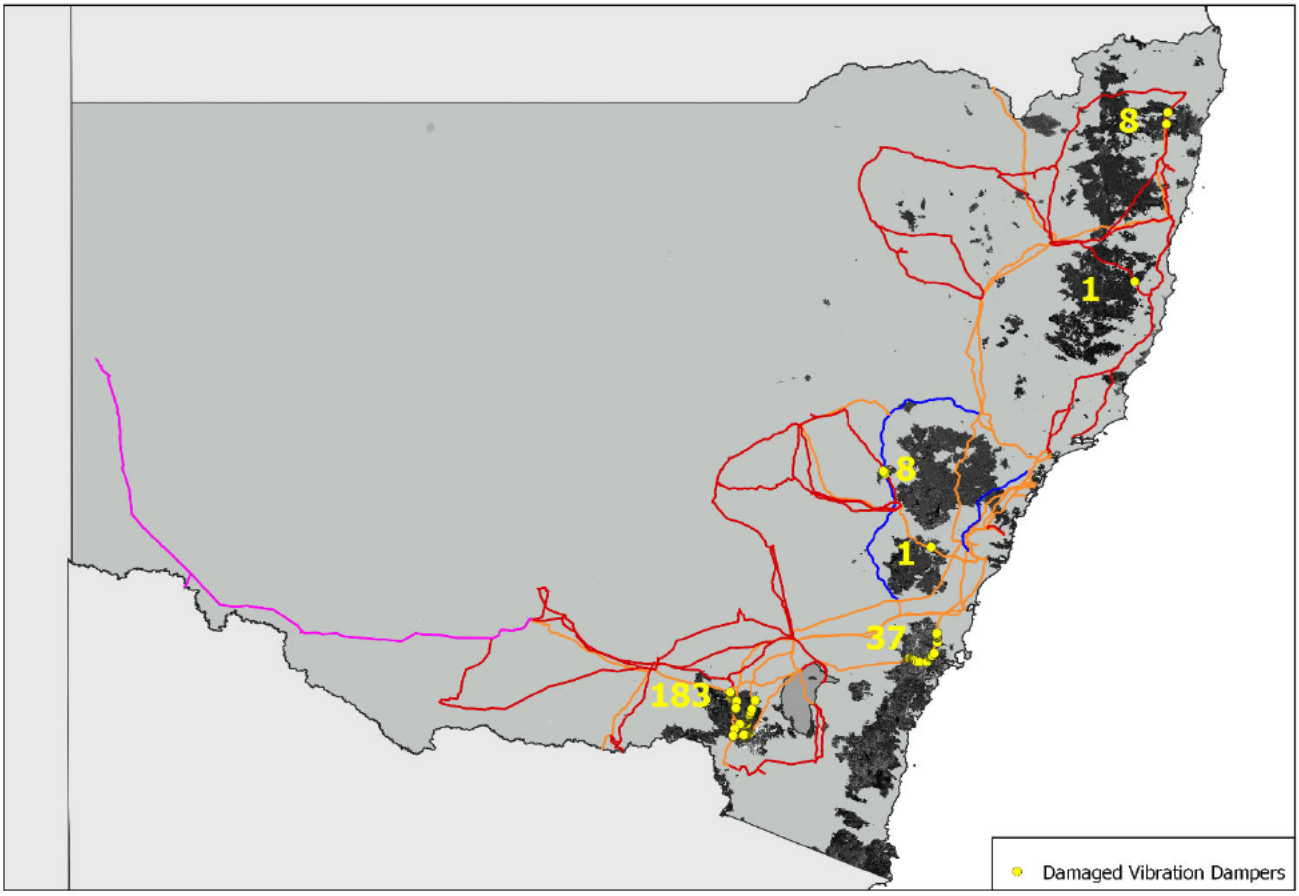

Figure 44 – Map of melted vibration damper defects

Table 1 – Vibration Damper Breakdown

Line	Line Description	Spans with melted dampers
5A3/5A5	Wollar - Mt Piper	4
76/77	Wallerawang – Ingleburn	1
89	Coffs Harbour – Lismore	3
01	Upper Tumut – Canberra	5
2	Upper Tumut – Yass	62
3	Lower Tumut – Yass	25
7	Lower Tumut – Canberra	12
U1	Upper Tumut – Tumut 1	16
U3	Upper Tumut – Tumut 1	9
U5	Upper Tumut – Tumut 2	8

Line	Line Description	Spans with melted dampers
U7	Upper Tumut – Tumut 2	9
64	Upper Tumut – Lower Tumut	10
65	Murray – Upper Tumut	4
66	Murray – Lower Tumut	10
3W	Capital Wind Farm – Kangaroo Valley	37
94M	Mt Piper – Beryl	4
965	Armidale – Kempsey	1
966	Armidale – Koolkhan	1
967	Koolkhan – Lismore	9

Where efficient, vibration damper replacements have been excluded from the listing in this table and included in the conductor remediation scope.

Figure 45 – Melted spiral vibration dampers

6.5 Aerial Marker Ball Damage

TransGrid has aerial marker balls for two purposes. On spans above 90 metres in accordance with AS 3891.1-2008 and where elsewhere required to maintain public safety and compliance with the requirements of AS 3891.2-2018 *Cables and their supporting structures - Marking and safety requirements - Low level aviation operations.*

Three spans were identified with melted aerial markers (refer Figure 46). Two spans were on Line 3W Capital to Kangaroo Valley (refer Figure 47) are installed for low level operation safety. One span, on Line 64 (refer Figure 48), is installed due to the 90 m requirement. This is significant due to the distance of the ball from the ground to be engulffed with enough heat to cause damage.

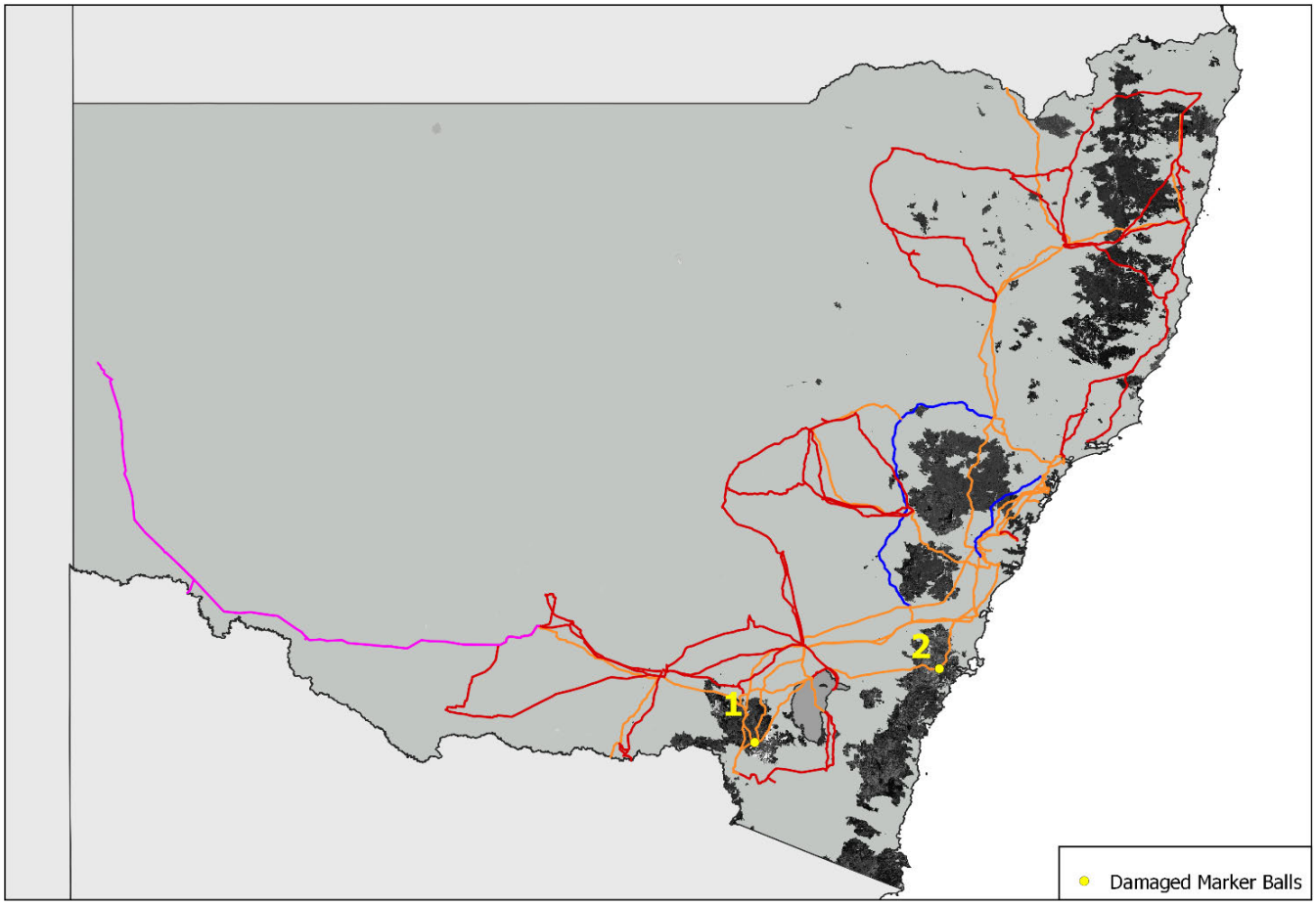

Figure 46 – Map of melted marker ball defects

Figure 47 – Melted aerial marker Line 3W

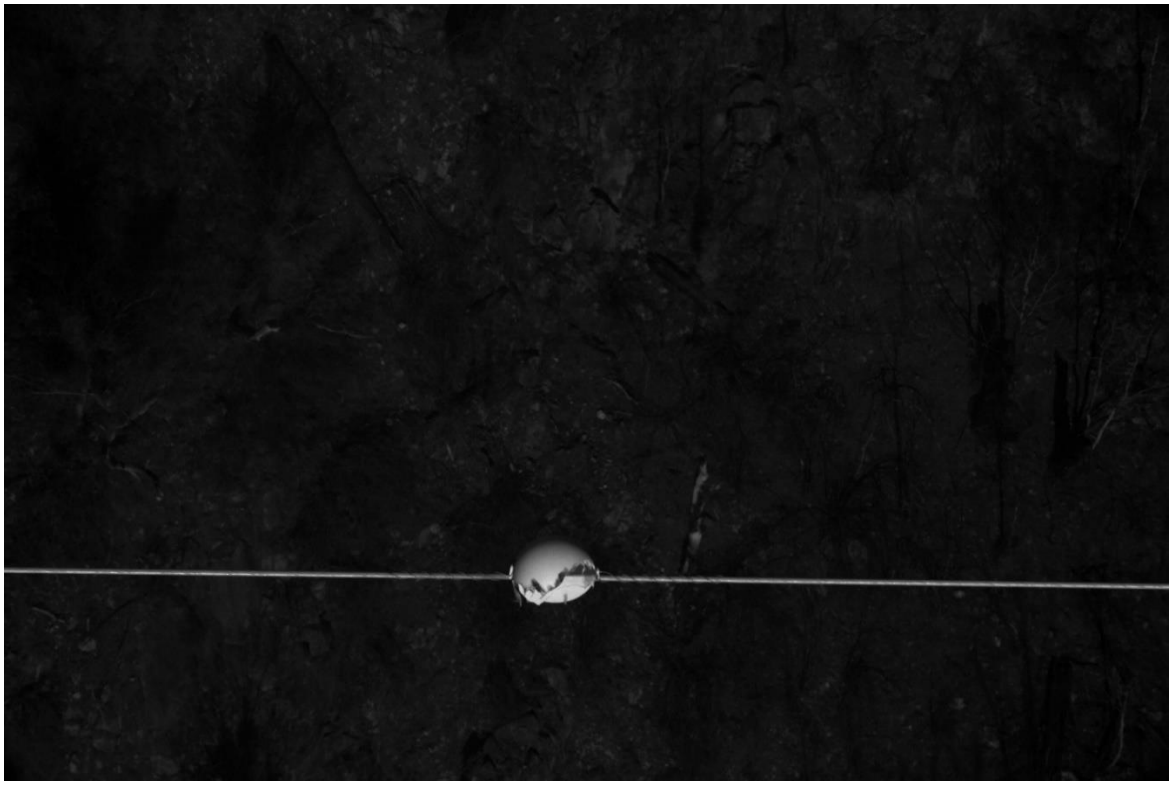

Figure 48 – Melted aerial marker Line 64

6.6 Composite Insulator Damage

There were no permanent fault outages that could be attributed failed composite insulators. There were a small number (three structures) of composite insulators on Line 967 that were identified with minor chalking or discolouration which is indicative of heat damage to the silicone sheds. An example of this is shown in Figure 49. This does not present an immediate risk, but may lead to deterioration of the insulation properties and require replacement at a later date, pending the outcomes of further testing as described in Section 5.1.2.7. No allowance for replacement of these insulators has been included in the pass-through application.

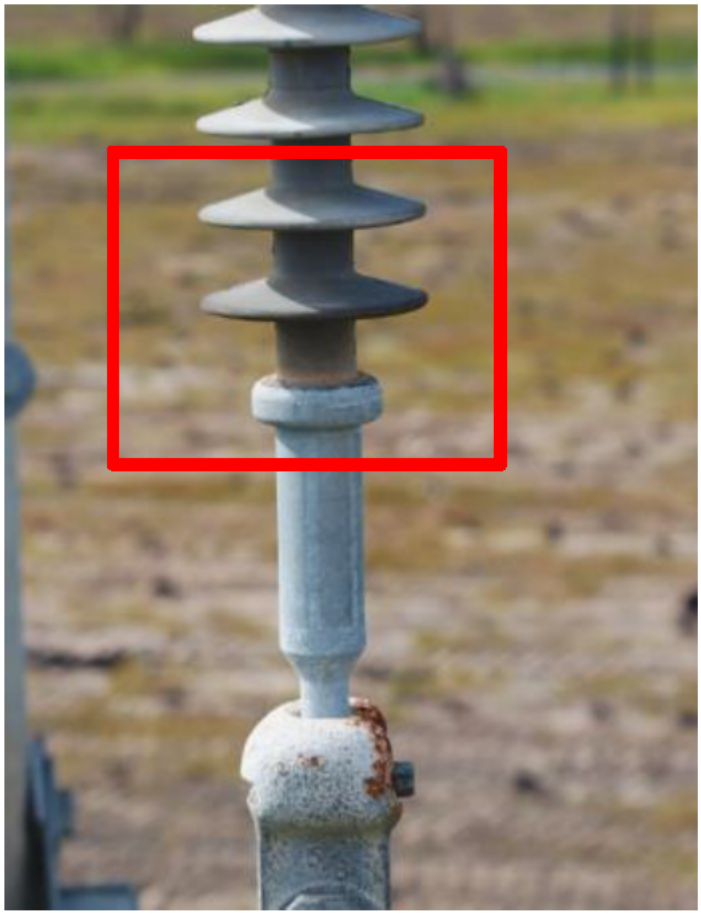

Figure 49 – Possible damaged composite insulators

6.7 Disc Insulators Damage

As described in in 4.2.1.2 Line 2 suffered multiple areas of damaged insulators. The extreme heat and energy released from the flashovers resulted in many discs being damaged. Testing has shown that unless the discs are visibly damaged, damage from the bushfires is unlikely as described in Section 5.1.1.3. All disc insulators that were broken in the fire are required to be replaced. Any pre-bushfire flashed, broken or cracked discs have not been included in the pass-through application.

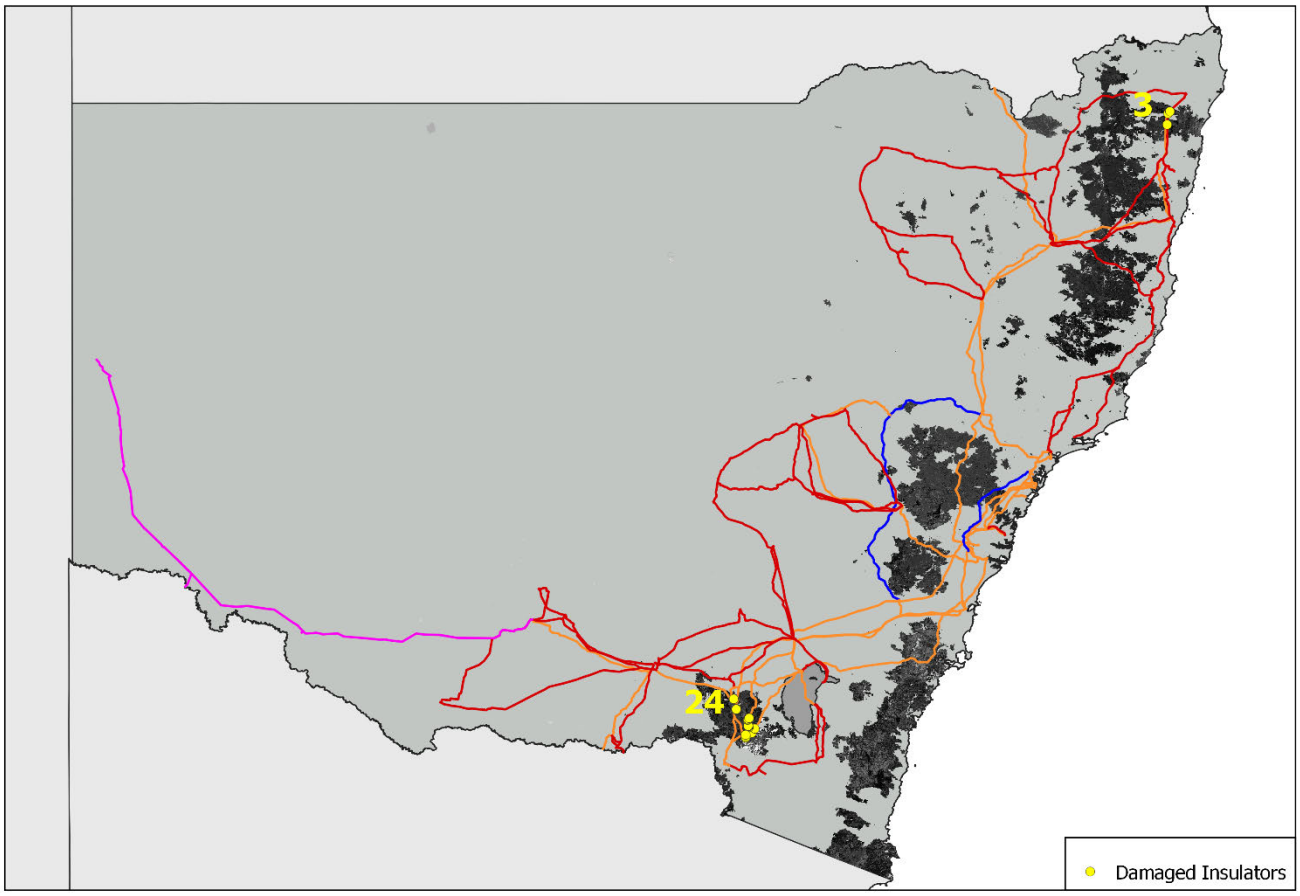

Figure 50 – Insulator damage

6.8 Pollution on insulators

Insulator washing was considered and deemed not necessary as described in Section 4.2.3. Extensive rainfall across the state in February resulted in sufficient washing of insulator pollution with reports from site inspections identifying discharge activity was back at normal levels.

6.9 Hazard Trees and Access Tracks

Access tracks repairs and hazard trees over the access tracks were managed under easement and access track after fire patrol works. Access track work on 830 km of track is required to restore access to the transmission lines.

Hazard trees impacting the transmission line still pose a threat and will require progressive works on a risk basis over 2020/21 and 2021/22. Based on works completed to date 14% of trees inspected requiring removal has been used, which is in addition to the 7.5% of hazard trees that TransGrid would be managing anyway had the fires not occurred.

The quantity of hazard trees inspected by qualified arborists and estimated to require management are summarised below.

Table 2 – Hazard Trees Inspected and Requiring Management

Transmission Line	Quantity of Hazard Trees impacted by bushfires	Actuals & estimated hazard trees requiring management
5A1/5A2	10	1
31/32	299	42
76/77	1173	164
5A3/5A4	26	4
5A3/5A5	57	8
5A6/5A7	26	4
76/77	45	6
5A1/5A2	79	11
5A3/5A4	8	1
22	29	4
25/26	0	0
31/32	319	45
87	394	55
96C	274	38
96L	990	139
89	703	98
963	720	101
964	34	5
965	991	139
966	2600	364
967	320	45
51	239	33
2	477	67
3	171	24
7	0	0
U1	125	18
U3	18	3
U5	192	27
U7	1465	205

Transmission Line	Quantity of Hazard Trees impacted by bushfires	Actuals & estimated hazard trees requiring management
3W	340	48
39	514	72
L1	0	0
L3	0	0
L5	0	0
YY	11	2
97D	152	21
978	22	3
64	1283	180
65	1286	180
66	2017	282
993	112	16
1	196	27

6.10 Substation Asset Impacts

Reports from site inspections for ash and fire-related impacts to substations showed no outstanding issues/activity and only a small number of indications of arcing activity that may have previously been active.

Significant rainfall was experienced in February across most of the state and is expected to have washed ash off insulators and eliminated any arcing activity.

CVT unbalance testing is complete without any issues identified.

Four of the five CBs identified for inspection and diagnostic testing have been completed. Reports on condition are yet to be finalised, however draft reports indicate no significant condition issues have been identified.

Maintenance and condition reporting of A Bus 1-2 Section CB 5102 at Upper Tumut Switching Station is not yet completed due to network access constraints.

6.11 Network Property Impacts

Minor damage exists for network property that required remediation:

> Boyne RRS fence earth wires damaged
> Lower Tumut Switching Station build-up of smoke/soot within the VESDA units and pipes, with the failure of one unit. Pipework filled with smoke. This VESDA is at end of life, replacement has not been included in this pass-through application. It will instead be included in the capital program;
> Snubba RRS waterproofing membrane was peeling in several areas and is now remediated. Fire damaged air conditioning was remediated as part of the response detailed in Section 4.6.1
> Upper Tumut Switching Station one VESDA unit failed, with smoke and soot build-up within the VESDA units and pipes.

6.12 Digital Infrastructure Asset Impacts

Minor impacts to Digital Infrastructure Assets that required remediation:

> Failed cell at Nerriga replaced
> Snubba RRS, several batteries failed test, bushfire exacerbated
> Line 07 OPGW open fibre on one core with no remediation proposed.

7. Asset strategy implications

This pass-through application is a “restore to normal” approach where required to manage risk to ALARP. There is however damage with longer term implications on the assets which may need rectification in the future. It is important to note that not all assets impacted from these fires are being replaced or repaired. The details of assets impacted requiring monitoring for possible future action are noted below.

7.1 Impact on wood poles

Numerous wood poles have been burnt which may impact their serviceability into the future and/or reduced their remaining service life. These wood pole structures may require replacement as part of future replacement capital expenditure programs.

7.2 Impact on conductors

As described in Section 6.2, the heat generated during bushfires can impact the longer term performance of conductors, through the loss of tensile strength and reduced corrosion performance. The SAIP inspections identified locations where the conductor displayed individual loose strands and discolouration of the outer strands. LiDAR inspections identified lines with material changes in conductor tension. These locations have been flagged for ongoing monitoring. No allowance is requested for these spans at this stage, but replacement may be proposed in future revenue proposals.

AAAC conductor also fared significantly worse than ACSR conductor due to bushfires. Future strategy will consider the replacement of legacy AAAC conductor with ACSR conductor.

7.3 Impact on climbing deterrents and warning signage

It is expected that tower climbing deterrents and warning signage has been extensively damaged but have not yet been assessed in detail yet. While they do not affect the integrity of the transmission line, they are required for ongoing public safety. The remediation of these may be included in future revenue proposals.

7.4 Impact on underground cables

Small sections of 11 kV underground cables were impacted by bushfire near Talbingo. The fires may have significantly reduced the remaining life of these cables and replacement may be included in future revenue proposals.

7.5 Impact on circuit breakers

The large amount of fault operations could have caused accelerated aging. No circuit breaker replacements have been included in this pass-through application. When identified through future routine inspections that condition requires replacement, the associated circuit breakers will be included in the circuit breaker asset replacement strategy capital program and the residual value written off.

7.6 Network resilience

The NSW Bushfire Inquiry final report widely acknowledged that maintaining electricity supply is crucial in ensuring other critical infrastructure continues to operate during bushfires. AEMO have also highlighted the need for continued action to improve power system resilience in their review of the 2019/20 summer[25].

In regards to network resilience, the Inquiry heard that the QNI 330kV transmission line is made up of timber power poles and stated *"The QNI is a vital asset and should be made more resilient through the replacement of the timber poles with suitable alternatives that are more fire resistant."* This statement reinforces the upcoming Line 86 (from Tamworth to Armidale) replacement justification included in the 2018-23 regulatory proposal. The business case for this project is being re-evaluated considering the Inquiry's statement.

Investment to create a more reliable network during a bushfire is desirable, however the commensurate charge to consumers required to do this to a level that can withstand low likelihood, but high consequence events must be considered.

TransGrid will be developing a network resilience program that it believes achieves the right balance of these considerations in the next regulatory proposal.

[25] AEMO 2019-20 NEM Summer Operations Review Report, June 2020