

Penrose substation fire 5 October 2014

Report on the inquiry conducted by the
Electricity Authority under section 18 of the
Electricity Industry Act 2010

20 November 2015



Version control

Version	Date amended	Comments
1.0	6 October 2015	Consultation draft for Vector, Transpower and NZFS feedback
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3.0	20 November 2015	Final version



Inquiry into the Penrose substation fire and power outage 5-7 October 2014

Section 18(1) of the Electricity Industry Act 2010 (the Act) provides that on written request by the Minister of Energy and Resources (the Minister), the Electricity Authority (the Authority) must review and report on any matter relating to the electricity industry that is specified by the Minister.

On 7 October 2014, the Minister wrote to the Authority requesting under section 18 that the Authority undertake an inquiry into the Penrose substation fire that occurred on 5 October 2014. The fire severely damaged electricity supply equipment at Penrose substation and caused a significant power outage that left some Auckland customers without electricity for more than two days.

This report (referred to as the Authority report) is the Authority's response to the Minister's request.

1 Executive summary

The impact of the Penrose fire on customers was significant

- 1.1 In the early hours of Sunday 5 October 2014, a fire was identified at Transpower New Zealand Limited's (Transpower's) Penrose substation. The fire resulted in a major outage to electricity supplies in parts of Auckland.¹
- 1.2 The fire was caused by the electrical failure of a cable joint in a medium voltage power cable owned by Vector Limited (Vector). The fire led to a widespread loss of supply due to the location of the cable joint within an in-air² cable trench containing a total of 3.99 km³ of power cables in 38 separate lengths (including 19 high-voltage cable circuits, 15 cable joints and a number of control cables).⁴
- 1.3 The power cables in the cable trench directly supplied over 39,000 electricity customers in Auckland. However, a total of 75,339 customers were affected by the fire because further electrical circuits had to be switched off to enable access for firefighting personnel. Electricity was progressively restored throughout Sunday and Monday and supply was restored to the final customers on the afternoon of Tuesday 7 October 2014.
- 1.4 The response of the New Zealand Fire Service (NZFS), and of Vector and Transpower personnel, was successful in bringing the fire under control and significantly limiting the potential consequences.⁵ The fire had the potential to cause much wider damage and disruption to power supplies than in fact occurred.
- 1.5 The Authority's estimate of the economic cost to customers due to the loss of supply is between \$47 million and \$72 million.⁶

The Minister requested this inquiry under section 18 of the Act

- 1.6 The Hon Simon Bridges, Minister of Energy and Resources, noted the significance of the loss of supply in terms of disruption and cost and requested that the Authority carry out an inquiry into the outage. Specifically, the Minister asked the Authority to address the following questions:
 - a) What caused the loss of supply or contributed to it, including potentially systemic factors such as risk management systems, asset health monitoring

¹ Abbreviated terms are defined when first used. Section 12 provides a glossary of terms.

² The term 'in-air' is used in this report to mean that the cable trench was not backfilled with solid material; the cables were accordingly laid 'in-air'. Figure 4 shows a cross-section of the cable trench and its contents.

³ Vector and its cable expert, Cable Consulting International, have stated different trench cable km over the course of the inquiry. The 3.99 km is the latest length that has been advised by Vector and is the length given in the final report from CCI

⁴ One cable was not in use making 19 operational power circuits. The combined length of all of the operational power cables was 3.885 km.

⁵ Vector was not involved in the management of the substation site during the fire but did provide assistance in undertaking distribution network switching and control.

⁶ This estimate is based on the Value of Lost Load (VoLL) which is a survey-based estimate of electricity users' willingness to pay to avoid an outage. The analysis supporting the estimate is included in section 8.

and maintenance practices, network design and regulatory incentives and controls?

- b) What fire hazard mitigation systems were in place; and did they operate as intended?
 - c) What actions were taken during the course of the outage in respect of:
 - (i) ensuring the safety of people and equipment?
 - (ii) communicating with affected and interested parties (including emergency services) about the impact of the event and timeframes for restoration of supply?
 - (iii) mitigating the loss of supply and expediting restoration?
 - d) What the estimated economic impact of the outage was on customers?
 - e) What actions will be taken or are recommended, as a result of the outage and subsequent investigations, to improve the resilience of power supplies and management of outages?
- 1.7 The Minister made his request under section 18 of the Act.
- 1.8 During the course of the inquiry, the Authority worked with the parties involved to answer the Minister's questions.
- 1.9 Vector and Transpower announced a joint investigation into the fire on 8 October 2014. The Authority's inquiry commenced on the same date.⁷ The Authority worked closely with Vector and Transpower and drew on the information and analysis provided in their joint investigation report.⁸ The Authority also drew on the findings of independent experts engaged by Vector and Transpower.
- 1.10 Vector and Transpower gave the Authority a draft report of their findings on 24 July 2015, and a final version of the report on 5 November 2015. In addition, Vector provided the Authority with a final draft report on the findings of Cable Consulting International Limited (CCI) on 26 August 2015, and provided the final version on 5 November 2015.⁹ The Authority received a final version of the NZFS Fire Investigation Report on 20 August 2015.

The inquiry considered a range of information

- 1.11 Establishing exactly how the fire started and the sequence of events that followed required technically specialised and complex work, particularly given the extent of the fire damage. The Authority's inquiry drew from, and relied on, a significant

⁷ This report refers to the 'Vector/Transpower joint investigation' as 'the investigation'. The Authority's inquiry is referred to as 'the inquiry'.

⁸ Transpower New Zealand Limited and Vector Limited, *Penrose Substation Fire – 05 October 2014 – Investigation Report*, the final version of which was undated, provided to the Authority on 5 November 2015. The joint Vector/Transpower investigation report is referred to as 'the Vector and Transpower report'.

⁹ Cable Consulting Limited, *Investigation into a Fire in a Cable Trench in Penrose Substation*, 3 November 2015. CCI's report is referred to as 'the CCI report'. CCI is an international company with expertise in high-voltage electricity cables. Vector and Transpower engaged CCI to undertake a detailed investigation of the fire-damaged cables at Penrose substation.

quantity of information and expert analysis produced by the investigation. In addition, the Authority drew from other publicly available information.¹⁰

- 1.12 At the outset, the Authority established a protocol with Vector and Transpower for sharing information and exchanging views. The Authority attended workshops with Vector and Transpower throughout the inquiry. The workshops provided opportunities for the Authority to clarify points of interest at relevant points in the investigation. The workshops also provided the opportunity for Vector and Transpower to provide information and ensure the Authority was kept updated in a timely manner.
- 1.13 The Authority was provided with information and documentation describing Vector's and Transpower's risk and asset management systems. The Authority considers that the systems presented align with international standards and practice.¹¹ These systems have been independently reviewed and are subject to periodic review. The Authority considers that, through consistent application of their risk and asset management systems, both Vector and Transpower will be operating to good electricity industry practice.
- 1.14 While the Authority drew significantly on information provided by the joint investigation, the Authority has formed its own views. The main focus areas of the inquiry were:
- a) establishing why the power outage occurred and why the disruption was extensive, including to:
 - (i) obtain accurate information from reliable sources
 - (ii) identify who was responsible for managing the substation and cables
 - (iii) identify what caused the fire to start and spread
 - (iv) identify what contributed to the power outage
 - b) considering the reasons why risks associated with the cable trench at the Penrose substation had not been identified, including to:
 - (i) assess the relevant risk and asset management systems
 - (ii) consider how the risk and asset management systems had been applied in practice at Penrose
 - (iii) identify why the fire was able to start and spread
 - c) assessing how the relevant parties responded to the fire, including how well the affected customers were kept informed of the status of restoration efforts
 - d) identifying improvements and making recommendations to reduce the potential for similar events in the future.
- 1.15 A draft of this report was provided to Transpower, Vector and NZFS for comment on 6 October 2015. The Authority received a submission from NZFS, and a joint submission from Transpower and Vector, on 20 October 2015.

¹⁰ References to the relevant sources of information referred to in this report are provided in the relevant sections of this report.

¹¹ Transpower informed the Authority that it considers risk management to be a subset of asset management.

- 1.16 In cases where the Authority was satisfied that the submissions pointed out factual inaccuracies in the draft report, or where the Authority otherwise accepted the points that were raised, the report has been corrected or amended to reflect that. Where the Authority disagreed with an issue raised in submissions, the report has been amended to state where that is the case.

The inquiry took a standard risk assessment approach

- 1.17 Both Transpower and Vector use risk and asset management systems that align with relevant international standards and good electricity industry practice. The Authority took into account international standards relevant to risk and asset management and used the basic components of these systems to form a structure for the inquiry.
- 1.18 The first step in risk management assessment is to identify risks. Accordingly, early engagement with Vector and Transpower sought to determine whether they had previously identified the risk of a cable trench fire at Penrose substation.

The risk of a cable trench fire at Penrose had not been identified

- 1.19 Before the fire, neither Vector nor Transpower had identified:
- a) the risk of fire ignition from failure of a power cable in the Penrose cable trench (the ignition risk) or
 - b) the risk posed by multiple power cables co-located in the Penrose cable trench (the co-location risk).
- 1.20 Consequently, neither Vector nor Transpower took steps to prevent a fire in the cable trench at Penrose or lessen the supply interruption impact of such a fire on customers.
- 1.21 A 33 kV indoor switchgear building and transformers are located close to the location of the fire. If the fire had destroyed these facilities, the impact would have been much greater.¹²

The electrical failure of a cable joint ignited the fire

- 1.22 The Remuera K10 cable was one of the original cables installed in the cable trench in 1966.
- 1.23 In 2001, a Vector maintenance contractor discovered bitumen leaking from a cable joint located in the Penrose cable trench section of the Remuera K10 feeder. To address the issue, the contractor removed the joint and spliced a new section of cable into the existing cable. The repair required a short section of new cable and, because the new and old cables were of a different type, two new transition cable joints.
- 1.24 One of the transition joints electrically failed on 4 October 2014 and this is believed to have provided the source of ignition for the fire.

¹² kV is the standard industry abbreviation for 1,000 volts (eg, 33 kV is 33,000 volts).

Other factors contributed to the fire

- 1.25 Although electrical failure of the cable joint ignited the fire, a significant contributing factor to the spread of the fire and the widespread loss of supply was the co-location of 38 lengths of power and a number of control cables in the Penrose cable trench. The large number of cables located in close proximity within the Penrose cable trench provided fuel for the fire. The air in the cable trench surrounding the cables provided the oxygen to sustain the spread of the fire.
- 1.26 The spliced cable that Vector installed in 2001 was longer than the section of cable it had replaced. This meant that the cable had to be returned to the trench in a bow shape rather than a straight line. CCI identified this as one of a number of contributing causes to the failure of the transition joint.
- 1.27 In the executive summary of its report, CCI sets out 14 main conclusions from its investigation of the cable trench installation. The Authority considers the forensic investigation undertaken by CCI was detailed and high quality. Accordingly, subject to the discussion in this report, the Authority has relied on and drawn from CCI's report and accepts its 14 main conclusions.
- 1.28 CCI concluded that the cause of the transition joint failure was a vulnerability of the transition joint design. CCI concluded that the jointing quality was satisfactory. CCI states that a number of technical factors contributed to the cable joint failure. These factors included the lack of a straight alignment of the joint and the cable, and the lack of cable cleats and joint supports.¹³
- 1.29 CCI considered that the number of cables in the cable trench contributed to the rate of spread of the fire, that by 2001 limited space remained in the trench and that, at the time of the fire in 2014, too many cables had been installed in the trench.¹⁴
- 1.30 The security and integrity of the cable trench and cables were critical to maintaining a reliable electricity supply to a large number of electricity customers in Auckland.

The Authority considers Vector and Transpower should have identified the risk

- 1.31 The Vector and Transpower report states that Vector could not have been expected to have the knowledge to specifically identify the risk of a joint failure causing fire in the cable trench as cable faults are very rare, and details of any incidents that have occurred globally have not been made public.¹⁵
- 1.32 However, the Authority found that Transpower was aware of the potential for cable installations to cause fires and had asset management documentation requiring cable installation design to consider and appropriately mitigate fire risks from potential cable failure.

¹³ CCI report, section 15.2.

¹⁴ CCI report, Executive Summary, page 5 and section 15.6.3.

¹⁵ Vector and Transpower report, section 8, paragraph 18.

- 1.33 The Authority considers that Vector and Transpower should have been aware of the factors that had the potential to affect the integrity of the cable trench and the cables that it contained and therefore should have identified the risk. This is because Vector and Transpower identify similar risks in other contexts, there are examples from overseas of cable insulation failures causing substation fires, there are international standards that mitigate the consequence of trench fires and cable joint failures, and there are products available to manage the risk of cable joint failures causing fires. This information is all available in the public domain.
- 1.34 In their submission on a draft of this report, Vector and Transpower disputed the Authority's conclusion that they should have identified the risks related to the co-location of multiple cables in the cable trench. The Authority reconsidered its conclusion in light of that submission, but has not changed its view. This is explained further in section 5 of this report.
- 1.35 Vector and Transpower have also emphasised in their submissions that they could not have been expected to know about the risk associated with the specific type of PILC-XLPE transition joint that was detailed in the CCI report. The Authority acknowledges this point. However, knowledge of the specific failure that occurred on 5 October 2014 is not needed to identify the risk associated with 38 cables in a single trench. Additionally, the possibility of fire as a result of failures of cable joints or cable insulation should be common knowledge within electricity network businesses.

The Authority considers there were opportunities to identify and manage the cable trench risk

- 1.36 Each cable added to the cable trench since its installation in 1966 provided an opportunity to review the risk posed by an increasing concentration of important cables in the cable trench.¹⁶ When Vector added new cables to the cable trench, the focus appears to have been on the individual project risk.¹⁷ Transpower and Vector did not consider the co-location risk implications of the overall cable trench installation.
- 1.37 Other opportunities arose to identify the risk associated with the concentration of cables in the trench, such as the biennial State of the Network Review commissioned by Vector for the Auckland Energy Consumer Trust (AECT), and Transpower's high impact, low probability (HILP) study at Penrose substation in 2013.
- 1.38 The Penrose cable trench was not a standard cable trench – the investigation found that the cable trench at Penrose was quite different from other cable trenches. Despite this, Vector and Transpower had not considered applying a different design standard to the Penrose trench based on its criticality to electricity supplies over a wide area.¹⁸ The Authority's view is that Vector should

¹⁶ The cables are considered to be important because failure of a single cable could impact on the security of electricity supplies to electricity customers and failure of more than one cable could lead to loss of electricity supply to a large number of consumers.

¹⁷ Vector and Transpower report, section 7.6.2.

¹⁸ The fire demonstrated the potential for damage to occur to all cables in the trench and the consequences, therefore the trench and its contents together were critical components of Vector's network.

have considered the specific features of an installation like the Penrose cable trench, including its criticality to electricity supply, before allocating it to an asset group or type. The categorisation should have also been periodically reviewed, especially when changes to the installation were undertaken, as they were at Penrose over a long period.

- 1.39 The Authority considers that all electricity lines businesses should review their asset policies and application to ensure that supply-critical components are appropriately categorised.¹⁹ This relates particularly to assets at grid connection substations, where multiple asset owners are always involved.

The application of risk and asset management systems can be improved

- 1.40 The Authority has considered both Vector's and Transpower's asset and risk management systems. The Authority considers that the documentation relating to these systems is consistent with good electricity industry practice. The Authority also investigated how these systems were applied in practice at the Penrose substation.
- 1.41 Specifically to the Penrose substation fire, the Authority considers that the risk identification stage of the risk management systems was not applied sufficiently well by Vector and Transpower, leading to opportunities to identify the cable trench risks being missed. As a consequence, Vector and Transpower did not take actions to remove or mitigate this risk.
- 1.42 The Authority notes that both Vector and Transpower intend to review their risk management practices to incorporate lessons from the Penrose fire. The Authority supports these initiatives.

Communications with customers worked well

- 1.43 Customer, media and public communications about the supply interruptions commenced early and utilised a range of media and communication methods. In the early stages, Transpower, and subsequently Vector, kept customers informed about the status of supply interruptions. Vector provided updates throughout the period of supply interruptions.
- 1.44 The Authority has not identified any concerns or issues about the management of medically dependent or vulnerable consumers related to the Penrose fire event.

The management of Penrose and other substations can be improved

- 1.45 It is neither feasible nor efficient to eliminate all risk from electricity network businesses. Identified risk controls and mitigations should undergo analysis of costs and benefits. Treatments for identified HILP risks in particular can accrue high costs.
- 1.46 The Penrose fire incident has presented Vector and Transpower with an important opportunity to reassess risks at Penrose and other network locations. The Vector and Transpower report recommends that the cable trench and cable

¹⁹ In this report, 'supply-critical' is used as a reference to an attribute of a component, or a combination of components, in the supply system where failure of that component or components would result in a major supply interruption.

configuration be redesigned. In its report, CCI recommends that several actions be taken at Penrose and other substations.

- 1.47 Vector is using a range of methods to reinstate its cables in a more permanent arrangement at Penrose substation. These methods should address the risk of fire ignition due to cable joint failures in in-air situations and the risk posed by co-location of multiple cables in an in-air trench.
- 1.48 In the Vector and Transpower report, Vector and Transpower identify four key lessons:
1. *Cable joints installed in air with other cables in close proximity can cause sustained fires when they fail;*
 2. *Risk management processes did not identify very low probability events that had not previously occurred on the network;*
 3. *The nature of the incident identified opportunities for improvement of standard operating procedures; and*
 4. *The asset and risk management processes at the physical interface between Transpower and Vector's networks need to be improved.²⁰*
- 1.49 The Vector and Transpower report and the CCI report include a number of recommendations relating to four identified areas. The Authority supports the recommended actions included in the Vector and Transpower report and the CCI report.
- 1.50 The Authority considers that the lessons and recommendations from the investigation, if implemented, will deliver improvements in the identification and management of HILP risks at Vector and Transpower. The Authority notes that Vector and Transpower have completed a number of recommendations and are progressing implementation of the others.

The Authority recommends a number of additional actions

- 1.51 To support the recommendations made in the Vector and Transpower report and the CCI report, the Authority makes the following recommendations:

Recommendations relating to the Minister's first question

Recommendation 1 – Lessons from the Penrose incident must be shared with industry stakeholders. Significant fire events at high-voltage substations are rare events and provide valuable opportunities to review policies and procedures.

Recommendation 2 – Supply-critical components should be given higher risk management priority than non-critical components, even if the probability of occurrence is low.

Recommendation 3 – The particular characteristics of each asset and co-located groups of assets must be considered in determining the risk profile of the asset.

²⁰ Vector and Transpower report, section 9.4.

Recommendation 4 – In-air cable joints must be identified and the associated fire risk mitigated.

Recommendation 5 – Asset boundaries require improved management between asset owners to ensure clear division of responsibility.

Recommendation 7 – Planning standards should be reviewed by Vector to ensure the standards are appropriate.

Recommendation 8 – Future State of the Network reviews should be re-scoped to ensure the reviews are effective.

Recommendation relating to the Minister's third question

Recommendation 9 – An independently peer-reviewed, post-event safety review must be undertaken to identify improvement opportunities.

1.52 The Authority considers that many of the recommendations are relevant to all electricity lines businesses.

The improvements must be completed

1.53 For customers to have confidence in the reliability of their electricity supplies, the Authority considers it important that:

- a) Vector and Transpower afford a high priority to reporting progress towards completion of the recommendations
- b) there is transparent external monitoring of the progress achieved towards implementing the remedial actions identified in the investigation and in this inquiry.

1.54 The Authority recommends that Vector and Transpower submit to the Authority for approval an implementation plan by 31 December 2015. After the plan is approved, Vector and Transpower should submit progress reports to the Authority every six months until all actions have been completed (the monitoring period). Vector and Transpower should engage with the Authority during the monitoring period as may be required by the Authority from time to time.

1.55 The Authority will monitor progress made towards completion of the recommended improvement actions and will report to the Minister if there are any deviations from the implementation programme.

The Security and Reliability Council (SRC) considered a draft of the Authority's report

1.56 The SRC is a statutory body set up under the Act to provide independent advice to the Authority on the performance of the electricity system and the system operator, and reliability of supply issues. The SRC considered a draft of this report and its advice to the Authority Board is attached as Appendix E to this paper. The SRC agreed with the Authority's findings and recommendations.

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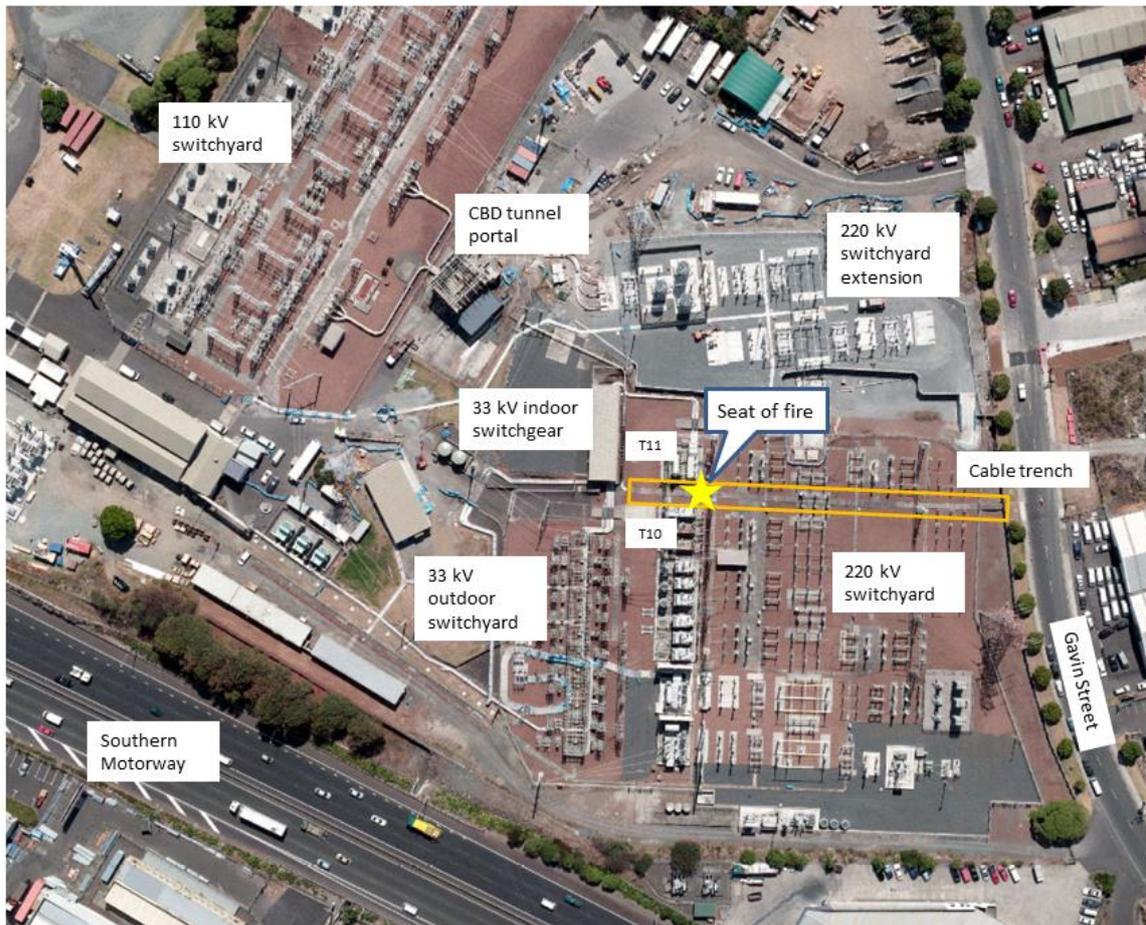
Part One Background to the inquiry

2 Why the Authority has carried out this inquiry

A fire at Penrose substation on 5 October 2014 caused a widespread power outage in Auckland

- 2.1 Penrose substation is a major national grid substation located in the industrial suburb of Penrose alongside the Auckland Southern Motorway, approximately 10 kilometres southeast of the city centre (figure 1). Transpower, the national grid owner and operator, owns Penrose substation.

Figure 1 – Penrose substation layout



Source: Vector and Transpower report (figure 5)

Note: T10 and T11 are labels for transformer banks

- 2.2 Late in the evening on Saturday 4 October 2014, a fire started at Penrose substation. At 2:04 am on Sunday 5 October, Transpower's National Grid Operations Centre (NGOC) controller observed a number of unusual alarms from equipment at Penrose substation and called out a substation maintainer to Penrose to investigate.
- 2.3 At 2:17 am on Sunday 5 October, a member of the public reported to emergency services of hearing explosions coming from the substation. NZFS responded and reported seeing thick smoke coming from the outdoor switchyard located behind the substation perimeter security fence.

- 2.4 The first NZFS fire appliance arrived at the Penrose substation perimeter security gate at 2:26 am. The substation maintainer arrived at 2:41 am and reported seeing thick black smoke in the vicinity of the 220/33 kV supply transformer T11.
- 2.5 Once safe access was arranged to the security-fenced area, Transpower and NZFS personnel traced the source of the smoke to a fire near the 33 kV switchroom adjacent to transformer banks T10 and T11.
- 2.6 Later investigation by Transpower and NZFS personnel determined that the fire started inside a cable trench containing 38 lengths of power cable and a number of control and communications cables.²¹ The power cables are owned by Vector, the local distributor of electricity and gas in Auckland. The cable trench also included a switchyard lighting cable owned by Transpower.
- 2.7 The fire destroyed all of the cables in the cable trench. The power cables are sections of the primary high-voltage circuits that supply over 39,000 customers through distribution 'zone' substations in:
- the residential suburbs in the Eastern Bays, Remuera and Epsom
 - the commercial/retail suburb of Newmarket
 - the industrial area through Penrose, Westfield and Mt Wellington.
- 2.8 To allow safe access to fight the fire, Transpower de-energised all 33 kV and 22 kV supplies at Penrose substation. Consequentially, by 3:08 am, 75,339 customers supplied from Penrose were without power, equating to a loss of around 116 MW of load from the network.²²
- 2.9 Figure 2 shows the area affected by the power outage.

Figure 2 – Supply area affected by the Penrose substation fire



Source: Vector and Transpower report (figure 3)

²¹ There are several cable trenches and above ground cable-racks installed at Penrose substation. The covered, concrete-lined cable trench in which the fire started runs west to east through the 220 kV switchyard, and is highlighted with a yellow border in figure 1. At the time of the initial firefighting by NZFS, it was not clear that the fire had actually started inside the cable trench.

²² MW is the standard industry abbreviation for 1,000,000 watts, a unit of power.

- 2.10 After the fire was extinguished, NZFS handed control of the site back to Transpower. Vector and Transpower were then able to start restoring electricity supplies. Supply was restored to 72 per cent of affected customers within 24 hours of the outage and to 98 per cent by 8:00 am on Tuesday. However, the extent of the fire damage meant that supply to some customers was not restored until the afternoon of Tuesday 7 October 2014.
- 2.11 To put the significance of the outages into context, Vector disclosed in its Annual Compliance Statement (published on 29 May 2015) that the Penrose fire resulted in power outages totalling 218.4 SAIDI minutes over the period 4–7 October 2014.²³ This equates to 44 per cent of Vector’s total unadjusted SAIDI for the reporting year to 31 March 2015.
- 2.12 Once supply to all affected customers had been restored, Vector and Transpower announced a joint investigation into the incident. In addition, the Minister asked the Authority to conduct an inquiry into the incident.
- 2.13 The next sections outline the scope of the Authority’s inquiry.

The Minister requested an inquiry by the Authority

- 2.14 The Minister wrote to the Authority on 7 October 2014, noting the significance of the 5 October power outage in terms of disruption and cost. Citing questions that the outage raised over the reliability of power supply, the Minister requested that the Authority carry out an inquiry into the outage and report its findings to him.²⁴
- 2.15 The Minister made his request under section 18 of the Act. Section 18(1) of the Act provides that, on written request by the Minister, the Authority must review and report on any matter relating to the electricity industry that is specified by the Minister.
- 2.16 The Minister requested that the Authority work with all parties to address the following questions:
- a) What caused the loss of supply or contributed to it, including potentially systemic factors such as risk management systems, asset health monitoring and maintenance practices, network design and regulatory incentives and controls?
 - b) What fire hazard mitigation systems were in place; and did they operate as intended?
 - c) What actions were taken during the course of the outage in respect of:
 - (i) ensuring the safety of people and equipment?

²³ SAIDI means System Average Interruption Duration Index and is a statistic reported annually by electricity distributors under the Electricity Information Disclosure Requirements administered by the Commerce Commission. The Penrose fire event constituted 44 per cent of Vector’s total unadjusted SAIDI for the reporting year ended 31 March 2015 (ie, SAIDI before making adjustments for major events). For further information about the information disclosure regime, see <http://www.comcom.govt.nz/regulated-industries/electricity/electricity-information-disclosure/current-electricity-information-disclosure-requirements/>. Vector’s 2014/15 compliance statement is available at <http://vector.co.nz/electricity-disclosures/price-quality-path>.

²⁴ Letter from Hon Simon Bridges, Minister of Energy and Resources, to Dr Brent Layton, Chair of the Electricity Authority, 7 October 2014. A copy is attached as Appendix A.

- (ii) communicating with affected and interested parties (including emergency services) about the impact of the event and timeframes for restoration of supply?
 - (iii) mitigating the loss of supply and expediting restoration?
- d) What the estimated economic impact of the outage was on customers?
- e) What actions will be taken or are recommended, as a result of the outage and subsequent investigations, to improve the resilience of power supplies and management of outages?
- 2.17 The Minister also requested that the scope of the inquiry include any policy implications. Accordingly, the Minister requested that the Ministry of Business, Innovation and Employment (MBIE) be kept fully informed throughout the process of the inquiry.

What the Authority is required to do under section 18 of the Act

- 2.18 On receiving a written request by the Minister under section 18 of the Act, the Authority must review and report on any matter relating to the electricity industry as specified by the Minister.
- 2.19 If, in the course of a review, the Authority considers that there are matters that fall outside the scope of the review, but which it should nevertheless report on to the Minister, the Authority may include a report on those matters in the final report or in a separate report.
- 2.20 Section 15 of the Act provides the Authority with a single statutory objective:
- To promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers.*
- 2.21 The questions to be addressed by the inquiry are consistent with the Authority's statutory objective.

The Authority commenced an inquiry

- 2.22 Following receipt of the Minister's letter, the Authority:
- a) established an internal inquiry project team within its market performance group
 - b) appointed two directors of Strata Energy Consulting Limited (Strata) as its specialist technical advisers
 - c) met with representatives of Vector and Transpower to establish a protocol under which the inquiry would be conducted.
- 2.23 This report sets out the findings of the inquiry conducted by the Authority under section 18 of the Act .

How the Authority has worked with Vector and Transpower

- 2.24 The Minister requested that the Authority work with all parties involved to address the Minister's questions.

- 2.25 The Authority identified that the parties involved included Vector, Transpower and NZFS. At an initial meeting, Vector and Transpower representatives advised the Authority that the two businesses intended to work closely together to conduct an investigation and to produce a joint investigation report. Vector and Transpower also advised the Authority that NZFS was investigating the fire and would provide a fire investigation report. The NZFS investigation was separate from and independent of the Vector and Transpower investigation.
- 2.26 Vector and Transpower recognised it would be necessary to draw on expert analysis and work through a significant quantity of information to comprehensively investigate the fire.
- 2.27 The Authority informed the Vector and Transpower representatives that it required their close cooperation so that it could:
- a) efficiently and effectively access information as the joint investigation progressed
 - b) ask timely follow-up questions as the Authority's inquiry progressed in parallel
 - c) discuss emerging themes and appropriate detail relevant to the Minister's questions in a timely manner
 - d) expedite the Authority's report to the Minister.
- 2.28 The Vector and Transpower representatives undertook to conduct an inclusive investigation process with the Authority's inquiry team, including:
- a) providing guided access to the site of the fire at an early stage for the Authority's inquiry team members
 - b) sharing draft and updated reports on specialist topics relevant to the investigation as they were produced
 - c) providing prompt responses to the Authority's formal questions
 - d) meeting with the Authority at appropriate times to share recently compiled information and discuss current topics of significance to the inquiry.
- 2.29 The Authority considers the respective investigation teams and the Authority have operated in accordance with the inquiry protocol throughout the investigation process.

Vector and Transpower commissioned supporting investigations

- 2.30 In addition to their report, Vector and Transpower have provided reports on two supporting investigations. These are:
- a) Cable Consulting International Limited, *Draft Notes: Investigation into a Fire in a Cable Trench in Penrose Substation*, Final Draft dated 13 August 2015 and a final version dated 3 November 2015
 - b) Edif ERA, *Analysis of Samples Taken From Cable Trench at Penrose Substation*, August 2015.
- 2.31 CCI carried out a detailed forensic examination of the damaged cables and cable joints, including work in New Zealand and the United Kingdom. Based on CCI's recommendation, Vector and Transpower engaged Edif ERA to undertake

specific tests and inspections of the cable and joint samples extracted from the cable trench.

NZFS investigated the cause of the fire

- 2.32 NZFS undertook its own investigation to determine the cause of the fire, which benefited from the assistance of the investigation team, including the cable expert. NZFS subsequently provided the following report to the Authority on 20 August 2015: New Zealand Fire Service, *Fire Investigation Report (final)* (referred to in this Authority report as the 'NZFS report').

The referenced reports have been provided to the Authority

- 2.33 In carrying out the inquiry, the Authority has drawn from each of the referenced reports and from a number of supplementary reports on specific topics. All reports directly referenced throughout this Authority report are listed in section 13.

The inquiry took many months to complete

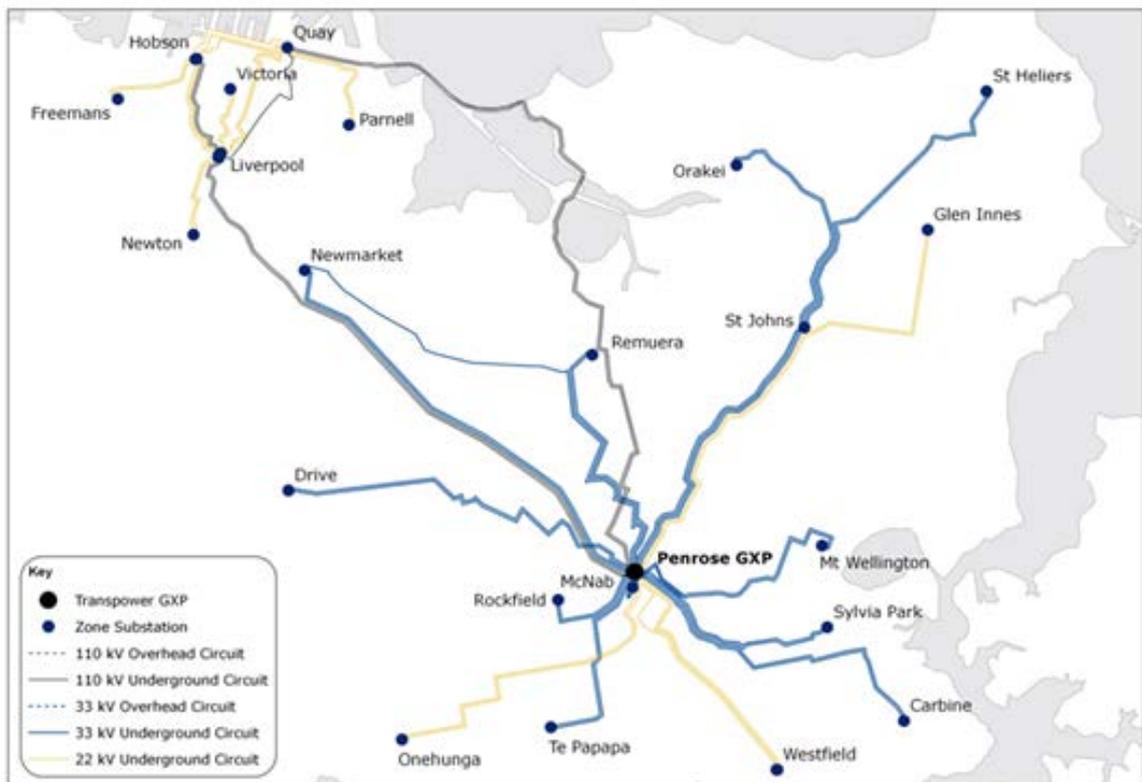
- 2.34 The inquiry started in October 2014. The Authority initially expected to provide a report to the Minister by the end of April 2015.
- 2.35 However, three investigation reports essential to the inquiry were provided to the Authority significantly later than expected. The timing of those reports was outside of the Authority's control:
- a) a 'final draft' of the CCI report dated 15 August 2015 was received by the Authority on 26 August 2015, and a final version of the report dated 3 November was received by the Authority on 5 November 2015
 - b) a 'final' version of the NZFS report was received by the Authority on 20 August 2015
 - c) Vector and Transpower provided a series of early drafts of their investigation report from 26 June 2015. The (undated) 'final draft' of the Vector and Transpower report was received on 1 September 2015, and the final version of the (undated) Vector and Transpower report was received by the Authority on 5 November 2015.
- 2.36 The inquiry has relied on the CCI report and the NZFS report to establish the initial cause of the fire and determine how it travelled along the cable trench.

3 Background information about Penrose substation

Penrose substation is a major national grid supply point into central Auckland

- 3.1 Penrose substation is a major electricity grid exit point (GXP) on the national grid owned and operated by Transpower. The extra high-voltage (EHV) transmission network into Auckland and across the Auckland isthmus provides connections through Penrose substation at 220 kV and 110 kV.
- 3.2 The national grid also supplies electricity into Vector's distribution network at Penrose, servicing a wide area of south-central Auckland starting at the south-eastern perimeter of the central business district (CBD) and running south and east as far as Westfield and Onehunga.²⁵
- 3.3 A large part of Vector's distribution network is supplied from Penrose substation at 110 kV, 33 kV and 22 kV to supply electricity customers throughout its south-central Auckland network (see figure 3).

Figure 3 – Vector network area and zone substations supplied at various voltages from Penrose GXP



Source: Vector

²⁵ KiwiRail also takes supply from Penrose at 25 kV for electrification of the commuter rail network in Auckland. Southpark is a further direct supply customer supplied from Penrose.

Penrose substation has a long history of development

- 3.4 Vector and Transpower have documented the history of development at Penrose substation in the Vector and Transpower report and in the supplementary report *Penrose Substation Fire 05 October 2014 History of Penrose Substation, 3 February 2015*. The main points of relevance to the cable trench fire on 5 October 2014 are set out in the following paragraphs.
- 3.5 Penrose substation was originally commissioned in 1925 as part of the initial reticulation of Auckland from the earliest Waikato hydropower developments. Electricity supply capacity from Penrose substation has grown steadily to the point that Penrose is amongst the very largest GXPs supplied by the national grid.
- 3.6 Penrose substation has undergone a number of significant developments in the last 15 years. This has significantly increased supply capacity into Vector's network and improved supply security throughout and north of the Auckland isthmus.
- 3.7 Notable recent developments include:
- a) in 1999, the capacity of the 220/33 kV supply transformers was doubled to 400 MVA²⁶
 - b) completed in 2001, the Auckland CBD supply upgrade added new 110 kV circuits from Penrose to Vector CBD zone substations via Vector's CBD cable tunnel
 - c) in 2001, the Penrose 220 kV bus was upgraded (sectionalised) to improve transmission and supply security
 - d) in 2010, a second 220/110 kV interconnecting transformer was installed to increase the security and capacity of supplies from the 110 kV bus
 - e) in 2011, a new 220/33 kV 200 MVA supply transformer was added to improve the security and capacity of supplies from the 33 kV bus
 - f) in 2014, the major 220 kV transmission upgrade into and across Auckland was completed. This involved a Penrose termination of new 220 kV circuits from Pakuranga and the CBD (via the Vector cable tunnel and on to the North Shore to link up with the grid at Albany).
- 3.8 Planned but not completed by October 2014, two further security upgrades are expected to improve security of supply at Penrose, particularly the 33 kV and 22 kV supplies. These are:
- a) a further 220 kV bus security upgrade at Penrose, by reconfiguring the existing single bus layout to form a four-section ring bus, which is also intended to provide regional transmission security benefits
 - b) replacement of the remaining outdoor 33 kV switchyard with a modern indoor switchgear installation.

²⁶ MVA is the standard industry abbreviation for 1,000,000 volt-amperes, a unit of energy. For the purposes of this report, MVA and MW can be considered to be approximately equivalent terms.

Penrose substation has a complex layout

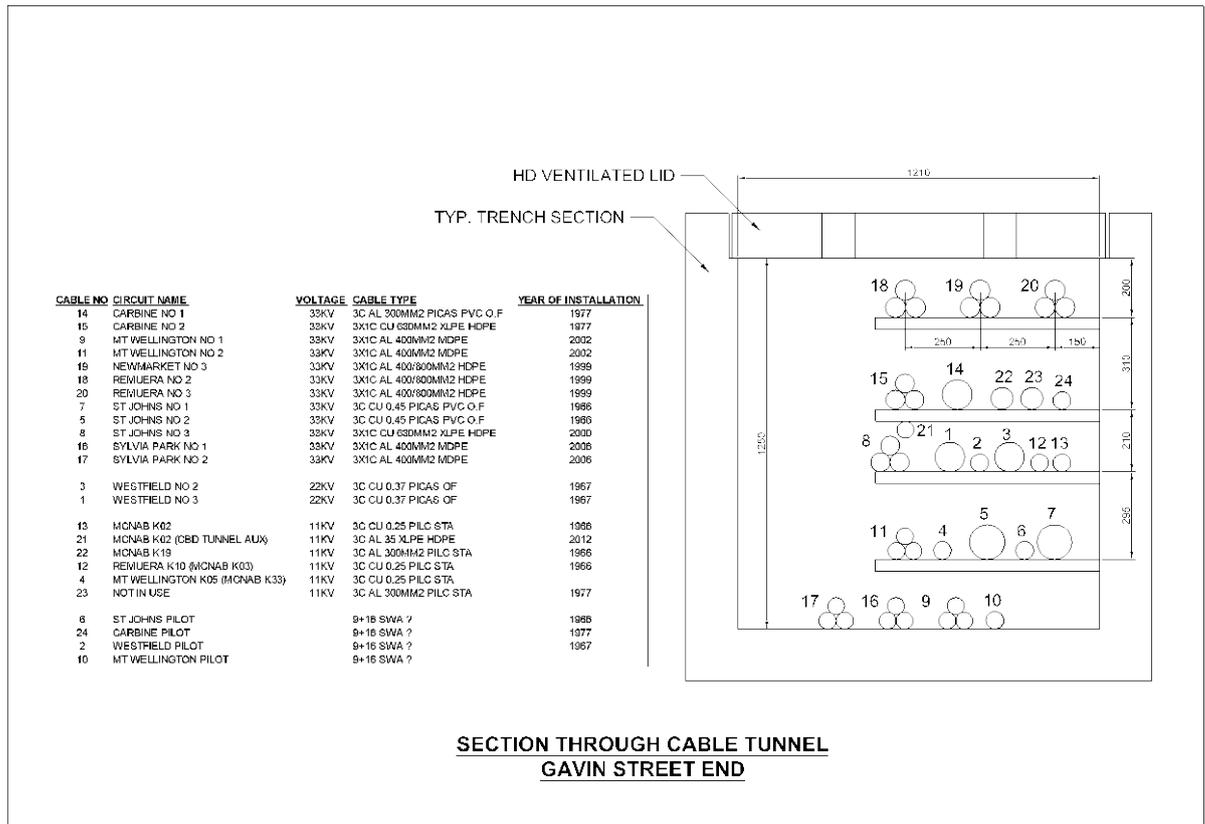
- 3.9 GXP's allow a transmission customer's electrical equipment (underground cables and overhead lines) to connect to Transpower's electrical equipment (switchgear). The physical point at which the transmission customer's electrical equipment connects to the grid is referred to as a 'point of connection'. Points of connection are located within Transpower's national grid substations.
- 3.10 Indoor and outdoor switchgear installations that operate at a standard supply voltage agreed with the transmission customer (eg, 110 kV, 33 kV, 22 kV and 11 kV) control the flow of electricity between the grid and the customer's network. This switchgear is usually owned by Transpower and this is the case at Penrose. The transmission customer lays its underground cables or runs its overhead lines on the site to connect to the switchgear.
- 3.11 The relatively large number of connections within Penrose substation between the grid and Vector's distribution network, and the basalt rock on which the substation is built, have contributed to the configuration of Vector's power cables at the site.

A concrete-lined cable trench contained many cables

- 3.12 The original development of the outdoor 220 kV and 33 kV switchyards at Penrose in 1966 included construction of a concrete-lined cable trench running west to east across the 220 kV switchyard.²⁷
- 3.13 The cable trench has ground-level removable lids and is owned by Transpower. It is used:
 - a) by Vector to provide a route for a number of its 33 kV, 22 kV, communications and control cables from points of connection within the substation to Gavin Street
 - b) by Vector as part of a through-route for a number of 11 kV cables that traverse the Penrose substation site (note that the 11 kV cables are not supplied from points of connection at Penrose substation – these cables are supplied from nearby Vector zone substations)
 - c) by Transpower for a power cable used to supply switchyard lighting.
- 3.14 Figure 4 shows a cross-section of the cable trench and cables at the Gavin Street end.

²⁷ The cable trench runs west to east (left to right) through the outdoor 220 kV switchyard from the 33 kV indoor switchgear building to Gavin Street. Interconnecting (220/110 kV) and supply (220/33 kV) transformers are located at the western edge of the 220 kV switchyard. Refer to figure 1 for the location of the cable trench within the substation.

Figure 4 – Cable trench cross-section as at October 2014



Source: Transpower/Vector

- 3.15 At the time of the fire, the cable trench contained:
- twelve 33 kV circuits, two 22 kV circuits
 - six 11 kV circuits²⁸
 - several communications, control and pilot (communication cables associated with specific cables) cables
 - a switchyard lighting power supply cable.
- 3.16 Figure 4 shows the Vector power and pilot cables only.
- 3.17 The combined equivalent single length of all the power cables in the cable trench was found by CCI to be 3.99 km.²⁹ The power cables in the cable trench had 15 in-air cable joints installed in their length.

Transpower is the owner and operator of land and facilities at Penrose substation

- 3.18 Transpower is the owner and operator of Penrose substation. In that capacity, and of particular relevance to the October 2014 fire, Transpower is responsible for:

²⁸ Five of which were in service and one (cable 23 in Figure 4) marked as 'not in use'.

²⁹ CCI report, section 2.4.

- a) site security and safety – the substation is a nationally and regionally significant extra high-voltage facility
- b) identification and management of risks and hazards to people and equipment
- c) management of access and occupation agreements/arrangements with owners of facilities installed (or to be installed) at the substation, including monitoring compliance with the agreements
- d) management of its equipment, including the cable trench but not including Vector’s cables
- e) development of the substation to meet future transmission requirements.

Vector is the local distributor that takes supply from Penrose substation

3.19 Vector distributes electricity in Auckland and owns electrical equipment located on Transpower’s land at Penrose substation. In that capacity, and of particular relevance to the fire event, Vector is responsible for:

- a) ownership and operation of power and control cables
- b) the security and safety of its cables – Penrose substation is an important GXP with regional significance within Vector’s network
- c) identification and management of risks and hazards to people and equipment related to the location of its cables within the substation
- d) compliance with the terms of relevant access and occupation agreements/arrangements with Transpower, including the requirement to:
 - (i) apply good industry practice to the management and development of its assets
 - (ii) obtain Transpower’s formal approval before installing new assets
- e) management of its assets, including the cables it owns within the cable trench but not including Transpower’s cable trench itself or the switchyard lighting cable
- f) development of its network to meet future network requirements.

3.20 The peak electricity demand supplied at 33 kV and 22 kV from Penrose is around 350 MW.³⁰ The Penrose supply area includes a wide range of customers typically found in large inner-urban and fringe CBD zones. These include residential, commercial and industrial customers.

Vector has rights to occupy parts of Penrose substation such as cable routes

3.21 Rights of occupation for transmission customers and access to their assets are routinely agreed between Transpower and transmission customers, such as Vector. Access and occupation agreements covering transmission customers’

³⁰ 33 kV peak demand is estimated from information provided in Transpower’s 2015 Transmission Planning Report and includes demand supplied at 22 kV, since 22 kV demand is supplied via 33/22 kV transformers from the 33 kV bus. At the time of the outages (ie, overnight), the demand on 33 kV and 22 kV supplies from Penrose was significantly less than the peak demand figure quoted here.

connection assets have evolved over several decades as the industry structure has evolved.

- 3.22 In 1966, the Auckland Electricity Power Board (AEPB) installed power and control cables that exited Penrose substation to Gavin Street in the newly constructed cable trench. The AEPB is a predecessor of Vector and operated as an electrical supply authority. At that time, the Electricity Supply Regulations provided for installation, operation and maintenance of the cables. These arrangements carried through until 1 January 1993, when the Electricity Act 1992 afforded the cables statutory protection as 'existing works'.
- 3.23 In October 1999, Transpower constructed the first indoor 33 kV switchgear building and entered into a 'licence to occupy' agreement with Vector. The agreement allowed Vector to install new cables at the Penrose substation and inspect, renew, maintain and operate those cables for an initial 20-year period. While the licence also allowed for the replacement of some existing cables in the cable trench, it did not affect the status of the cables already laid in the cable trench, which were protected as existing works under the Electricity Act 1992.
- 3.24 In 2000, Vector entered into a connections contract with Transpower for Penrose substation. The connections contract included an access and occupation schedule, which granted Vector a licence to occupy, and access, certain parts of Penrose substation to install, operate and maintain specified facilities for the conveyance of electricity.³¹
- 3.25 However, Vector and Transpower disagree about what contracts apply with respect to access and occupation at Penrose substation:³²

Transpower's view is that when the Connections Contract was entered into the intent was for all existing and future Vector assets at Penrose to be covered by it, to the exclusion of previous agreements.

Vector's view is that the current version of the Connections Contract does not cover all existing Vector assets at Transpower's Penrose substation. Vector agrees that greater certainty is required, and that the Connections Contract should be updated to reflect all existing and future Vector assets.

The list of Facilities at Penrose in the Access and Occupation Schedule is incomplete and inaccurate. Some Facilities are not described correctly¹⁶ and Vector's 11 kV cables installed in the Cable Trench in the 1960s and 1970s (including the cable on which the joint that faulted was installed) are not listed.

Neither Transpower nor Vector has records showing unequivocally that the Access and Occupation Schedule has been updated since the original 2000 version.

- 3.26 The most recent agreement entered into that provides for access and occupancy is the 2000 Connections Contract. In the 2000 Connections Contract, Vector

³¹ Vector and Transpower report, section 6.2 and 6.2.1.

³² Vector and Transpower report, section 6.2.1. Note that footnote 16, included in the quoted text, is a footnote from the referenced report.

must comply with operating standards related to safety, security, access and operating practice.³³ However, these standards do not apply to the design of Vector's assets at Penrose substation, which are required to comply with 'good industry practice'.

- 3.27 Relevant to an electricity distributor such as Vector, good industry practice is generally accepted to be the exercise of that degree of skill, diligence, prudence, foresight and economic management that would reasonably be expected from a skilled and experienced electricity network owner engaged in New Zealand in the distribution of electricity.³⁴

Access arrangements for NZFS personnel are provided in TP.SS 07.40

- 3.28 Transpower's approved service specification governing station security and entry control is TP.SS 07.40.³⁵ The purpose of this service specification is:

*To specify the responsibilities of personnel entering Transpower stations and communication sites, and to stipulate the entry protocols, safety management and security requirements for those stations and sites.*³⁶

- 3.29 The section related specifically to entry by NZFS personnel states:

10. FIRE BRIGADE ENTRY

10.1 General

10.1.1 Fire Service personnel are prohibited by their management to enter a restricted area to attend fires unless they are accompanied by the holder of a valid Competency Certificate.

*10.1.2 The RAE Competency Certificate holder accompanying the fire brigade must obtain a permit where required to ensure any fire brigade activities in the vicinity of high-voltage equipment can be carried out safely.*³⁷

³³ 2000 Connections Contract for Penrose substation, Access and Occupation Schedule, clause 5.1.

³⁴ For example, this is essentially the same definition provided in Part 1 of the Code for "good electricity industry practices".

³⁵ Transpower, *TP.SS 07.40 Station security – procedures*, issue 13, February 2012.

³⁶ TP.SS 07.40, clause 1.

³⁷ TP.SS 07.40, clause 10. RAE means Restricted Areas Entry.

4 What happened on 4–5 October 2014?

4.1 The following references have informed the following description of events that occurred in the lead up to discovery of the fire at Penrose substation:

- a) section 3.2 of the Vector and Transpower report
- b) the NZFS report
- c) the CCI report.

4.2 A timeline of key events is included in Appendix B.³⁸

An 11 kV feeder fault occurred at 11:21 pm on 4 October 2014

4.3 At 11:21 pm on Saturday 4 October 2014, a fault caused the Vector 11 kV feeder designated Remuera K10 to trip.³⁹ That feeder supplies electricity to customers in parts of Remuera and Ellerslie, and includes sections of overhead line and underground cable. At the time of the fire event, Remuera K10 was supplied from Vector's Remuera zone substation.

4.4 Remuera K10 includes a section of cable installed in the cable trench at Penrose substation. The feeder does not supply loads within the substation but uses the cable trench as a through-route from one side of the substation to the other.

4.5 The investigation concluded that the fault in the section of Remuera K10 located in the cable trench caused the Penrose substation fire.⁴⁰

4.6 At the time this fault occurred, the Vector Electricity Operations Centre (EOC) controller considered that the Remuera K10 trip had resulted from a routine feeder fault. To locate the cause of the fault, the EOC controller dispatched a faultman to carry out a line patrol. Remuera K10 has a history of faults caused by tree branches contacting the overhead lines.

4.7 Following established procedure, the faultman started patrolling from Remuera substation, following an outward route along the overhead line. The faultman observed the status of fault passage indicators installed on the feeder during his line patrol.⁴¹ He concluded that the fault was most likely located within an overhead section along Michaels Avenue between Marua Road and the Ellerslie Panmure Highway.

4.8 However, as the faultman found no physical evidence of the fault during the line patrol, and given the history of tree-related faults on the overhead line sections of

³⁸ Some event times cited in the various reports are time-stamped to the nearest second: however, the times stated in this report omit the seconds and state only hours and minutes. A consequence of this adjustment is that some of the times and durations cited in this report are plus or minus one minute, depending on the reference used.

³⁹ When electrical equipment 'trips', circuit breakers automatically open to de-energise the faulted equipment (in this case, an 11 kV feeder). Vector and Transpower have reported numerous equipment trippings in the sequence of events associated with the fire. Some of these were as a consequence of fire damage to control cables.

⁴⁰ This is corroborated by the CCI report and the NZFS report.

⁴¹ Fault passage indicators are installed on feeders to assist with fault location. They indicate to a faultman if high fault currents have passed by the point at which they are installed.

the feeder, the EOC controller concluded that the fault was a transient fault.⁴² In accordance with established operating procedure, the EOC controller then manually reclosed the feeder at 1:21 am on Sunday 5 October 2014 (ie, two hours after the feeder had originally tripped). The feeder immediately tripped again.

- 4.9 At this point, the EOC controller considered the most likely cause of the fault was a faulty cable termination. The EOC controller then transferred some residential load from Remuera K10 to an alternative feeder to restore supply to those customers.
- 4.10 The EOC controller and the faultman then carried out a sequence of switching operations along the remainder of the Remuera K10 feeder. This was done to isolate the fault location to a smaller section of the feeder.
- 4.11 While these switching operations were underway, supply to the whole of Remuera zone substation was lost. Information received by the EOC controller regarding the fire meant that EOC attention shifted to the developing situation at Penrose substation.

Attention was drawn to Penrose substation by alarms and a neighbour's call to emergency services

- 4.12 The following description of events that occurred as the fire took hold at Penrose substation is taken largely from section 3.1 of the Vector and Transpower report.
- 4.13 From 2:04 am on 5 October 2014, Transpower's remote monitoring and control system recorded a series of unusual alarms from equipment at Penrose substation. The initial alarms were associated with the 220/33 kV supply transformer T11 (refer to figure 1 and note the proximity of T11 to the indicated seat of the fire).
- 4.14 At 2:09 am, Transpower's NGOC dispatched a substation maintainer to investigate the cause of the alarms. T11 subsequently tripped at 2:11 am, followed in quick succession by a number of 33, 22, and 11 kV feeder and transformer trippings. This sequence resulted in an escalating series of power outages to customers.
- 4.15 A neighbour at a property adjacent to Penrose substation called emergency services at 2:17 am to report hearing explosions coming from the Penrose substation.⁴³ NZFS dispatched fire appliances in response to the call and notified NGOC. The first fire appliance arrived at the perimeter security gate in Gavin Street at 2:26 am.
- 4.16 The maintainer met the first-response fire appliances and opened the Gavin Street perimeter security gate at 2:41 am. The maintainer reported seeing thick smoke near the 220/33 kV supply transformer T11. This quickly developed into

⁴² A transient fault is a fault that self-clears due to the high fault current (eg, a tree branch that is burned clear of the live overhead conductors).

⁴³ The investigation has determined that the 'explosions' most likely resulted from a number of outdoor 33 kV circuit breaker (CB) trippings logged between 2:11 am and 2:16 am. See Vector and Transpower report, paragraph 3.1, footnote 6.

flames visible above ground between the adjacent transformers (T10 and T11) and the 33 kV indoor switchgear building (located next to the 220 kV switchyard).

- 4.17 A live, extra high-voltage switchyard (in this case containing 220 kV and 33 kV equipment) is a hazardous environment. Firefighting in a live switchyard is a hazardous activity. Transpower's site access procedure accordingly requires that emergency services personnel are accompanied by an authorised person (an RAE Competency Certificate holder).⁴⁴
- 4.18 At 2:50 am, NGOC informed EOC that all 33 kV equipment in the 220 kV switchyard would be de-energised to provide safe access for firefighting by NZFS personnel. This required planning and executing a long sequence of switchgear operations by the NGOC controller. Once those operations were completed, all 33 kV and 22 kV supplies at Penrose were de-energised. This resulted in the interruption of electricity supply to 75,339 customers.
- 4.19 The area around the fire adjacent to the 33 kV switchroom was declared safe to enter at 3:22 am. By this time, the fire was burning freely against the exterior wall of the 33 kV switchgear building.
- 4.20 A comment in the executive summary section of the NZFS report states:
- The first fire appliance arrived at 2:26am but it was not until 3:23am when an initial fire attack occurred in the area of the switchgear building.*
- 4.21 This means that NZFS access to the security fenced switchyard area occurred 57 minutes after the first fire appliance arrived at Penrose substation.
- 4.22 TP.SS 07.40 requires that the RAE Competency Certificate holder accompanying the fire brigade must obtain a permit where required to ensure any firefighting activities in the vicinity of high-voltage equipment can be carried out safely.⁴⁵ No permit was issued at this point.⁴⁶
- 4.23 While the NZFS report stated that an initial fire attack commenced in the area adjacent to the 33 kV switchgear building at 3:23 am, this was the time NZFS first entered the security fenced switchyard area. The application of foam commenced at 3:32 am.
- 4.24 At 3:35 am, the firefighters withdrew due to concerns that the cables exiting the cable trench might still be energised. At this time, the onsite Transpower personnel asked the Vector EOC controller if there was any back-feed from the Vector network into the 33 kV circuits at Penrose substation.⁴⁷

⁴⁴ Vector and Transpower report, paragraph 3.1.

⁴⁵ TP.SS 07.40 clause 10.1.2.

⁴⁶ Transpower has informed the Authority that, in its opinion, issue of a permit is only required if 'work' is to be undertaken on electricity equipment (eg, if a cable was to be cut). In light of this submission, the Authority reviewed the relevant service specification and considers that, if Transpower's view is correct, then the procedure is at best unclear and should be reviewed. This issue is discussed further in section 7.

⁴⁷ Transpower and Vector disagree with NZFS on some of the facts relating to this part of the sequence of events. At the date of this report, no consolidated version of events, agreed by all the parties involved, has been made available to the Authority. This is discussed further in section 7.

- 4.25 At 3:55 am, NZFS noted that power was confirmed as being isolated and that firefighting was underway with two foam deliveries in use. This point was 89 minutes after the first fire appliance arrived at Penrose substation.

The fire continued to spread inside the cable trench across the 220 kV switchyard

- 4.26 After NZFS brought the fire adjacent to the 33 kV switchgear building under control, the fire continued to burn and spread eastward along the cable trench through the 220 kV switchyard towards Gavin Street. The 220 kV switchyard was still energised at this point. NZFS had been made aware of the energised status of the 220 kV switchyard at 3:34 am when Transpower notified NZFS not to go past the line of the transformers (ie, not to go any further into the 220 kV switchyard) because that area was still energised.
- 4.27 To enable firefighting in the cable trench from the edge of the transformers across the 220 kV switchyard, the onsite Transpower manager requested NGOC to shut down the 220 kV switchyard at 4:26 am.
- 4.28 At 4:30 am, NGOC initiated switching operations to de-energise the entire 220 kV switchyard. These operations were completed at 4:35 am. The Vector and Transpower report states:

Arcing and corona discharging was also occurring in the 220 kV switchyard. Damage from flashovers could have impeded restoration of electricity supply once the fire was extinguished. To avoid equipment damage and to allow NZFS better access, the entire 220 kV yard was de-energised.

- 4.29 The NZFS report states that:

Re-entry to the switchyard area did not occur until 4:37am when confirmation was received of the power being isolated.

The delay in being able to recommence firefighting did allow fire spread from where the fire originated to along the length of the trench.

- 4.30 After the firefighters entered the de-energised 220 kV switchyard, they were able to control the fire in the cable trench running eastward from the transformers towards Gavin Street by 6:45 am.
- 4.31 The cable trench was flooded with water at 8:00 am to cool any hot spots and eliminate the risk of re-ignition. NZFS transferred control of the site back to Transpower at 9:57 am but remained at Penrose on standby.

Part Two Responses to the Minister's questions

5 Why the power outage occurred

5.1 This section answers the Minister's first question:

What caused the loss of supply or contributed to it, including potentially systemic factors such as risk management systems, asset health monitoring and maintenance practices, network design, and regulatory incentives and controls?

5.2 In summary, the inquiry has concluded that:

- a) too many cables had been installed in the cable trench that traverses the Penrose 220 kV switchyard⁴⁸
- b) a cable joint failure ignited the fire in the cable trench, which was identified in the early hours of 5 October
- c) the cable joint design and method used to install the cable joint in 2001 were factors that contributed to its failure
- d) the manual reclose of the Remuera K10 feeder at 1:21 am on 5 October accelerated the fire
- e) the failure to apply risk and asset management policies and procedures meant that the risk of fire in the Penrose cable trench was not identified
- f) the co-location of the cables in the trench contributed to the spread of the fire and meant that the fire affected more feeders, which threatened Transpower's assets and resulted in a widespread outage
- g) there are no systemic issues related to regulatory incentives and controls.

5.3 The Authority considers that Vector and Transpower should have been aware of the factors that had the potential to affect the integrity of the cable trench and the cables that it contained and therefore should have identified the risks.

5.4 This section explains the basis for these conclusions.

A cable trench traversed the Penrose 220 kV switchyard that had too many cables installed in it

5.5 As summarised in section 0, a concrete-lined cable trench was installed as part of a major 1966 development to connect 220 kV national grid lines at Penrose substation. The cable trench runs for 103.9 metres west to east across the substation's 220 kV switchyard.

5.6 The cable trench was used by:

- a) Vector as a route for a number of its 33 kV, 22 kV and associated pilot cables from points of connection within Penrose substation to Gavin Street
- b) Vector as part of a through-route for some 11 kV cables that traverse the Penrose substation site
- c) Transpower for a power cable used to supply switchyard lighting.

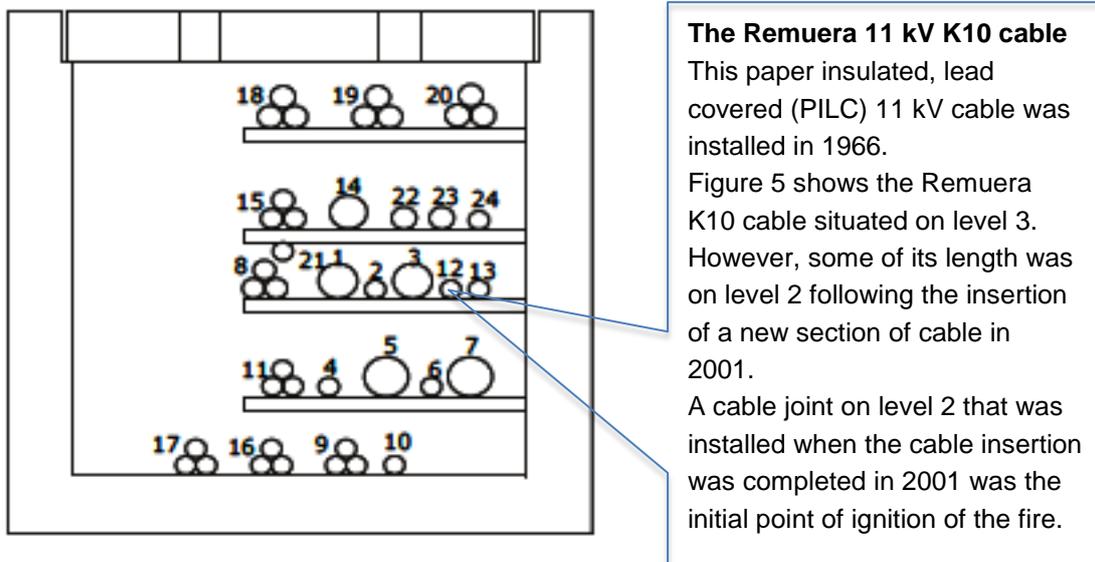
⁴⁸ CCI report, section 15.6.3.

- 5.7 CCI considered the cable trench to be a 'significant in-air application' containing:
- (i) 19 operational power cable feeders
 - (ii) 37 operational lengths each of 105m with a total combined cable length of 3.89km
 - (iii) 15 joints (4 x 11 kV PILC, 3 x 3 x 33 kV XLPE and 2 x 11 kV PILC/XLPE)
 - (iv) a volume of 84L per metre length of trench of flammable material comprised of oversheathing and hydrocarbon insulation and low viscosity cable oil in the cable (and additionally within the oil reservoir tanks).⁴⁹

5.8 In its report, CCI states that, by 2001, limited space remained in the trench for the installation of future cables⁵⁰ and that at the time of the fire in 2014, too many cables had been installed in the trench.⁵¹ CCI notes that, while the co-location of a large number of cables did not directly cause the joint failure, it did contribute to the rate of fire spread.⁵²

5.9 Figure 5 shows the cables in the cable trench in 2014, and the location of the cable that contained the joint that failed. The material used in the cables provided the fuel for the fire.

Figure 5 – Cross-section of the Penrose substation trench Gavin Street end



Source: Vector and Transpower report

5.10 The cable trench is covered with ground-level removable concrete lids. At the time of the fire, the cable trench had no fire barriers or fire, heat or smoke detectors. No fire suppressant systems had been installed. Figure 6 is a

⁴⁹ CCI report, section 15.6.1.

⁵⁰ CCI report, section 4.6.

⁵¹ CCI report, section 15.6.3.

⁵² CCI report, section 15.6.3.

photograph of the cable trench taken in 2001. Note that more cables were added to the trench after this photograph was taken.

Figure 6 – Penrose cable trench in 2001



Source: CCI report

A cable joint failure ignited the fire in the cable trench which was identified early on 5 October

- 5.11 In 2001, Vector observed that an existing 11 kV PILC straight joint was leaking bitumen. The cable in which the cable joint was installed formed a section of the Remuera K10 feeder circuit. The cable joint was located in a section of the circuit that ran inside the Penrose substation cable trench.
- 5.12 To fix this issue, a Vector maintenance contractor cut out a section of the cable that included the leaking joint and spliced in a new length of cable, requiring two new joints. The new cable was a more modern type, with cross-linked polyethylene (XLPE) insulation. Joints installed to connect two different types of cable are called ‘transition joints’ – in this case, a ‘PILC to XLPE’ transition joint.
- 5.13 The two new joints were installed in the confined space of the cable trench, and the spliced XLPE cable was longer than the section of PILC cable it replaced. This meant that the Vector contractor had to lay the cable in a bow shape rather than in a straight alignment.
- 5.14 The CCI report confirms that one of the two transition joints in the Penrose cable trench section of the Remuera K10 feeder failed while in service and provided the initial source of ignition for the fire.

- 5.15 Figure 7 is a cutaway diagram of an 11 kV, three-core, heat-shrink sleeve PILC to XLPE transition joint.

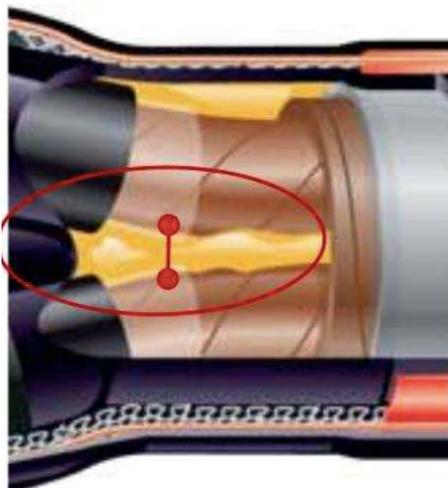
Figure 7 – PILC to XLPE transition joint example



Source: CCI report⁵³

- 5.16 CCI's detailed examination identified that a power arc occurred in the 'crutch' of the transition joint at the location shown in figure 8.⁵⁴ CCI concludes that the fire is likely to have ignited from the 11 kV power arc that would have resulted as the insulation material in the joint failed.

Figure 8 – The arc position in the failed transition joint



Source: CCI report⁵⁵

- 5.17 Once the fire had started, it spread to the west towards the 33 kV indoor switchroom and east towards Gavin Street. The acceleration of the fire and the manner in which it spread along the trench were assisted by:
- a) the in-air environment of the trench, which provided oxygen to fuel the fire
 - b) the contents of the trench, which contained fuel for the fire (eg, wood, oil, plastic)
 - c) the manual re-close of Remuera K10 at 1:21 am, 120 minutes after the feeder originally faulted and tripped.

⁵³ Draft CCI report dated 15 August 2015, figure 98.

⁵⁴ CCI report, section 5.3.

⁵⁵ Draft CCI report dated 15 August 2015, figure 31.

The method used to install the cable joint in 2001 contributed to its failure

5.18 CCI examined the burnt remains of the failed joint, and the second intact transition joint, and concluded that Vector had completed each of the two joints in accordance with the manufacturer's instructions. Note that this comment is about how each of the joints was individually completed.

5.19 Following detailed forensic inspection of the two transition joints, CCI concludes that:

The cause of the transition joint failure is the vulnerability of the transition joint design, with respect to the electrically stressed insulation in the crutch between the PILC cable cores.⁵⁶

5.20 CCI also concluded that, from the examination of the unfailed transition joint, the jointing quality was satisfactory.⁵⁷

5.21 CCI identifies likely contributing factors as:

i) *The concentration of thermo-mechanical disturbance of the crutch insulation resulting from:*

a. *Lack of straight alignment of the joint and cables (the joint was positioned at the start of a curve in the cable).*

b. *Lack of cable cleats and joint supports.*

ii) *Ingress of moisture into the crutch insulation at the lead sheath cut.*

iii) *Drying-out of the cable impregnating compound from the paper insulation.*

iv) *Migration of void-filling compound material into the compound paper insulating tapes in the crutch.*

v) *The jointing process of inserting 'void-filling compound' insulation into the PILC crutch of the transition joint, this being difficult for the jointer to consistently accomplish and risked damage to the cable insulation.⁵⁸*

5.22 That is, one of the likely contributing factors to the ignition of the fire was the installation of the spliced cable section in a bow shape, which placed stress on the correctly completed transition joint. As CCI notes, this contributed to the failure of the transition joint and ignition of the fire.

5.23 CCI notes:

By the year 2001 when the two PILC to XLPE transition joints were installed as a repair measure in the Penrose trench the CCI Author was aware that transition joints had a higher failure rate than conventional PILC straight joints. The CCI Author notes that failure rates were not available in the public domain.⁵⁹

⁵⁶ CCI report, section 15.2.

⁵⁷ CCI report, section 15.2.

⁵⁸ CCI report, section 15.2.

⁵⁹ CCI report, section 15.2.

The manual reclose of the Remuera K10 feeder at 1:21 am on 5 October accelerated the fire

- 5.24 The cable trench section of the Remuera K10 feeder was not included in the line patrol that was carried out before the manual reclose at 1:21 am. The CCI report considers it likely that the fire accelerated when Vector manually reclosed Remuera K10.
- 5.25 All electrical networks have protection systems installed that automatically detect electrical faults and rapidly trip the appropriate circuit breaker(s) to isolate the faulted equipment. Vector and Transpower's protection report confirms that the feeder protection system for Remuera K10 operated as designed.⁶⁰
- 5.26 The cable fault that occurred at 11:21 pm was cleared in 0.561 seconds. After the manual reclose of the feeder at 1:21 am, the fault cleared in 0.550 seconds. The CCI report considers that reclosing the feeder circuit breaker onto a failed cable joint would have significantly increased the severity of joint damage and collateral circuit damage and increased the risk and rate of acceleration of the fire.

Potentially systemic factors related to risk management

- 5.27 The Joint Australian New Zealand International Standard ISO 31000:2009 Risk Management – Principles and Guidelines (ISO 31000) is a reference and guide on good practice risk management. Both Vector and Transpower align their risk management with ISO 31000.
- 5.28 The Authority considers that, consistent with the international standard ISO 31000, risk management processes should:
- a) identify potential risks
 - b) assess the probability and impact of an identified risk
 - c) rank the priority of identified risks
 - d) form and implement plans to control or mitigate identified risks.
- 5.29 Managing an electricity network requires a network owner to identify and assess many complex risks and combinations of risks.
- 5.30 The Authority concludes that, prior to the Penrose fire, neither Vector nor Transpower had identified:
- a) the risk of fire ignition from failure of a power cable in the Penrose cable trench (the ignition risk) or
 - b) the risk posed by multiple power cables co-located in the Penrose cable trench (the co-location risk).
- 5.31 Therefore, steps were not taken that could have prevented the widespread supply disruption or mitigated the extent of the disruption.

⁶⁰ Transpower New Zealand Limited and Vector Limited, *Penrose Substation Fire – 05 October 2014 – Summary of Protection Operations report*, 22 May 2015, section 3.2.

- 5.32 The Vector and Transpower report concludes that Vector could not have been expected to identify the risk of fire in the cable trench and supports this conclusion by:⁶¹
- a) noting that no previous cable failures had occurred within the cable trench
 - b) referencing international experience researched since the fire, which points to a very low incidence of fires related to cable joints in in-air situations
 - c) noting that details of any cable fires that have occurred globally have not been made public.
- 5.33 Vector also informed the Authority that no fires had arisen from transition joint faults elsewhere on its network.
- 5.34 However, the Authority considers that both Vector and Transpower should have been aware of the factors that had the potential to affect the integrity of the cable trench and the cables that it contained and therefore should have identified the risk to electricity supplies and to the integrity of the substation. The basis for this view is explained further below.
- 5.35 In reaching its view on the risk management aspects related to the Penrose fire event, the Authority has relied on and accepts CCI's conclusion that:

*At the time of the fire, too many cables had been installed in the trench. This did not contribute to the cause of the joint failure, but did contribute to the rate of fire spread.*⁶²

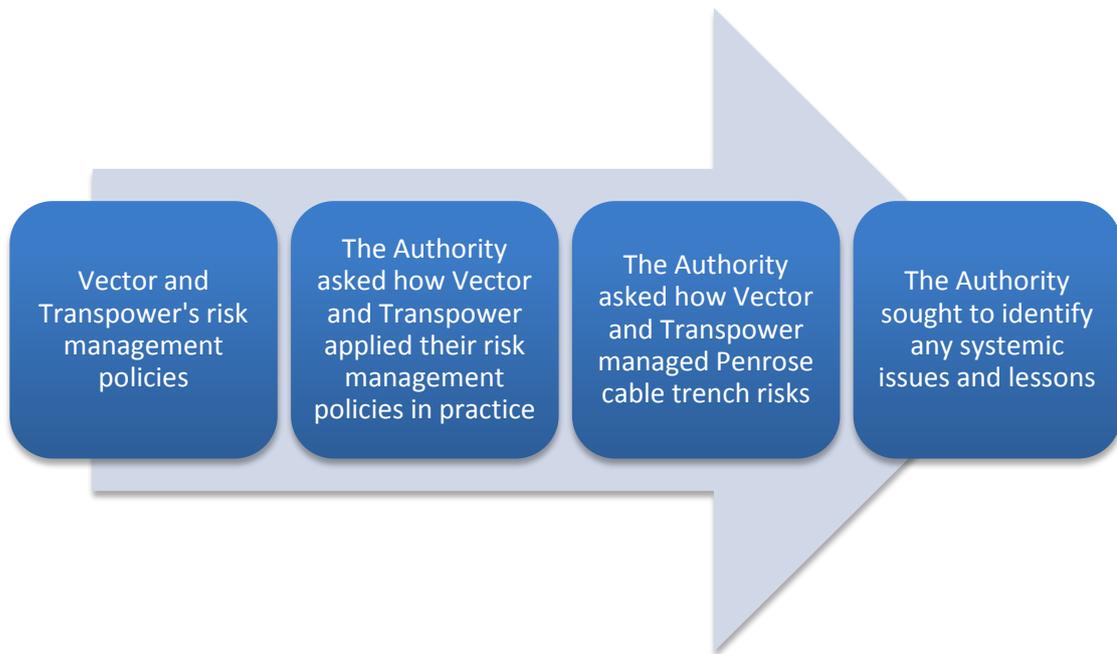
The Authority's approach when considering potentially systemic factors in risk management

- 5.36 The inquiry took the initial step of establishing whether Vector and/or Transpower had identified the risks associated with the cable trench at Penrose substation. As Vector and Transpower told the Authority that neither had identified the risks, the Authority moved on to consider why the risks had not been identified.
- 5.37 In order to answer the question as to why the cable trench risks had not been identified the Authority used a 'top-down' review of governance and management to establish what the businesses say they do and then compare this with what was seen to have been applied in practice. This approach is described in figure 9.

⁶¹ Vector and Transpower report, section 7.6.3 and section 8, paragraph 15.

⁶² CCI report, Executive summary, conclusion 13.

Figure 9 – The Authority’s top-down review process



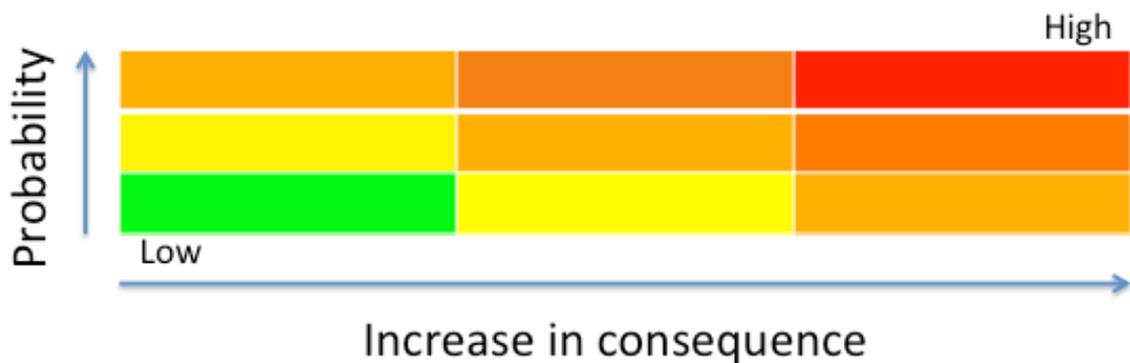
- 5.38 Vector owns and manages the power cables installed in the cable trench at Penrose. Accordingly, the Authority assessed Vector’s management practices in relation to its role as asset owner. As owner of the Penrose substation, Transpower has obligations to manage risks that could threaten the integrity of the substation and the safety of people at the substation. Accordingly, the Authority assessed Transpower’s risk management practices in relation to its obligations at the Penrose site.
- 5.39 When undertaking its assessment of the management of the cable trench risks at Penrose substation, the Authority:
- used ISO 31000 as a reference and guide on good practice risk management. As noted above, both Vector and Transpower align their risk management with ISO 31000
 - took account of Vector’s and Transpower’s documentation including risk policies, strategies and asset management strategies and plans
 - considered the biennial State of the Network reports provided to AECT by external expert consultants, the CCI report and additional advice on transition joint fire risk knowledge
 - participated in discussions at workshops to gain an understanding of how Vector and Transpower applied their risk management policies and strategies in practice at the Penrose substation
 - took into account the draft Vector and Transpower report and supplementary documentation provided by Vector on its risk management methods
 - considered the Authority’s technical adviser’s views on how risk management is applied in electricity network businesses both in New Zealand and internationally
 - considered other information gathered from public sources.

The risk was identifiable but was not identified

- 5.40 CCI identified that the Penrose cable trench was ‘a significant in-air application’. The Authority agrees with CCI’s finding and, in addition, considers that a contributor to the loss of supply was the co-location of a very large number of supply-critical cables within an in-air trench, some of which had cable joints installed.
- 5.41 That is, setting aside the risk of a specific type of cable joint failure causing ignition, Vector and Transpower did not identify a generic risk to electricity supplies and the consequences of all the cables in the Penrose cable trench being disabled simultaneously. This is confirmed in the Vector and Transpower report which states:
- No specific risk reviews were carried out with respect to the cables in the cable trench. Risk assessments were made for each network project that involved new cables being installed in the trench, but these were focused on the construction and environmental risks pertaining to the specific project. In these projects the trench simply formed a small section of the cable route and the associated construction risks were considered minor.*⁶³
- 5.42 The Authority considers that the specific risk to electricity supplies posed by the co-location of a large number of supply-critical cables within an in-air trench at Penrose substation should have been identified and assessed. There were several opportunities to identify the risks, including:
- a) on each occasion when cables were added or jointed in the cable trench
 - b) during periodic maintenance inspections
 - c) during Transpower’s HILP study for Penrose substation, carried out in 2013
 - d) when biennial reviews of the state of the network were undertaken for the AECT.
- 5.43 A common aspect of Vector’s and Transpower’s risk management frameworks is that both probability and consequence of a potential risk must be considered. This approach should ensure that specific assets, or groups of assets, that are critical to the operation of the network, are considered, regardless of how small the probability of an occurrence is.
- 5.44 Figure 10 shows how, at a high level, risks can be considered on the basis of probability and consequence.

⁶³ Vector and Transpower report, section 7.6.2.

Figure 10 – Risk priority assessment matrix



Source: Draft Vector and Transpower report provided to the Authority on 1 September 2015

- 5.45 Had the above approach been applied to the risk to electricity supplies resulting from the co-located power cables within the Penrose cable trench, the Authority considers it likely that the ignition risk would have been assessed as:
- a) high consequence (impact)
 - b) low probability.
- 5.46 Such risks are generally termed ‘HILP events’. Assessing the risk as a HILP event would have led to further detailed consideration of specific risk controls and mitigations. Nevertheless, as noted above, Vector and Transpower have both confirmed that the risk of a very large number of power cables co-located within the cable trench at Penrose substation had not been identified in their respective risk management systems.
- 5.47 The investigation found that, on the occasions when Vector laid additional cables in the cable trench, the focus was on specific project risks rather than combined or grouped cable trench risks.⁶⁴ The Authority considers that correct application of the risk management framework means that it should have been applied to the trench as a whole. The Authority considers that this is likely to have contributed to the fact that neither Vector nor Transpower identified the wider cable trench risk (ie, the co-location risk).

Transpower had identified but not acted on a relevant generic risk

- 5.48 In its document *Asset Management Practices: Penrose Cable Fire Investigation*, Transpower described how it identifies, assesses and manages risks, as follows:⁶⁵

Detailed risk registers are prepared by various teams within Transpower as part of a ‘bottom-up’ approach to grid asset risk identification and management. These bottom-up risk registers are aggregated to Divisional risk registers that are in turn consolidated into the Corporate Risk Register.

⁶⁴ Vector and Transpower report, section 7.6.2.

⁶⁵ Transpower New Zealand Limited, *Asset Management Practices: Penrose Cable Fire Investigation*, May 2015, section 6.8.1.

The lower level risk registers focus on initial capture of risks. Following a preliminary assessment, the higher severity risks are populated with risk controls and treatments, and considered for escalation to the relevant aggregated Division risk register.

The bottom up process typically generates a large number of risk statements, but not all of these warrant escalation. Priority for further risk analysis, including documenting risk controls and treatments, is based on an initial risk assessment.

This initial risk assessment is used as the main means of selecting risks for escalation from lower level team-based register to higher level divisional risk registers. In general, priority for escalation and further risk analysis is given to risks assessed with inherent risk levels of “High” or “Extreme”. In some cases, risks from separate teams are aggregated where there are overlaps or duplications.

The aggregated Grid Performance risk register is presented regularly to meetings of the Grid Performance leadership team, and top risks are selected. The top risks from Grid Performance, together with those from other Transpower divisions, are communicated to the Transpower staff Risk Committee. This is a cross-Divisional team. They are responsible for the compilation of the Corporate Risk Register. The Transpower Board regularly reviews the top risks in the Corporate Risk Register.

- 5.49 In the same document, Transpower also gave details of a specific risk entry it considered relevant to the Penrose fire:⁶⁶

Grid Performance NNI Register – NNI 23

Failure of equipment (eg cables and joints) owned by connected customer on Transpower site causes safety hazard and fire/explosion damage to critical Transpower assets leading to loss of supply.

- 5.50 Transpower risk register entry NNI 23 is relevant to the Penrose fire because:
- the cables were owned by a connected transmission customer (ie, Vector)
 - the cables were located on a Transpower site (ie, Penrose substation, in the cable trench that crosses the 220 kV switchyard)
 - the fire caused a safety hazard that destroyed sections of other Vector and Transpower cable assets
 - before it was contained, the fire threatened to damage supply-critical Transpower assets (switchgear, transformers, a 33 kV switchgear building and associated auxiliary equipment in and near the 220 kV switchyard)
 - the fire led to a widespread loss of supply.
- 5.51 Transpower’s asset management practices document goes on to explain the status of risk NNI 23 at the date of the Penrose fire.⁶⁷

⁶⁶ Transpower New Zealand Limited, *Asset Management Practices: Penrose Cable Fire Investigation*, May 2015, section 6.8.2.

⁶⁷ Transpower New Zealand Limited, *Asset Management Practices: Penrose Cable Fire Investigation*, May 2015, section 6.8.2.

This risk statement ref NNI-23, as at October 2014, was a product of the bottom-up risk identification process outlined above. The risk statement was developed by the team in the Transpower Auckland office who are responsible for the management of grid maintenance in the Northern North Island region. The risk statement ref NNI-23 was first entered into the team risk register on 6 May 2014. It is a generic risk statement, applying to all substations where customers are connected. A preliminary risk assessment was undertaken, scoring this risk as 'Medium' risk level, before controls (ie the inherent risk level). The risk level scoring was based on the Transpower risk assessment matrix.

The rationale for the initial team-based assessment of this risk is not recorded. However, the team would have been aware that failure of customer assets on Transpower land is an unusual event, and (at that time), there were no previous instances of severe damage to Transpower assets from this cause. The risk assessment of "Medium" severity is consistent with these understandings, and with the Transpower risk assessment matrix.

In general, priority for further risk analysis was given to risks assessed with inherent risk levels of 'High' or 'Extreme'. As a consequence, risk controls and treatments for the risk statement NNI 23 had not been documented as at October 2014, and this risk had not been escalated to the aggregated Grid Performance risk register.

- 5.52 In summary, at the time of the Penrose fire, Transpower had identified a generic risk (ie, a risk not related to a specific site) that failure of a connected customer's assets located at a Transpower site could lead to damage of supply-critical Transpower assets and cause a loss of supply. Transpower rated this risk as having an inherent risk level of medium.
- 5.53 Transpower had entered this bottom-level risk into its risk management register but, by October 2014, had not progressed beyond the stage of identification and initial assessment.

Transpower's Penrose HILP study should have identified the risk to electricity supply

- 5.54 In 2013, Transpower undertook a programme of HILP event studies at a number of its high-priority substations, including at Penrose substation.⁶⁸ The purpose of the studies was to identify HILP risks, propose mitigations and make recommendations to carry out works or to progress further investigations.
- 5.55 The HILP study did consider the cable trenches at Penrose, and suggested that consideration should be given to undertaking a:

... programme to replace timber cable trench covers in the 220 kV yard with concrete covers.⁶⁹

⁶⁸ Penrose Substation High Impact Low Probability (HILP) Event Study June 2013.

⁶⁹ Penrose Substation High Impact Low Probability (HILP) Event Study June 2013, section 4.8.

- 5.56 In a study commissioned by Transpower and undertaken by Marsh Risk Consulting (Marsh) as part of the HILP study at Penrose substation, cable trenches were identified as a HILP risk. Marsh identified that damage to cables in the cable trench along the southern fence line in the 220 kV yard would contribute to the potential for a high impact event.⁷⁰
- 5.57 The HILP study considered the cable trench risk could arise from damage to the cables from external events such as vehicles breaking through the wooden covers and damaging cables.
- 5.58 Despite the broad scope of the HILP study, it did not identify potential risks related to the use of the cable trench by Vector for its cables. The discussion of cable trench risks was limited to potential damage to one specific trench. The study did not identify the potential risks to the safety and security of Penrose substation related to the contents of the cable trench.

Vector's independent State of the Network reviews identified the risk event of simultaneous failure of two cables but not simultaneous failure of 38 cables

- 5.59 The AECT deed requires that Vector management obtain a biennial report from an independent expert on the state of the Auckland electricity reticulation assets. This is called the 'State of the Network' review. The scope of the review is to prepare a report on:
- a) the state of Vector's electricity assets across its Auckland and Northern networks with regard to maintenance programmes and the appropriateness of expenditure levels
 - b) any need for the upgrading of Vector's electricity assets, taking into account what is already being planned by Vector management
 - c) the capacity of Vector's electricity assets in relation to forecast demand
 - d) any security risks to Vector's electricity assets.
- 5.60 Vector's expectation was that the review would cover:
- ... existing Vector plans and policies, forecasts, and expenditure profiles, as well as field inspections of typical Vector assets and interviews with technical and management staff. Vector will assist with the provision of the required information and to facilitate interviews and field visits.*⁷¹
- 5.61 State of the Network reviews have been undertaken since 2008/9, as follows:
- a) by Siemens PTI in 2008/9
 - b) by Sinclair Knight Merz Pty Limited in 2010
 - c) by Sinclair Knight Merz Pty Limited in 2012
 - d) by PA Consulting Group Limited in 2014 (report completed and submitted on 30 September 2014 (just before the Penrose fire)).

⁷⁰ Penrose Substation High Impact Low Probability (HILP) Event Study June 2013, [Marsh Risk Review, Appendix M](#), page 11.

⁷¹ Auckland Energy Consumer Trust, *Electricity Network Review – Request for Proposal 2010*, Scope.

5.62 In two of the biennial reviews, the reviewers identified a risk relating to installing two cables in common trenches at zone substations. However, none of the State of the Network reviews have identified or discussed the Penrose cable trench specifically.

In summary, Vector and Transpower should have identified the risk

5.63 Vector should have identified the criticality to electricity supplies of the cables co-located in the cable trench. As noted above, the risks could have been identified on a number of occasions, including:

- a) when cables were added to the cable trench
- b) when routine inspections and subsequent maintenance, such as cable jointing, were undertaken that involved the cable trench
- c) during periodic risk reviews.

5.64 Transpower should have identified the risk to the integrity of the Penrose substation due to the co-location of a large number of power cables within the Penrose cable trench. As the national grid owner, Transpower should be aware of all risks relating to the integrity of national grid facilities, particularly those relating to security of supply and the safety of people and equipment.

5.65 Both Vector and Transpower have said they intend to review their risk management practices to incorporate lessons from the Penrose fire. The Authority strongly supports these initiatives and recommends that electricity network businesses more generally review their risk management procedures and ensure the procedures are followed in practice.

Vector and Transpower's submission

5.66 Vector and Transpower, in their submission on a draft of this report, gave significant emphasis to their view that the Authority's conclusion that they should have identified the risks related to the co-location of multiple cables in the cable trench was wrong. Accordingly, the Authority has reconsidered that conclusion in light of Vector and Transpower's submission.

5.67 The Authority's understanding of Vector and Transpower's submission on risk identification relating to the Penrose cable trench is summarised as follows:

- The only relevant risk is fire caused by electrical failure of a specific type of PILC-XLPE cable transition joint.
- The co-location of cables relates to the potential consequences that may arise from any risk, but is not itself a risk.
- The specific fire risk relating to the transition joint was not identified and therefore no risk mitigation actions were taken.
- Publicly available 'risk intelligence' on in-air transition joint failures posing a fire risk was not available to Vector and Transpower.
- Limited publicly available information means that Vector and Transpower cannot be expected to have identified the fire event risk in the Penrose cable trench.

5.68 In summary, the Authority understands that Vector and Transpower consider that the Authority has incorrectly categorised the co-location of multiple cables in the trench as a separate risk, rather than a factor that affects the potential consequences of a failure. Vector and Transpower consider that, as the risk of the specific type of PILC-XLPE cable transition joint was unknown, they could not have been expected to consider risk mitigation actions for the cable trench.

The Authority's assessment of Vector and Transpower's submission

5.69 When formulating its view in the draft report given to Vector and Transpower, the Authority applied its understanding and interpretation of ISO 31000, which defines risk as the *effect of uncertainty on objectives*.

5.70 ISO 31000 defines **risk assessment** as
overall process of risk identification, risk analysis and risk evaluation.

5.71 ISO 31000 defines **risk identification** as the *process of finding, recognizing and describing risks*.

Note 1 Risk identification involves the identification of risk sources, events, their causes and their potential consequences.

Note 2 Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.⁷²

5.72 In light of Vector and Transpower's alternative interpretation of 'risk', 'risk identification' and 'risk assessment' the Authority has reconsidered its interpretation of ISO 31000, and in doing so has taken particular note of the following definition of **risk** provided in ISO 31000:

Note 1 An effect is a deviation from the expected.

Note 2 Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).

Note 3 Risk is often characterized by reference to potential events and consequences, or a combination of these.

Note 4 Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

Note 5 Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.⁷³

5.73 When undertaking a risk assessment, the system under consideration and the system's objectives must be defined. The Authority considers that, for the scope of this inquiry, it is reasonable to assume that:

⁷² ISO 31000, section 2.15.

⁷³ ISO 31000, section 2.

- a) in the case of Vector, the system starts at the Penrose substation and ends where consumers take supply. The objective is safe, secure and reliable power supply to consumers
 - b) in the case of Transpower, the system has an end point at the Penrose substation and the objective is safe, secure and reliable supply to Vector, its customer.
- 5.74 The definition of risk provided in ISO 31000 specifically deals with the uncertainty of risk. Note 5 states that uncertainty includes deficiency of information and knowledge. Vector and Transpower appear to be submitting that knowledge of a specific risk source is a prerequisite to identification of a risk.
- 5.75 Notes 3 and 4 specifically recognise that risks can be characterised as a combination of risks and events and, in particular, the consequences and probability of an event. The Authority considers that Vector and Transpower have incorrectly expressed the risk of loss of supply at the Penrose cable trench as only relating to the possibility of transition joint failure.
- 5.76 Consistent with guidance provided in ISO 31000, the Authority considered how uncertainty could arise in relation to the objectives stated above. This requires consideration of the system components and, in each case, asking what could happen to introduce uncertainty for the safety, security and reliability of electricity supplies. One such part of the system is the cable trench. This is a critical part of Vector's network, and it runs alongside Transpower transformers and control cables.
- 5.77 The Authority has chosen to consider the risk of the cable trench as a whole (the co-location risk) and the specific fire risk (the ignition risk).
- 5.78 The Authority chose to focus on the co-location risk because it is common to separate elements of the power system to reduce risk. For example, separation is part of the permanent restoration at Penrose, and modern switch room basements are designed using fire barriers between independent parts. Separation is an effective treatment of any risk that affects one part of the system (for example, separation would address vandalism and directional drilling risks). Because co-location risk is commonly managed in the industry, and Vector's and Transpower's design standards show that both were aware of this type of risk, the Authority has concluded that they should have identified the co-location risks associated with the Penrose cable trench.
- 5.79 Accordingly, the Authority's view remains that the identification and assessment of the co-location of supply-critical components based on the consequences and probability of failure is appropriate and consistent with the guidance in ISO 31000.
- 5.80 The Authority considers that, when applying risk management practices, it would not have been necessary for Vector and/or Transpower to have knowledge of a specific source of ignition to manage the risk of fire – it is only necessary to know that fire is a possibility. The evidence set out in this report shows that both Vector and Transpower knew about the risks and consequences associated with co-located cables, and therefore could have managed the risks and avoided, or at least reduced, the impact the fire had on electricity supplies to consumers.
- 5.81 The Authority's view is that, by applying the ISO 31000 guidelines:

- a) it was possible for Vector to have identified the criticality of the cable trench contents to maintaining reliable and secure electricity supplies to a large number of its customers. It was also possible to identify potential events other than a transition joint fire that could cause such an event
- b) it was possible for Transpower to have identified the potential risks to critical substation assets and the associated risks to maintaining secure and reliable supplies to its customers.

The submission is inconsistent with Vector and Transpower practice

5.82 In its reconsideration of its interpretation of ISO 31000, the Authority reviewed past Vector and Transpower risk management practices with regard to potentially high impact events that have low probability of occurrence (HILP events). That review demonstrates that it is common practice for risks associated with supply-critical components to be characterised and expressed in terms of consequences of an event and the associated likelihood of occurrence.

Transpower HILP studies

5.83 Transpower undertook a series of HILP studies commencing in 2013. The first HILP study was for Islington substation in Christchurch. The HILP study identified that *the control building fire risk was found to be of particular concern* and noted that:

The control building not only houses the control and protection relays, but SCADA and communications equipment, staff kitchen/office areas, and workshops.

5.84 For Islington, Transpower identified a generic fire event risk in the control room building. The identification and consideration of the potential HILP event risk did not require a specific fire risk source to be identified. Nor did the HILP risk assessment rely on information intelligence of previous destructive control room fires.

5.85 Transpower also undertook a HILP study at Penrose substation in 2013. Amongst other HILP risks, Transpower identified a HILP event risk relating to fire spreading between supply-critical transformers. The HILP study report recommended that *there is a risk-based case to seriously consider fire barriers for transformers T8, T9 and T10 in order to limit fire spread to adjacent transformers.*

5.86 The Penrose transformer HILP event risk is an example of where Transpower has identified a generic transformer fire risk that does not rely upon knowledge of a specific component that might fail and ignite a fire. This appears to be analogous to the identification of a generic risk of a joint or cable fire event in the Penrose cable trench that can affect other cables and also other equipment such as transformers in the immediate vicinity.

5.87 Transformer T10 is located next to the cable trench close to the position where CCI identified the fire as having ignited. This means that the HILP study identified the risk of a transformer fire spreading to other transformers, but did not consider the potential for it to spread to the cable trench or vice versa.

- 5.88 The HILP study clearly shows that the cable trench was a significant risk to the integrity of Transpower's assets at Penrose with the potential to have an adverse and serious impact on its ability to supply its customers.
- 5.89 Unfortunately, despite the broad scope of the HILP study, it did not identify potential risks relating to the use of the cable trench by Vector for its cables.

Vector HILP studies

- 5.90 Vector has undertaken HILP assessments of its network that identified several potential HILP events and expressed these by reference to their consequences and probability.
- 5.91 In its 2013 Asset Management Plan (AMP), Vector identifies events that could lead to extensive loss of supply:

There are a number of credible but highly unlikely contingency events that may occur on a distribution network that would almost inevitably give rise to extensive and extended outages. These are the so-called HILP (high-impact, low-probability) events that would have a widespread impact, but would be inordinately expensive to avoid (if indeed possible) and where the likelihood of their occurring is so low this expenditure cannot be realistically justified. HILP events that Vector, therefore, accepts which could lead to major power outages include:

- *Destruction of the Penrose/Liverpool tunnel and all circuits within. This would leave the CBD supply exposed;*
- *Failure of a tower or structure on the double circuit 110kV overhead line feeding Wairau substation in the North Shore, which would leave a shortfall in supply capacity for the North Shore;*
- *Loss of multiple transmission/sub-transmission cables in a common trench;*
- *Vector has a number of double circuits feeding zone substations which share a common trench. In theory, a single event could, therefore, damage more than one circuit;*
- *Complete failure of a 110kV, 33kV, 22kV, or 11kV busbar at a substation, which would affect multiple circuits; and*
- *Total loss of a zone substation (single or multiple transformers) through a force majeure event such as an earthquake, volcanic activity, flood or plane crash.⁷⁴*

- 5.92 The first and third bullet points show that Vector was aware of the potential threat to electricity supplies arising from the loss of multiple cables in a common trench or tunnel.
- 5.93 In the fourth bullet point, Vector identifies that a theoretical single event could damage double circuits in a common trench at zone substations. It is not unreasonable to conclude that Vector should also have looked at the situation at

⁷⁴ Vector 2013 AMP, section 5, page 16.

the other end of the cables where many circuits were contained in a single trench.

5.94 Included in Vector's list of HILP events are several that are less significant in terms of consequence to customers than the loss of the Penrose cable trench.

5.95 The AMP goes on to state:

For all these cases, the risks are managed to the fullest practical extent possible and contingency plans are in place to minimise the impact of the event.

5.96 Vector's approach in its AMP does not depend on identifying component specific risks (eg, transition joint fire) but on more generic risks expressed as a combination of consequences and the associated likelihood of occurrence.

5.97 The Authority's reconsideration of this issue has reinforced its original recommendation that supply-critical assets must be identified and their assessment given a high priority.

Transpower knew about the fire risk posed by cable installations

5.98 As discussed earlier in this section, Transpower had identified the generic risk related to cables and joints on Transpower sites it considered relevant to the Penrose fire:

Grid Performance NNI Register – NNI 23

Failure of equipment (eg cables and joints) owned by connected customer on Transpower site causes safety hazard and fire/explosion damage to critical Transpower assets leading to loss of supply.

5.99 Transpower's 2013 Fleet Strategy on power cables shows that it had detailed knowledge of cable-related fire risks and the potential for fire to spread:

When cable insulation fails, there is normally an arc flash and a resultant fireball resulting from the ejected materials. In the case of oil-filled cables this can be especially severe because the oil, being pressurised, continues to feed the fire. As the failed cable contains many flammable elements, it can become a source of fuel for a continuing fire (or trigger a fire in adjacent combustible materials). It is this continuing fire that presents a safety risk to people and equipment.

5.100 The description of a potential cable-related, arc-ignited fire event in the Fleet Strategy is very similar to the actual event at Penrose substation.

5.101 Transpower's Fleet Strategy document also states that it is important that "cable installation design considers and appropriately mitigates fire risks from potential cable failure".

5.102 The Authority therefore disagrees with Transpower's submission that it did not have knowledge of cable and cable joint fire risks.

Could Vector have known of the generic risk of a cable trench fire?

5.103 During its investigation, Vector asked CCI to undertake a review of publications to establish the level of information available on in-air cable installation-related fires. CCI's conclusion was:

*From a review of publications, while in-air cable installations have been reliable, there has been an appreciable, low incidence of major cable fires. A few of the major cable fire reports and cable system failure reports were found in the public domain. In general i) the cause of a fire, the remedial measures and the lessons learnt are not given in sufficient detail and ii) it is only possible to find information if the incident has received wide publicity.*⁷⁵

- 5.104 The Authority accepts CCI's conclusion in relation to the scope and questions that it was asked to address.
- 5.105 The Authority's understanding of CCI's conclusion is that, while in-air cable fires have been rare, they are known to have occurred. CCI's study of information in the public domain did not generally provide details of the causes of the fires and lessons obtained from the events unless they had a high public profile.
- 5.106 The Authority has undertaken its own desk-based high-level internet research of available information, and considers that, while there appear to have been few reports of major cable fires, there is sufficient information available to conclude that cables (including cable joints) can and do suffer electrical failures caused by a breakdown of their insulation. These failures can ignite a fire if they happen in air. In conjunction with CCI's conclusion, stated above, the Authority considers it reasonable that electricity network asset managers would be aware that cables can fail electrically due to insulation breakdown and ignite a fire if this happens in air.
- 5.107 For example:

*On February 15 1999 an electrical failure and subsequent fire occurred at Azopardo substation which affected 160,000 customers. The fire was caused by a failed cable joint which ignited a fire which destroyed all the cables in the affected area of a tunnel.*⁷⁶

*On December 20, 2003, a [12kv] cable failure inside of Mission Substation in San Francisco caused a fire that led to the interruption of service to over 100,000 customers. Pacific Gas and Electric's investigation of the event found that, over time, the particular application of PILC cable (40 years in a vertical position) caused the cable to lose its insulating capability.*⁷⁷

- 5.108 As discussed above, Transpower had a detailed knowledge of potential cable-related fire risk, even though cables make up a relatively minor proportion of Transpower's assets. Cables are a much larger proportion of Vector's assets and Vector would have been expected to have at least the same level of knowledge as Transpower.
- 5.109 If Vector had not developed its knowledge of cable-related fire risks to the same level that Transpower had, given the importance of power cables to Auckland's electricity supplies, the Authority recommends that it do this as a priority.

⁷⁵ CCI report, Executive summary, conclusion 14.

⁷⁶ Second-generation Reforms in Infrastructure Services by Federico Basañes, Robert D. Willig, Inter-American Development Bank.

⁷⁷ Extract from Pacific Gas and Electric's investigation

https://www.pge.com/regrel-public/GRC2007NOI/GRC2007-Ph-I_Test_PGE_20050000-00-Exh004-Ch06.doc

5.110 Accordingly, the Authority remains of the view that Vector could and should have identified the Penrose cable trench as a supply-critical component and had knowledge of the generic risk sources from cable-related fires. Had this occurred, in accordance with Vector's AMP statement, Vector would have ensured that "*the risks are managed to the fullest practical extent possible and contingency plans are in place to minimise the impact of the event*".

Could Vector have known of the specific transition joint related fire risk?

5.111 Vector and Transpower's submission on the draft Authority report suggests that the only relevant risk source is transition joint failures that result in fires. The submission argues that such failures are rare, and therefore Vector "*could not have been expected to have the knowledge to specifically identify this risk [fire from cable fault]*".⁷⁸

5.112 Limited desk-top research undertaken by the Authority has revealed that publicly available information is present regarding transition joint fires. For example, Substation Reliability Experts, Inc. has developed a standard solution to address similar situations to the Penrose cable trench:

Cables located in the vicinity of cable joints are at an increased risk of catching fire. Cables running throughout the plant serve as a pathway for fire spread.

SRE Solution:

*This standard is used to apply a protective wrap to power cable joints and power cables in the vicinity of joints. The intent of this procedure is to reduce the effects of an arc blast upon power distribution cables and to reduce the spread of fire after a 'flash' event. The EP3990 wrap material is not designed to contain an arc blast. The intent of the wrap is to mitigate the impact of flame, hot gasses and molten materials upon surrounding power cables.*⁷⁹

5.113 Regarding fire risks related to transition joints in in-air situations, UK Power Networks standard EI 02-0031 installation of power cables and joints (21/11/2013) in air states:

Underground cables and cable joints are designed to be buried direct in the ground. Installation in air should be avoided to limit the possible effects of a fire, caused by a failure and its subsequent spread, unless no other engineering solution is possible.

5.1 Transition Joints between Existing Solid PILC and new XLPE Cables

Experience has shown that this particular type of joint is more prone to an electrical failure than other types due to a mix of old and new technology and particularly the condition of the existing PILC cables. Therefore, the use of such joint in an in-air situation should be avoided unless no other economic engineering solution is achievable.

⁷⁸ Vector and Transpower report page, section 8, paragraph 18.

⁷⁹ Cable Wrap Protection, Substation Reliability Experts, Inc., 2175 Dunavant Street, Charlotte, NC 28203, www.srexperts.com.

- 5.114 The Authority's limited research is insufficient to support a conclusion that Vector should have been aware of a specific risk from transition-joint fires. However, there is evidence that others in the electricity industry were aware of an issue with transition joints.
- 5.115 Further research on this subject has not been undertaken as the Authority considers that knowledge of this specific risk was not a prerequisite to identifying the cable trench as a supply-critical component and HILP event risk.
- 5.116 As set out above, the Authority considers that it is not credible for the only risk relating to nearly 4 km of high-voltage cables, oil cable cooling systems, many cable joints, low-voltage lighting cable and system control circuits, to be a specific type of failure of a transition cable joint.
- 5.117 The Authority therefore does not accept Vector and Transpower's submission that knowledge of the specific transition joint risk was a prerequisite to the identification and management of the supply-critical cable trench.

The SRC review supports the Authority's views

- 5.118 In its consideration of risk factors relating to the Penrose fire, the SRC emphasises that risk identification for assets needs to take a broader consequence-based view, as well as an event-based view.⁸⁰

Potentially systemic factors related to asset management systems, processes and practices

Asset failures can be predicted and investments supported

- 5.119 The CCI report describes CCI's view of how Vector should apply probability analysis in its asset management practices:

It is recommended that in performing the first stage of a risk assessment a sensitivity study be performed in which failure accelerating factors are applied to the fault rates for the main generic types of joints and cables to represent design, condition, age and proportion of the load to their rated current carrying capacity. Such factors should be applied in particular to the more vulnerable components such as transition joints and to older PILC joints. In the second stage of the risk assessment it is recommended that the consequence of failure be assessed (such as fire spread and disruptive violence to other assets).⁸¹

- 5.120 Over the last 20 years, forecasting the risk of failure of an asset over its lifetime has become standard asset management practice in the electricity industry. Information gathered internationally on failure rates has enabled asset failure rate curves to be developed and applied when making asset management decisions.⁸² Using probability forecasting techniques, asset managers are able to

⁸⁰ SRC letter, page 1. A copy of the SRC letter is attached as Appendix E.

⁸¹ CCI report, section 15.6.1.

⁸² For example, a continuous probability distribution curve called a Weibull curve has been used since the 1950s. It is used in Reliability Centred Management (RCM) to forecast asset reliability over an asset's lifecycle. This is

predict when assets are likely to fail and use this information to develop appropriate replacement, refurbishment and maintenance strategies. Cable failure rates increase as cables approach the end of their expected lives. Identifying the point at which the risk of failure becomes higher than the cost of replacing or refurbishing the asset is a core asset management activity.

- 5.121 A simple cost benefit analysis calculation has demonstrated that that there would have been significant net economic benefit for work to reduce the cable trench risk.⁸³ Further discussion on the cost benefit calculation is provided in section 8.

Categorisation of assets did not take sufficient account of the characteristics of the cable trench

- 5.122 The Authority has assessed the potential for systemic issues within the asset management practices adopted by Vector and Transpower. The approach the Authority took in this assessment was a ‘top-down’ review of governance and management to establish how the businesses document their asset management plans (AMPs).⁸⁴ Electricity industry AMPs document what businesses intend to do. Information provided in the AMPs can be compared with observations about what businesses actually do in practice.
- 5.123 Vector has a well-documented asset management system that aligns with industry standards and is independently reviewed periodically. A review of Vector’s recent AMPs reveals that cable trenches are not specifically addressed.
- 5.124 The Penrose cable trench was a special cable trench because it had some features comparable to an extension of a switchroom basement or cable tunnel. For example, it contained a large number of power and control cables laid in close proximity. Categorising and treating the power and control cable installation as a cable trench meant that Vector did not consider the specific features of the Penrose cable trench that meant its security was critical to the maintenance of electricity supplies. As a result, Vector did not routinely undertake monitoring or maintenance inspections. CCI found that some cables were not secured (cleated) properly. The investigation confirmed that the trench covers were rarely lifted and were not lifted during Transpower’s HILP study.
- 5.125 In its 2013 AMP, Vector described the enhanced Condition-based Risk Management (CBRM) framework to be implemented. Included in the purpose of the CBRM framework is:

... a criticality-assessment framework that rates the importance of all assets in terms of the potential impact failure or mal-function of the asset would have on public and operator safety, on network reliability and on operational effectiveness. The criticality assessment takes into account factors such as asset location (geo-spatial analysis), network

sometimes referred to as a ‘bath-tub’ curve due to its shape. See:
<http://www.weibull.com/hotwire/issue14/relbasics14.htm>

⁸³ Such a calculation would require identification of an appropriate failure probability value. An example of such a value is provided in the CCI report, in section 15.6.1.

⁸⁴ Information disclosure requirements under subpart 9 of Part 4 of the Commerce Act 1986 include the requirement for electricity distribution businesses to publish AMPs. An AMP is intended to be the principal document that drives an electricity distribution business’s asset investment planning.

*capacity impacted by failure of the asset and the likely customer impact as a result of the failure of the asset. The criticality information forms the basis for assessing the impact that the failure of an asset will have.*⁸⁵

5.126 Vector should have captured the supply-criticality of the Penrose cable trench and its cables within the purpose of the CBRM framework. If this had occurred, Vector would have been able to control the associated risks. In its 2013 AMP, Vector notes that the initial stages of the implementation of the CBRM programme focused on overhead line assets because these are vulnerable assets in Vector's network. Prioritising in this way meant that Vector's identification of the Penrose trench and cables would occur later in its CBRM roll-out.

5.127 The AMPs cover the information and communication technologies (ICT) that have become vitally important components of network management. When considering cyber security risks, Vector considered the following:

*Communication protocols are one of the most critical parts of power system operations, responsible for retrieving information from field equipment and, vice versa, for sending control commands.*⁸⁶

5.128 Vector's AMP does not identify the fact that control cables at the Penrose GXP are critical to the proper functioning of the ICT system or that these cables are run in the same trench as the power cables.

5.129 The CCI report recommends for new installations that:

*... data and pilot and control cables be fire segregated from the power cables, preferably outside the trench.*⁸⁷

5.130 Completing the roll-out of Vector's CBRM framework, including identifying supply-critical assets, is an important step in asset management. The collection of reliable asset data on large complex electricity networks is challenging and can take several years to complete. Prioritising the roll-out of the CBRM is essential and Vector's initial focus on the more vulnerable overhead assets is understandable. However, the Authority considers that Vector should have categorised the cable trench in such a way as to reflect its criticality to electricity supplies and ensure that it was able to prioritise the associated risks appropriately.

Vector and Transpower failed to meet all of their access and occupation responsibilities

5.131 The access and occupation arrangements related to Vector's cables in the Penrose cable trench are described in section 3.

5.132 The Authority found that Vector and Transpower failed to meet all of their responsibilities under the prevailing access and occupation arrangements relevant to the cable trench at Penrose substation because:

⁸⁵ Vector Electricity AMP 2013, section 6.1.3.

⁸⁶ Vector Electricity AMP 2013, section 5.12.6.

⁸⁷ CCI report, section 15.4.1.

- a) the original schedule of cables was not accurate, as it did not identify all cables in the cable trench
- b) as cables were added to the cable trench over time, cable asset documentation (eg, drawings and schedules) in respect to the access and occupation documentation, were not accurately maintained by either party
- c) neither party followed formal request and approval processes for recent cable additions
- d) Transpower did not undertake compliance reviews of the requirements of the access and occupation arrangements.

5.133 The Authority considers that Vector and Transpower asset managers had an inadequate understanding of the requirements of the Penrose access and occupation arrangements. For example, early in the inquiry, the Authority encountered uncertainty from Vector and Transpower as to which party owned the cable trench and what formal agreements were in force with respect to Vector's cables within the cable trench. Inconsistencies between Vector's and Transpower's views regarding access and occupation responsibilities are discussed in the Vector and Transpower report:

Transpower's view is that when the Connections Contract was entered into the intent was for all existing and future Vector assets at Penrose to be covered by it, to the exclusion of previous agreements.

*Vector's view is that the current version of the Connections Contract does not cover all existing Vector assets at Transpower's Penrose substation. Vector agrees that greater certainty is required, and that the Connections Contract should be updated to reflect all existing and future Vector assets.*⁸⁸

5.134 In addition, the Vector and Transpower report states that there has been "*limited centralised awareness within Transpower of the Vector cables in the trench at Penrose*".⁸⁹

5.135 These findings highlight the need for greater attention to formalised asset management practices at network asset boundaries.

5.136 The Authority considers that these findings indicate issues that may be relevant to all electricity lines businesses. To address this, the Authority considers that Vector and Transpower should comprehensively review their asset management practices at all points of connection between their respective networks. In addition, Transpower should also review its asset management practices at all network asset boundaries.

The SRC review emphasised the issue of evolving risks associated with incremental development over long periods of time

5.137 Relevant to the points discussed in this section, the SRC review emphasised what it termed the 'creeping' nature of the risk over a long period of time, as more cables were added to the cable trench. The SRC considers incremental

⁸⁸ Vector and Transpower report, section 6.2.1.

⁸⁹ Vector and Transpower report, section 6.3.

development over decades makes it hard for parties to be sensitised to evolving risk, but nevertheless considers it important that parties are sensitised to it.

Potentially systemic factors related to network design

An appropriate planning criteria was not applied to the cable trench

- 5.138 The design of electricity network architecture includes consideration of an appropriate level of built-in redundancy. This anticipates that electrical equipment can fail for a variety of reasons, and seeks to ensure continuity of supply in such circumstances.
- 5.139 The level of network redundancy provided is specified in a network business's planning criteria. Elements of the planning criteria are justified on economic grounds, related to the value that customers place on having a continuous supply of electricity.
- 5.140 Planning criteria incorporate the concept of a 'single credible contingency', similar in concept to a 'common-mode failure risk'. For example, the loss of a sub-transmission circuit supplying a zone substation is a risk (ie, a single credible contingency) that is commonly anticipated.⁹⁰ When the peak load on the zone substation grows over time to a specified level, the supply continuity risk is mitigated by providing two circuits, each of which is capable of carrying the peak demand on the zone substation. With two sufficiently separated circuits operating in parallel, a loss of supply is avoided if a fault occurs and one circuit is tripped.
- 5.141 Applied to the specific situation of the sub-transmission cables in the Penrose cable trench, it is evident that Vector's planning criteria did not consider that the loss of all power cables within the trench was a single credible contingency. Separation of circuits (eg, in different trenches) supplying common loads would have significantly mitigated the risk to electricity supplies due to the destruction of any one cable trench. This would have meant that supply would have been restored far more quickly to Auckland consumers.
- 5.142 The cable trench contained both sub-transmission and distribution cables. Vector's asset strategy for the Remuera K10 11 kV distribution cable was different from that applied to the higher voltage sub-transmission cables in the cable trench.
- 5.143 Vector applied a 'run to failure' strategy to the 11 kV PILC cables and a 'predictive time to failure' approach for the 22 kV and 33 kV cables.⁹¹ By laying 22 kV and 33 kV cables in the same cable trench, Vector effectively linked the security of the higher voltage 22 kV and 33 kV cables to the run to failure risk of the 11 kV PILC cables. As discussed earlier, 'failure' in this case can result from a failed cable joint and a faulty cable joint can fail and produce a power arc if its insulation breaks down.⁹² Given the context of the Penrose in-air cable trench a

⁹⁰ Sub-transmission circuits relevant to the Penrose fire are circuits that operate at 22 kV and 33 kV. Distribution circuits operate at 11 kV.

⁹¹ As advised by Vector by email to the Authority *Re 11kV cables* on 24 September 2015.

⁹² Transpower ACS Power Cables Fleet Strategy, TP.FS 04.01, Issue 1, October 2013, section 2.2.1.

fire is more likely to result from an arc event due to the presence of combustible material present (eg, plastic, oil, wood and oxygen).

- 5.144 Failure to identify the single credible contingency risk inherent in the Penrose cable trench is a shortcoming in the application of Vector’s network planning criteria related to identification of single contingency risks. All network businesses should undertake processes to review periodically network planning criteria related to situations that would create a single contingency risk.

The SRC review supports and augments the Authority’s views on risk management

- 5.145 In its consideration of risk factors relevant to the Penrose fire, the SRC emphasises that the consideration of the risks associated with the co-location of critical assets is a vital part of risk management, particularly when the asset management regime for some of the co-located assets is different from the regime for other co-located assets.
- 5.146 As an example of this point, the SRC considers that the co-location of ‘run to failure’ assets with other assets critically undermines the intended reliability of the critical assets.⁹³
- 5.147 The SRC review emphasises that risk identification needs to encompass the complete power system, from the consumer right through the supply chain, so that critical areas for supply reliability can be identified for review. The SRC considers that such an approach can help to ensure that co-located assets, and the boundaries between the assets of different industry participants, can be clearly identified for risk assessment purposes.
- 5.148 The SRC review emphasises the desirability of undertaking collaborative risk assessment involving all relevant asset owners. Experience gained from the Penrose fire highlights that a collaborative approach, while difficult, is particularly relevant at points in electrical networks where assets owned by different parties connect. The SRC considers collaborative risk assessment could have prevented the Penrose event, and is a lesson that should be conveyed to risk owners in a variety of utility settings.
- 5.149 The SRC review notes that Vector and Transpower are now pioneering collaborative risk assessment from which the broader industry could take lessons. The SRC considers that Transpower should be encouraged to:
- a) contact all of the parties with direct connections to the national grid and propose they undertake a collaborative risk assessment using the approach that has now been undertaken with Vector
 - b) share the collaborative risk assessment process and templates it has developed with Vector with other industry participants.
- 5.150 The Authority agrees with the SRC’s points concerning collaborative risk assessments and considers they emphasise important lessons that have wide application across all utilities.

⁹³ SRC letter, page 1.

Sufficient separation of assets was not provided

5.151 The cable trench contained a variety of cables of different types. In addition to the power cables, the cable trench contained control and communication cables that perform important monitoring, protection and control functions.

5.152 The CCI report considers that:

... by 1999, when the first XLPE cables with PE oversheaths and wire screens were installed in the Penrose trench, the manufacturing and supply industries were aware that:

- (i) Cables for in-air use were available with improved fire retardant oversheaths.*
- (ii) Fire segregating measures between circuits were an available option.*
- (iii) Fire detection and extinguishing measures were an available option.*
- (iv) PE oversheath and XLPE insulation materials propagate fire.*
- (v) PVC oversheath material at elevated fire temperatures of > 400°C can propagate fire.*
- (vi) Oil-filled cables were a fire-spread hazard for in-air applications.⁹⁴*

5.153 In addition, the CCI report notes that:

However, the CCI Author accepts that industry engineering recommendations and specifications did not, and still do not, clearly communicate fire precaution knowledge for new circuits, nor give clear advice for existing installations on what retrospective action, if any, should be taken.⁹⁵

5.154 The CCI report recommends that where new XLPE cables are installed in-air:

- (i) XLPE insulated cable circuits that do not have fire retardant oversheaths not be installed in close proximity above, or adjacent to, other circuits.*
- (ii) Wire screened XLPE cables not be installed close to other cables and services without having fire retardant oversheaths/coatings, fire segregation and increased spacings. Should a cable failure occur, a power arc is likely to emerge through the screen wires and spread fire to adjacent cables not having fire retardant coatings.*
- (iii) Data and communication cables not be installed between power cables, as this risks i) acting as a fire bridge between power cables, ii) early loss of signals in a fire, iii) disturbing the power cables and joints during installation and iv) impairing the power cable heat dissipation in normal service. It is recommended that data and pilot and control cables be fire segregated from the power cables, preferably outside the trench.⁹⁶*

⁹⁴ CCI report, section 15.4.1.

⁹⁵ CCI report, section 15.4.1.

⁹⁶ CCI report, section 15.4.1.

- 5.155 The Authority considers that, when making decisions to purchase and install XLPE cables after 2000, Vector should have researched and taken into account manufacturers' information and canvassed industry knowledge. However, the Authority acknowledges, given CCI's advice, that this information may not have been made available to Vector.
- 5.156 CCI has made important recommendations that could be relevant to all network businesses.

Network protection could not identify the fault location

- 5.157 The investigation concluded that the protection schemes at Penrose performed as designed with two exceptions.⁹⁷ The protection operation indications did not show that the fault was in the Penrose section of the Remuera K10 feeder. However, it is normal practice that protection schemes do not provide an indication of the location of faults.
- 5.158 The manual reclose of Remuera K10 at 1:21 am was undertaken following a line patrol of the overhead sections. The faultman undertaking the line patrol suggested that:

*... the fault was in the overhead section ... based on information from fault passage indicators.*⁹⁸

- 5.159 The practice of only inspecting overhead sections⁹⁹ and the absence of a fault location indication meant that the faultman did not identify the cable fault in the cable trench during the initial line patrol.
- 5.160 The Authority notes Vector's recommendation to make:

*... specific amendments to the procedures in light of the incident.*¹⁰⁰

The Authority has been informed by Vector that these amendments have now been completed.

Potentially systemic factors related to regulatory incentives and controls

Vector and Transpower have not commented on regulatory constraints

- 5.161 The Commerce Commission regulates Vector and Transpower under Part 4 of the Commerce Act 1986. Transpower is regulated under individual price-quality regulation. Vector is regulated under default or customised price-quality regulation.
- 5.162 Price-quality regulation is designed to ensure that electricity distribution businesses such as Vector:

... have similar incentives and pressures to suppliers operating in competitive markets to innovate, invest and improve their efficiency. It

⁹⁷ Vector and Transpower report, section 3.9.

⁹⁸ Vector and Transpower report, section 3.2.

⁹⁹ Including cable risers and ground mounted switchgear.

¹⁰⁰ Vector and Transpower report, section 3.2.

*also aims to limit the ability of suppliers to earn excessive profits, while also ensuring that consumer demands on service quality are met.*¹⁰¹

5.163 The Authority has reviewed:

- a) a number of Vector's AMPs
- b) Vector's State of the Network reports
- c) Transpower's Penrose site strategy document
- d) Transpower's Penrose HILP report
- e) the Vector and Transpower report.

5.164 No issues have been identified by the Authority regarding regulatory constraints that would prevent either Transpower or Vector from addressing asset risks at the Penrose substation.

5.165 In discussions, Vector and Transpower did not raise any comment or raise concerns relating to price-quality regulation, as applied by the Commerce Commission. The Authority considered if price-quality regulation could have been a contributing factor to the Penrose fire. The Authority found that the price-quality regulation provides for both Vector and Transpower to secure sufficient revenue to make investments and maintain their assets. The Authority concluded that price-quality regulation was not a contributing factor to the Penrose fire.

¹⁰¹ <http://www.comcom.govt.nz/regulated-industries/electricity/electricity-default-price-quality-path/>

6 Assessment of the fire hazard management systems at Penrose substation

6.1 This section covers the Minister's second question:

What fire hazard mitigation systems were in place; and did they operate as intended?

6.2 The inquiry has found that:

- a) fire hazard mitigation systems were not installed in the Penrose cable trench
- b) fire hazard mitigation systems are not routinely installed in cable trenches
- c) the Penrose cable trench was an unusual installation
- d) the repair of fire-damaged equipment provides an opportunity to improve fire hazard management.

6.3 This section explains the basis for these conclusions.

Fire hazard mitigation systems were not installed in the Penrose cable trench

6.4 No fire hazard mitigation systems were installed inside the Penrose cable trench or in the vicinity of the cable trench.¹⁰²

6.5 The Vector and Transpower report states:

*Transpower and Vector use a range of design standards in planning and developing their networks. These ensure assets are designed to appropriately mitigate risks such as fire risk.*¹⁰³

6.6 The Authority considers that the Penrose event has demonstrated that the design standards were either not applied, or were not sufficiently scoped, to include the fire hazard risk inherent in the Penrose cable trench.

6.7 As noted above, Vector and Transpower disagree with the Authority's conclusion that they could have been expected to identify the risk.

Fire hazard mitigation systems are not routinely installed in cable trenches

6.8 The investigation included a survey of international practices related to hazard detection and containment systems in cable trenches. It found that terms such as culverts, ducts, troughs and channels are commonly used as an alternative to 'trench'.

6.9 The survey undertaken for the investigation identified that:

*No network companies were found to have installed fire detection or suppression systems in structures like the cable trench.*¹⁰⁴

¹⁰² The Vector and Transpower report does not directly state that no fire hazard mitigation systems were in place but this has been confirmed in discussions with Vector and Transpower.

¹⁰³ Vector and Transpower report, section 7.3.3.

¹⁰⁴ Vector and Transpower report, section 7.6.4.

- 6.10 However, the Penrose cable trench had features that made it quite different from general cable trenches. It was situated in a major substation and contained important supply cables that were critical to maintaining electricity supplies to a large number of customers.
- 6.11 The survey did identify actions taken with respect to the fire risk in such structures, which is the result of the risk management practices of the network businesses. The survey did not specifically research how other network businesses would have identified and managed the risks associated with co-locating multiple supply-critical cables in a common trench.
- 6.12 Applying international risk and asset management standards and modern asset management systems allows supply-critical components to be identified and managed. Whilst adopting such standards does not guarantee that all risks will be identified, the Authority considers that Vector and Transpower, having adopted these standards and systems, should have identified the Penrose cable trench as a critical network component and as a potential HILP event risk.
- 6.13 As noted above, Vector and Transpower disagree with the Authority's conclusion that they could have been expected to identify the risk.

The Penrose cable trench was an unusual installation

- 6.14 As discussed in section 5, the Penrose cable trench was unusual in that it contained so many supply-critical circuits in an in-air cable trench. Distribution cables that were run to failure were co-located with sub-transmission cables that are managed to a higher security standard. In this respect, identifying this installation as a cable trench was insufficient to reflect its criticality to power supplies and its potential risk to safety.
- 6.15 The Authority considers that had Vector and Transpower fully assessed the characteristics of the Penrose cable trench the risks to supply would have been identified and assessed. The actions taken by Vector and Transpower since the fire show that there were a number of practical actions that Vector and Transpower could have taken to reduce the risks to supply. For example, Transpower informed the Authority that cable joints it had subsequently identified in cable basements were now covered with sand bags. This is a low-cost but effective interim measure to mitigate the risk of joint failures causing a fire.

Fire hazard mitigation measures should have been considered

- 6.16 The Authority acknowledges that international practice related to risk management of cable trenches is inconsistent. There is evidence that some network businesses have adopted practices that would prevent cable joint fires. For example, a number of Australian network businesses now do not allow cable joints to be installed in sections of cables laid in in-air situations.
- 6.17 Some network businesses were aware of the potential risks from cable joints in in-air situations; however, this information does not appear to have been widely shared across the electricity industry. No evidence has been provided to the inquiry that Vector researched this area prior to the October 2014 fire.
- 6.18 Fire hazard mitigation measures are likely have been economically viable given the potential consequences of a fire. As the investigation has shown, it took

nearly 7.5 hours to locate and contain the fire after the initial cable joint fault on the Remuera K10 feeder.¹⁰⁵

- 6.19 The Authority considers that a fire hazard mitigation system would have led to early detection and extinguishment of the fire, possibly eliminating (or at least reducing) the damage to the adjacent cables and substation equipment.

The Penrose fire provides an opportunity for improved fire hazard management across the industry

- 6.20 The Authority considers that the Penrose fire provides important lessons about asset management, relevant to all network businesses. The lessons should be reviewed by network businesses for relevance to their individual situations.
- 6.21 For existing installations where cable joints are installed in in-air situations, interim fire prevention measures should be considered, such as sandbagging. Longer-term fire hazard mitigation approaches, such as segregation of cables, application of fire retardant paint and cable sheaths and periodic inspection and monitoring, should also be considered.

¹⁰⁵ See sequence of event timings and durations in Appendix B, table 4.

7 Safety, communication and mitigating loss

7.1 This section covers the Minister's third question:

What actions were taken during the course of the outage in respect of:

(a) ensuring the safety of people and equipment?

(b) communicating with affected and interested parties (including emergency services) about the impact of the event and the timeframes for restoration of supply?

(c) mitigating the loss of supply and expediting restoration?

7.2 This section first considers parts (b) and (c), then returns to questions related to safety.

7.3 The inquiry has found that:

- a) Vector and Transpower managed affected customer and public communications well
- b) Vector and Transpower managed the process of supply restoration well, given the extent of the damage
- c) Vector and Transpower have not completed safety-focused reviews with sufficient formality and urgency
- d) some safety issues have not been identified by Vector and Transpower
- e) the Penrose substation fire provides valuable lessons regarding safety and coordination with emergency services during incidents at substations
- f) Vector and Transpower must share the lessons with other stakeholders
- g) an independent review of safety should be undertaken.

Vector and Transpower managed communications with affected customers well

7.4 The Vector and Transpower report states that there was extensive communication during the outage to a wide range of stakeholders, including affected customers, emergency services, council and government.¹⁰⁶

7.5 The first customer communication was an update on Transpower's Facebook page at 3:20 am on 5 October. The first media statement was issued at 3:50 am. As the events unfolded, primary responsibility for external communications passed from Transpower to Vector.

7.6 In total, 18 customer updates were provided by Transpower and Vector during the event. This provided a source of frequently updated information for stakeholders.

7.7 Vector and Transpower provided customer and public updates using a broad range of communication channels, including:

¹⁰⁶ More detailed information on external communications is available in the report: Vector, *Penrose Substation Fire – 05 October 2014 – Customer Management*, Issue 1, 10 March 2015.

- a) websites
 - b) Facebook pages
 - c) Twitter accounts
 - d) Vector's contact centre (calls and email)
 - e) calls to electricity retailer call centres
 - f) direct contact with larger consumers by Vector account managers
 - g) Vector's recently developed smartphone outage application
 - h) media releases
 - i) media interviews by Vector and Transpower CEOs.
- 7.8 Vector provided additional information to retailers to assist them in managing medically dependent and vulnerable consumers. The Electricity and Gas Complaints Commissioner has informed the Authority that no complaints had been lodged with the service from medically dependent consumers relating to the Penrose fire.
- 7.9 While it is not possible to canvass every impacted stakeholder, the Authority has identified no concerns regarding the management of stakeholder communications related to the Penrose fire event. The Authority considers the joint communications effort fronted initially by Transpower and subsequently by Vector:
- a) was well planned and coordinated between Vector and Transpower, with clear role responsibilities
 - b) used a wide range of channels to ensure the latest information was available to stakeholders, including use of digital media
 - c) was mindful of medically dependent and vulnerable consumers.
- 7.10 Nevertheless, major event management is only rarely experienced. The Authority considers the Penrose fire event provides valuable lessons for all electricity lines businesses and retailers, particularly related to:
- a) joint planning for responding to major events
 - b) inter-business coordination as events unfold, to ensure consistent, up-to-date status information is constantly available for the duration of the event
 - c) application of the widest range of communications channels.

The process of supply restoration was well managed given the extent of the damage

- 7.11 The Vector and Transpower report states that operational coordination between Vector and Transpower during re-livening and repair works functioned effectively.¹⁰⁷

¹⁰⁷ More detailed information on supply restoration is available in the report: Vector, *Penrose Substation Fire – 05 October 2014 – Customer Management*, Issue 1, 10 March 2015.

- 7.12 Control of the site passed from NZFS back to Transpower at 9:57 am on 5 October. The Vector and Transpower report states that established site procedures were used, such as site access and issuing of permits for work.¹⁰⁸
- 7.13 Restoration of supply to all affected customers required effective coordination between Transpower, Vector and their respective contractors. This was initially achieved through regular onsite meetings and close coordination with EOC and NGOC.
- 7.14 Vector and Transpower established restoration priorities, initially focused on restoring supply to the 220 kV Penrose bus with sufficient capacity to supply the anticipated loads.¹⁰⁹
- 7.15 All equipment was inspected before it was re-livened and restoration followed a planned process to ensure it was carried out safely with no further equipment failures. The switchyard was vacated of all personnel before each major item of equipment was energised. The first equipment inspections were completed at 10:41 am on 5 October, allowing step-by-step restoration of 220 kV and 33 kV supplies.
- 7.16 Communications during the restoration phase were affected by degradation of mobile phone services from around 11:00 am.
- 7.17 Restoration was suspended for approximately one hour around 1:47 pm when smouldering timber re-ignited. NZFS was called to deal with this, requiring de-energisation of some already re-livened equipment to ensure safe access for firefighters.
- 7.18 In parallel with Transpower's restoration work, Vector commenced assessment of the extent of damage to feeder cables to identify the undamaged feeders that could be safely re-livened.
- 7.19 33 kV bus re-livening commenced at 2:52 pm, allowing Vector to commence re-livening of the undamaged feeders to zone substations. By 6:21 pm, Vector had re-livened seven zone substations, restoring supply to over 36,000 customers in Epsom, Newmarket, Glen Innes, Penrose and Westfield.
- 7.20 Transpower continued restoring the Penrose 220/33 kV supply transformers to provide additional capacity and improve supply security. After smoke residue had been cleaned off equipment, the T8 220/33 kV supply transformer was re-livened at 4:26 pm.
- 7.21 The restoration process was expedited by Transpower operating equipment above normal ratings for short periods. This allowed Vector to restore supply to some customers earlier than would otherwise have been possible, while Transpower continued inspecting 220 kV equipment.
- 7.22 Throughout Sunday night, Vector EOC controllers extensively reconfigured the Vector network to enable back-feeds from alternative zone substations into de-

¹⁰⁸ Vector and Transpower report, section 3.4.

¹⁰⁹ Supply *capacity* can usually be provided by one circuit; however, full supply *security* is only provided when an additional circuit or circuits is/are livened to provide redundancy, so that a subsequent single circuit fault does not result in a loss of supply.

energised areas.¹¹⁰ This allowed supply to be restored to a further 18,786 customers overnight on 5/6 October.

- 7.23 Transpower brought additional staff to Auckland from other areas to enable 24-hour work during the recovery phase. Specialist engineering resources were also deployed to Penrose substation to assist with damage assessment and restoration.
- 7.24 Transpower's next priority was to achieve full restoration of the Penrose 220 kV switchyard, to improve supply security to the Auckland CBD via the Auckland tunnel 220 kV cable to Hobson Street substation.¹¹¹

With some 220 kV and 33 kV supply capacity restored, progressive restoration of Vector's network could proceed

- 7.25 The Vector and Transpower report states that the repair works to restore supply to the remaining 20,257 customers were large and complex.¹¹²
- 7.26 All circuits in the cable trench were fire-damaged beyond repair. Recovery initially focused on repairing five cables, each supplying a different de-energised zone substation. With one cable restored to provide capacity to each zone substation, the remaining destroyed cables were then repaired to restore normal supply security.
- 7.27 As the cable trench was extensively damaged by the fire, Vector and Transpower identified alternative temporary routes through the substation for the new cables. These were agreed between the parties by the evening of 5 October. Vector commenced cable repair work at 9:00 pm.
- 7.28 Each repair required the damaged section of cable to be cut out and a replacement section of new cable spliced in. Crews worked continuously to complete repairs. Working conditions over the initial 24 hours of the repair operation were challenging, with periods of severe rain, high wind and hail through the night of 6 October.
- 7.29 Repairs to the first two cables were completed by early morning on 7 October. A third cable was re-livened by 1:35 pm on 7 October and this enabled full supply restoration to all affected customers shortly afterwards.
- 7.30 Repairs to all remaining damaged cables were completed by 15 October. The repair effort was a 24-hour operation for the first week before reverting to a daily operation to relieve worker fatigue.
- 7.31 Over 50 people were dedicated to working on the recovery effort, requiring over 4,000 hours of effort. No safety incidents were reported in this time. In total over:
- a) 8 km of temporary cables was installed
 - b) 60 new cable joints were installed

¹¹⁰ Vector's network design enabled extensive use of back-feeds to restore supply to affected customers from adjacent areas that were unaffected. This was carried out in stages starting on the morning of 5 October. Over 23,000 customers (nearly one-third of affected customers) were restored using back-feeds.

¹¹¹ Normal supply security was eventually restored to Penrose substation at 9:22 pm on 8 October.

¹¹² Vector and Transpower report, section 3.5.

- c) 1,000 cable supports were used
- d) 2,000 cable clamps were installed
- e) 5,000 sandbags were used on the site.

Supply restoration to customers

7.32 The Vector and Transpower report states that Vector focused on safely restoring all customers as quickly as possible.¹¹³

7.33 Restoration of customers was carried out in the following order:

- a) re-livening customers supplied by undamaged cables
- b) switching the distribution network to back-feed customers from adjacent unaffected substations
- c) repairs to damaged cables.

7.34 The Vector and Transpower report states that:

- a) 36,296 (48 per cent) of customers were restored by 6:21 pm on 5 October
- b) 54,113 (72 per cent) of customers were restored by 8:00 am on 6 October
- c) 73,552 (98%) of customers were restored by 8:00 am on 7 October
- d) all customers were restored by 2:08 pm on 7 October.

The Authority's conclusions relating to the process of supply restoration

7.35 The Vector and Transpower report expresses the following view about the restoration effort after the site was handed back to Transpower at 9:57 am on the morning of 5 October:

The incident was a large and complex event that placed extreme demands on Transpower and Vector. The joint response is considered to have been effective because:

- a. *There were no reported injuries or safety incidents affecting the public, Transpower and Vector staff, their contractors, or members of Emergency Services;*
- b. *Relivening and repairs were completed without delay once control of the site was returned to Transpower. Transpower and Vector promptly mobilised all necessary resources, and drew on existing spares holdings to achieve this;*
- c. *Customers were kept well informed during the outage through regular updates delivered across a wide range of communication channels; and*
- d. *No other equipment at the substation was damaged during the restoration and recovery efforts.*¹¹⁴

¹¹³ Vector and Transpower report, section 3.6.

¹¹⁴ Vector and Transpower report, section 8, paragraph 14.

- 7.36 The Authority considers that Transpower and Vector carried out equipment repairs and supply restorations quickly. The Authority appreciates that Transpower and Vector were required to make a vast number of decisions under urgency and a significant repair effort involving prioritisation and management of a large workforce was required.
- 7.37 The need to bring NZFS back to the substation on the afternoon of 5 October had a relatively minor impact on the repair and restoration effort, but indicates the level of vigilance required at all times.

The SRC supports the Authority's view that the restoration phase was well managed by Vector and Transpower

- 7.38 The SRC notes that various post-event activities have been performed well. In particular, the response of Vector and Transpower during the event, the communication with the public and media, and the subsequent implementation of actions, have all been areas of success.

Safety-focused reviews have not been completed with sufficient formality and urgency

- 7.39 The Authority notes that there were no reported injuries or safety incidents affecting the public, Transpower and Vector staff or contractors, or emergency services personnel.¹¹⁵ However, the Authority has a number of concerns relating to safety risk management during the firefighting and supply restoration phases.
- 7.40 The Authority notes that ensuring the safety of people and equipment is not one of its functions and accordingly falls outside the Authority's core expertise. However, the Authority makes the following observations with a view to this topic being considered more fully by other parties, as outlined below.
- 7.41 It is important that experiences at the time of an event are documented and evaluated as early as possible. This allows all relevant detail to be documented when it is fresh in mind and ensures that improvements are identified and implemented as soon as possible. This is particularly important for identifying lessons that may reduce the risk of injury to firefighters and electricity industry personnel attending future substation fires.
- 7.42 Transpower has confirmed to the Authority that it has not undertaken a formal review of the conduct of the Penrose fire event with NZFS and Vector. The investigation has relied on interviews with Transpower and Vector staff and contractors in reaching the conclusion that there were no safety issues.¹¹⁶ Transpower has also provided copies of correspondence that it had with NZFS.
- 7.43 Taking into account the seriousness of the fire, the potential lessons that could be drawn and the level of review undertaken to date by Transpower and NZFS, the Authority considers that a formal assessment of the safety procedures for dealing with substation fires should be undertaken.
- 7.44 The Authority also considers that the informal approach described to it by Transpower lacks the necessary rigour to capture important lessons on safety

¹¹⁵ Vector and Transpower report, section 8, paragraph 14 (a)

¹¹⁶ Confirmed during a teleconference with Vector and Transpower staff and Strata directors on 26 August 2015.

performance. At a minimum, the Authority considers that Transpower, as the substation owner, should have led a comprehensive review of safety to personnel and equipment with NZFS and Vector as soon as possible after the fire. The relevant documents provided by Transpower together with its descriptions of what has been undertaken to date have convinced the Authority that a formal assessment of the safety procedures for dealing with substation fires should be undertaken.¹¹⁷

Some safety issues have not been identified and reviewed by Vector and Transpower

7.45 The Authority has identified a number of issues it considers should have been comprehensively reviewed and reported on. The issues include the following:

- a) Transpower's documented procedure requires that a permit be issued prior to allowing fire service access for firefighting, yet a permit was not issued.¹¹⁸ Transpower and Vector dispute this interpretation of the wording of the procedure. Transpower's view is that no permit was required. The Authority's view is that whether a permit is required or not is secondary to the fact that the standard itself is unclear and needs to be reviewed as part of a wider review of safety at the Penrose site during the fire.
- b) EOC confirmed that the Vector cables in the cable trench were de-energised based on SCADA information showing that all substations supplied from Penrose substation were de-energised. Hence there was no possibility of a backfeed from the Vector system. However, at the time of the initial fire attack, neither Transpower nor Vector onsite and control room personnel appeared to have an accurate understanding of the combined contents of the cable trench. Vector EOC is unlikely to have been aware of any cables that Transpower had placed in the trench and Transpower appears to have had an inaccurate knowledge of the Vector cables in the trench. Accordingly, it remains unclear how it was determined that all circuits in the cable trench had been de-energised and made safe for firefighting to commence. The NZFS memorandum highlights this issue when describing the need for firefighters to withdraw due to concerns that not all electrical circuits had been switched off.¹¹⁹ Further, feedback on a draft of this report from the NZFS quotes from post-incident debrief notes that "*[an NZFS staff member] was designated safety officer and described his actions. He was advised by a workmen [sic] from either Vector or Transpower, who stated that he couldn't be 100% sure that power was off in the affected area. [NZFS staff member] then ordered the firefighters to withdraw from the area and advised the OIC of this.*"
- c) NZFS initiated its fire attack at 3:32 am after Transpower advised at 3:22 am that power was switched off in the area adjacent to the 33 kV switchgear building. However, NZFS stated that its frontline personnel were soon

¹¹⁷ NZFS memorandum (9 October 2014) and NZFS letter (undated) and emails all providing time stamped-event sequences.

¹¹⁸ Transpower, *Operating and Emergency Management Procedure TP SS 07.40 Station security procedures*, Issue 13, dated February 2012, paragraphs 10.1.1 and 10.1.2.

¹¹⁹ NZFS memorandum (9 October 2014), second page.

withdrawn "... due to uncertainty that power was actually off and isolated".¹²⁰ The Authority considers that there is significant doubt about the facts related to this part of the fire response. The Vector and Transpower report does not directly refer to this incident and the Authority's subsequent discussions with Vector and Transpower have revealed that Vector and Transpower disagree with the NZFS report of events. Nevertheless, Transpower's reported sequence of events notes that a query was raised with Vector at 3:35 am as to whether there was any back-feed into the substation from Vector's 33 kV network. At 3:38 am Vector EOC confirmed to Transpower NGOC that there was no back-feed. These logged event entries would appear to support the NZFS view that firefighting stopped for a period and that there was doubt onsite as to whether all energised equipment in the vicinity of the fire had been isolated prior to the commencement of firefighting.¹²¹ However, there continues to be disagreement about this aspect of the incident. In particular, there appears to continue to be disagreement as to who raised the concern about whether the power was off and isolated, on what basis the concern was raised, and who ordered the firefighters to withdraw.

- d) The NZFS letter referenced in list item (c) states:

The Fire Service experienced problems knowing who to ask for advice, as there was more than one electricity agency taking responsibility for the site in attendance (i.e. both Transpower and Vector). Conflicting advice from different representatives at various levels, within each organization caused confusion in identifying if extinguishing options could be performed safely.

As stated in item (c), Vector and Transpower have disagreed with this report of events in a follow-up discussion with the Authority subsequent to receipt of the NZFS letter. Regardless of the dispute over the facts, the summary of minutes taken of the incident debrief undertaken by NZFS on Monday 10 October 2014 clearly records that the NZFS personnel who attended the fire had concerns regarding the uncertainty as to whether the power had been switched off, and that they experienced problems knowing who to ask for advice.

- e) The cable trench was contaminated with heavy metal residues and unexpected presence of arsenic.¹²² It is also likely that the oils and residue from plastics had contaminated the trench. The Authority was told that a disadvantage of the rapid expansion foam used to contain the fire in the trench is that it leaves caustic residues.
- f) The Authority was informed that after the fire, NZFS filled the cable trench with water to cool it down. The controls used for disposal of the water to avoid broader contamination are important, but have not been addressed in the Vector and Transpower report.

¹²⁰ Letter from Director, Office of the Chief Executive, NZFS to Manager Market Monitoring, Electricity Authority, 15 September 2015.

¹²¹ The Authority has compiled a sequence of time-stamped events from event logs provided by Vector, Transpower and NZFS – see table 4 in Appendix B.

¹²² As noted to the Authority during its first visit to the Penrose substation on 28 November 2014.

- 7.46 In its letter to the Authority, NZFS provides a synopsis of minutes from a post-event debrief. This synopsis contains some errors of fact; for example, there is no common oil supply for the cables and transformers at Penrose. There is also confusion in the letter about whether the onsite electricity personnel NZFS liaised with were Transpower or Vector staff.
- 7.47 Some confusion is understandable for NZFS frontline personnel who are not familiar with the electricity industry. Feedback on this report from NZFS states that *“The Fire Service’s letter of 15 September was intended to reflect the understanding and perception of firefighters and officers who attended the Penrose substation fire at the time and shortly afterwards at the debrief; namely that its personnel were unsure who was responsible for the site, and making decisions about the isolation of power at different parts of the site.”* The Authority’s view is that these likely errors of fact do not detract from the main conclusion the inquiry has reached regarding safety, which is that the absence of a post-incident review is a significant gap.
- 7.48 Once it became clear that there was a difference of views about safety during the fire at the Penrose substation, the Authority wrote to NZFS, copied to Vector and Transpower, suggesting that they undertake a review to capture the lessons from the fire. This suggestion has been adopted by the parties involved.
- 7.49 Due to the absence of a formal post-incident review involving all onsite personnel, the Authority considers there are important unanswered questions. These include the following:
- a) Were the firefighters adequately briefed on extra high-voltage substation site risks prior to the initial attack? Particularly, site risks associated with:
 - (i) the extent of high-voltage and extra high-voltage equipment de-energisation
 - (ii) the presence of hazardous materials.
 - b) At the time of the fire, who possessed authoritative knowledge of the cable trench contents, sufficient to warrant safe access for NZFS personnel to commence firefighting activities?
 - c) The Authority notes that no permit was issued in accordance with TP.SS 07.40 prior to commencement of firefighting. Transpower initially informed the Authority that this was because safety ‘earth-stick’ connections could not practically be placed on or around burning equipment. As noted in paragraph 4.22, Transpower subsequently informed the Authority that, in Transpower’s opinion, the issue of a permit was not required to allow access for fire services to fight fires.¹²³ The Authority undertook a further review of TP.SS 07.40 and reconsidered the two clauses specifically relating to fire service access to substations:

10.1.1 Fire Service personnel are prohibited by their management to enter a restricted area to attend fires unless they are accompanied by the holder of a valid Competency Certificate.

¹²³ Meeting at the Electricity Authority’s offices on 13 October 2014.

10.1.2 The RAE Competency Certificate holder accompanying the fire brigade must obtain a permit where required to ensure any fire brigade activities in the vicinity of high voltage equipment can be carried out safely.

Regarding determining when a permit is required, section 6.3 of Transpower's Fire Services Familiarisation Checklist provides the following guidance:

If Access is required to work within the minimum approach distance of conductors the Equipment must be isolated and then earthed to the station earth grid. Then an access permit can be issued for work. When the work is complete and everyone has signed off the permit can be cancelled.

During the inquiry, Transpower's responses to questions on the requirement to issue a permit for fire service access have been inconsistent. The Authority considers that Transpower must undertake a review of TP.SS 07.40, and its application, with the objective of removing ambiguity and obtaining a robust procedure in light of what has been learned from the Penrose fire.

- d) What are the facts associated with the apparent need to stop firefighting and question the possible presence of 33 kV back-feeds into the substation from Vector's network (around 3:32–3:38 am)?
- e) Did the firefighters employ appropriate tactics and are there any lessons for fighting possible future substation fires involving high-voltage equipment?

The NZFS report states that the NZFS investigation team interviewed the NZFS Operational Commander on the choice of firefighting tactics and observations during the incident.¹²⁴ However, no further details are provided in the NZFS investigation report on the findings from this interview.

- f) Did flooding the cable trench with water introduce an additional risk associated with dispersal of hazardous fire by-product contaminants into the ground?
- g) Were procedures for handing over control of a fire site involving high-voltage equipment from NZFS to Transpower established prior to the fire? If so, were the procedures followed during the Penrose substation fire event?

Were there sufficient safeguards in place to manage post-fire risks? For example, risks related to possible fire re-ignition (as in fact occurred) and contact by onsite personnel with hazardous substances? The Authority received from Vector a copy of an occupational hygiene assessment report commissioned by Vector. That report considers contaminant risks to personnel working onsite since the fire.¹²⁵ The occupational hygiene assessment concludes that there is a very low risk to short- or long-term

¹²⁴ NZFS report, Process of Investigation, page 11.

¹²⁵ Paragon Health & Safety Consultants, *Occupational Hygiene Assessment – Penrose Substation*, 25 November 2014.

health from the contaminants found on the site at the time the assessment was taken.

7.50 The Authority has not been able to answer the questions raised in the preceding paragraph as many of these questions emerged late in the inquiry process and are outside the Authority's area of expertise. The Authority considers there are sufficient unanswered questions as to justify a comprehensive joint review, and a possible joint standard, related to managing the risks associated with firefighting activities involving electricity network facilities. Such a review should include at least the areas identified in the following paragraph.

7.51 The Penrose fire was a significant and unusual fire event that must be fully reviewed to identify opportunities for improving management of substation fire risks and controls. The Authority considers that a post-event evaluation must include:

- a) the adequacy of fire prevention planning between NZFS and Transpower
- b) the accuracy and adequacy of information available to NZFS on arrival at the substation
- c) how NZFS gained access to the site and the reasons for any delays
- d) how well coordination and communication occurred between NZFS and Transpower prior to and during firefighting activities
- e) identification and management of safety hazards on arrival and during the fire, including possible hazards associated with the fire suppressants used
- f) the appropriateness of methods used to control/extinguish the fire, taking into account the hazardous substation environment
- g) the process of handing over control of the fire site between NZFS and Transpower
- h) a comprehensive peer review by an independent expert.

The SRC review supports the Authority's view regarding the lack of a timely post-event review with NZFS

7.52 The SRC review supports the Authority's view that there should have been a timely post-event review between Vector, Transpower and NZFS so that lessons could be identified while the event was still fresh in the minds of the participants.

The Penrose substation fire provides valuable lessons that must be shared with other stakeholders

7.53 Fires in electricity substations are rare but very dangerous events. This is particularly the case for major substations containing high-voltage equipment. Capturing and sharing lessons from actual events provides an important opportunity to minimise the risks to people and equipment from future fires.

7.54 The Authority has reviewed the Vector and Transpower report, the CCI report and the NZFS report, including draft versions of the first two reports.¹²⁶ None of

¹²⁶ The NZFS report was reviewed and approved by NZFS Area Manager for Auckland City on 11 August 2015.

the post-event evaluation points listed in the previous section have been addressed in those reports.

- 7.55 The Authority considers that a comprehensive and transparent review of the safety aspects of the Penrose substation fire should be undertaken by Vector and Transpower. The review must include engagement with NZFS. To provide assurance that all aspects have been fully covered, the review should be peer reviewed by an appropriate independent safety expert.
- 7.56 Vector and Transpower must share the lessons from the safety review with appropriate stakeholders. To achieve the widest dissemination, lessons must be communicated to all stakeholders, including to other electricity distributors and relevant industry associations.

NZFS has made important points in its submission

- 7.57 The Authority provided NZFS with a draft of the Authority report and NZFS provided comments on two issues relating to perceptions that firefighters had at the time of the fire event. NZFS acknowledges that Transpower holds a different perspective of its management of the event.
- 7.58 NZFS note that “*while Transpower and Vector may be clear about the organisation to which the staff or contractor’s [sic] on site were aligned, that was not the experience of the Fire Service during the event*”.
- 7.59 The Authority agrees with NZFS that the differences in the firefighters’ experience and Transpower’s is important and, when reviewed, is likely to reveal important lessons.
- 7.60 NZFS has restated its understanding that *its staff were withdrawn from firefighting for a period because it was not certain that power in the affected areas was off and isolated*. NZFS’s understanding is different from Transpower’s description of this issue.
- 7.61 The Authority remains of the view that this is a very important safety-related issue that must be fully reviewed. The key point for Transpower to take on board is that NZFS firefighters who attended the fire had the perception that supplies may not have been isolated. A review must focus on why the NZFS firefighters had this perception and not on proving that the perception was wrong.
- 7.62 The Authority notes that NZFS, Vector and Transpower have responded to the concerns raised by the Authority during the inquiry and are in the process of arranging a workshop to consider the event and identify lessons that could lead to improvements when responding to future incidents.
- 7.63 The Authority welcomes the commencement of the joint workshop.

8 An assessment of the economic impact of the fire

8.1 This section covers the Minister's fourth question:

What [was] the estimated economic impact of the outage ... on customers?

8.2 The inquiry has found that:

- a) the magnitude of the supply outage was significant
- b) the economic cost to electricity customers is estimated to be between \$47 million and \$72 million
- c) the economic cost would have exceeded this value but for the performance of NZFS, Vector and Transpower personnel in bringing the fire under control and restoring supply
- d) investment to reduce the cable trench risk would have been justified but was not carried out.

The magnitude of the supply outage was significant

8.3 Under clause 11 of the Commerce Commission's Electricity Distribution Services Default Price-Quality Path Determination 2012,¹²⁷ Vector is required to submit annual compliance statements to the Commerce Commission. Vector publishes its statements on its website.

8.4 The Commission uses Limits (annual SAIDI and SAIFI values) to assess a distribution business's performance.

8.5 On its website, Vector has published its compliance statement for the year ended 31 March 2015.¹²⁸ The compliance statement states that Vector exceeded its allowance, and therefore failed to meet its annual reliability assessment requirement for SAIDI in the year to 31 March 2015.

8.6 Vector also exceeded its annual reliability assessment requirement for SAIDI for the previous assessment period ending 31 March 2014, but did not exceed the reliability requirement in any of the preceding three years.

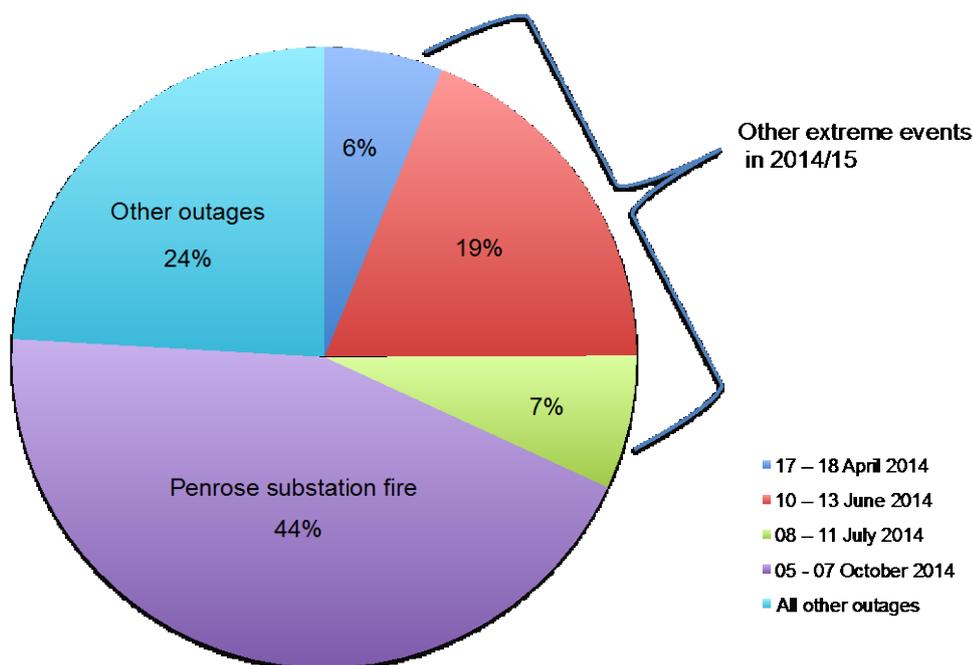
8.7 In the assessment year ending 31 March 2015, Vector classified four events as major event days. Three of the major events were related to extreme weather events and one to the supply interruptions that resulted from the Penrose substation fire.

8.8 Figure 10 highlights the proportion of the supply interruptions on Vector's network caused by the four major events in the year to 31 March 2015. The impact of the Penrose fire in terms of loss of supply to customers can be clearly seen.

¹²⁷ The Commerce Commission issues the price-quality determination pursuant to Part 4 of the Commerce Act 1986. This requires non-exempt suppliers of electricity lines services to provide information to relevant parties for the assessment of their performance against the price path and quality standards.

¹²⁸ <http://vector.co.nz/documents/101943/659865/Electricity+Compliance+Statement+May+2015.pdf>

Figure 11 – Contributions to Vector’s SAIDI for the year ended 31 March 2015



Source: Data from Vector's 2015 Electricity Compliance Statement

The economic cost to electricity customers is likely to have been high

- 8.9 The first step to calculate the economic cost requires an assessment of the amount of energy (load) that would have been used by customers if the fire and the resulting power outages had not occurred.
- 8.10 Owing to the limited information available, it has been necessary to make assumptions when estimating the total amount of unserved load.
- 8.11 To test the sensitivity of assumptions about the amount of unserved load for different customer groups, the Authority has produced a range of estimated results using three alternative assessment methods. Table 1 summarises the methods and the assessed unserved load.

Table 1 – Estimated load not served (MWh)¹²⁹

Customer group	Method		
	Based on Penrose GXP volumes	Based on Penrose and neighbouring GXP volumes	Based on available individual customer metered volumes
Residential	1,286	641	999
Small non-residential	635	336	472
Medium non-residential	547	511	527

¹²⁹ MWh is the standard industry abbreviation for 1,000,000 watt-hours, a unit of energy. 1 MWh = 1,000 kilowatt-hours = 1,000 'units' of electricity. 'Units' are an amount of energy that customers should be familiar with from electricity invoices.

Large non-residential	1,463	1,461	1,462
Total	3,930	2,949	3,461

- 8.12 Over many years, electricity industry stakeholders have assessed the VoLL multipliers. VoLL multipliers represent an average value that a group or category of electricity customers place on electricity not supplied (or 'lost load'). VoLL is not a perfect methodology and may exclude costs such as emergency services costs which the Authority has chosen not to estimate. This suggests that the costs could well be higher than estimated using VoLL.
- 8.13 The total lost load is initially broken down into four Vector customer categories. The lost load is then reassigned to the four customer groups for which VoLL multipliers are available so that the total cost of non-supply can be estimated.
- 8.14 VoLL multipliers (table 2) have been sourced from a report prepared by the Authority.¹³⁰ The report provides VoLL multipliers (in units of \$/MWh) for the following four customer groupings:
- Residential
 - Small non-residential (< 200,000 kWh per annum)
 - Medium non-residential (200,000 to 1,000,000 kWh per annum)
 - Large non-residential (> 1,000,000 kWh per annum).

Table 2 – VoLL multipliers (\$/MWh)

Residential	\$ 11,980
Small non-residential	\$ 56,815
Medium non-residential	\$ 27,992
Large non-residential	\$ 3,906

- 8.15 The lost load per customer group is then multiplied by the corresponding VoLL multiplier to provide an estimate of the dollar value of the load not supplied. This represents an estimate of the economic value of the load not supplied due to the outages that resulted from the Penrose fire.
- 8.16 Table 3 provides a breakdown of the results for each customer group.

Table 3 – Estimated cost of load not supplied (\$)

Customer group	Method		
	1. Based on Penrose GXP volumes	2. Based on Penrose and neighbouring GXP volumes	3. Based on available individual customer metered volumes
Residential	\$ 15,401,215	\$ 7,677,016	\$ 11,973,289
Small non-residential	\$ 36,063,111	\$ 19,070,178	\$ 26,834,430
Medium non-residential	\$ 15,320,679	\$ 14,309,842	\$ 14,763,539
Large non-residential	\$ 5,713,028	\$ 5,706,634	\$ 5,709,570
Total	\$ 72,498,033	\$ 46,763,670	\$ 59,280,828

¹³⁰ Electricity Authority, *Investigation into the Value of Lost Load in New Zealand – Report on methodology and key findings*, 23 July 2013, table 1 – VoLL for Auckland respondents, 8 hour outage.

- 8.17 Table 3 indicates that the estimated economic cost to customers from the outages that resulted from the Penrose fire is in the range \$47 million to \$72 million.

The economic cost to customers could have been much higher

- 8.18 The Vector and Transpower report and the NZFS report confirm that, just prior to commencement of firefighting at 3:23 am, there was an imminent risk of the fire spreading to the Penrose 33 kV indoor switchgear building. Recorded images of the fire show that flames were lapping the side of the building and that the spouting downpipe and adjacent cable racks were on fire. The initial firefighting attack sought to extinguish the fire at the switchgear building.
- 8.19 The point of ignition of the fire was between two large power transformers. Owing to the damage to the control cables near the fire, control signals automatically sent to the substation during the early stages of the fire led Transpower to suspect that one of the transformers could have been on fire.
- 8.20 If the switchroom had been even partly destroyed, supply interruptions would likely have taken significantly longer to restore. Had this occurred, the potential costs of extended supply interruptions could have exceeded the estimated economic costs summarised in table 3.

Investment to reduce the cable trench risk would have been justified

- 8.21 CCI has calculated the cumulative number of faults for the Penrose cable trench at 1.2 over the 48 years it has been in service. CCI notes that this number of faults is 'small, but not zero'. This means that a failure of a cable in the trench could have been expected to occur once every 40 years ($= 48/1.2$ – this value is often referred to as the 'mean time between failures' or MTBF).¹³¹
- 8.22 Using a lower-end value for the estimated cost of the fire to electricity customers of \$50 million, a discount rate of 7% and the MTBF of 40 years results in a present value of \$3.3 million. This indicates that \$3.3 million of investment in prevention actions could have been economically justified for the cable trench on the basis of the cost to customers due to a failure and fire every 40 years. This calculation assumes that a failure will lead to a fire. Given the context of the cable trench with sufficient fuel and oxygen and the failure likely to consist of an arc, the Authority believes that this is a reasonable assumption.
- 8.23 As the potential consequences of the failure and fire could have been much higher, and taking into account the costs of restoration are not included in these calculations, the justifiable investment value is likely to be much higher than the estimated \$3.3 million. This means that there would have been low economic barriers for work to reduce the cable trench risks if Vector or Transpower had identified the need for them.

¹³¹ Cables deteriorate over time and as they age the probability of a fault increases. This is particularly the case as cables approach the end of their expected lives.

9 Other matters considered during the inquiry

9.1 This section covers the Minister's question relating to policy implications and also considers areas not explicitly covered in the Minister's letter but relevant to the Penrose fire.

No policy-related issues were identified during the inquiry

9.2 During the inquiry, the Authority has considered if any policy issues contributed to the cause or effects of the Penrose substation fire.

9.3 The Authority has also considered if issues relating to the structure of the electricity industry may have adversely affected communications with customers during the event. The Authority has not identified any issues relating to the interactions between customers, electricity retailers and Vector. As discussed in section 7, the Authority has found that communications throughout the event with customers, media and the public appear to have worked well.

9.4 As discussed in paragraphs 5.161 to 5.165, the Authority has identified no issues with price/quality regulation relating to the fire.

Part Three Recommendations to improve the resilience of power supplies

10 Actions being taken by Vector and Transpower to improve resilience

10.1 This section covers the Minister's fifth question:

What actions will be taken or are recommended, as a result of the outage and subsequent investigations, to improve the resilience of power supplies and management of outages?

10.2 The inquiry has found that:

- a) Vector and Transpower have identified, and are implementing, a number of actions to improve systems and practices
- b) the actions being taken by Vector and Transpower are appropriate and necessary – several actions have already been completed
- c) the Authority has identified additional actions that Vector and Transpower should take
- d) the Authority should monitor and report on how Vector and Transpower implement the actions, to provide assurance that security of supply will be improved.

The investigation has recommended several actions

10.3 Through their joint investigation, Vector and Transpower have identified 'key learnings' (lessons) applicable to each business individually, and jointly where collaboration will be required to implement remedial actions.

10.4 Vector and Transpower have identified four high-level key learning areas:¹³²

1. *Cable joints installed in air with other cables in close proximity can cause sustained fires when they fail;*
2. *Risk management processes did not identify very low probability events that had not previously occurred on the network;*
3. *The nature of the incident identified opportunities for improvement of standard operating procedures; and*
4. *The asset and risk management processes at the physical interface between Transpower's and Vector's networks need to be improved.*

Vector's and Transpower's actions from Learning 1

10.5 The investigation has recommended that:

- a) *Vector and Transpower implement changes at Transpower's Penrose substation as part of the recovery works, including installing replacement cables in two trenches containing segregated ducts for each cable to effectively eliminate the risk of fire causing multiple cable failures.*

¹³² Vector and Transpower report, section 9.4.

- b) *Vector and Transpower review locations where power cables are installed in open air environments to identify any risks associated with assets at the following locations:*
 - (i) Transpower/Vector points of connection (GXPs)
 - (ii) Vector's network
 - (iii) Transpower sites
 - (iv) take appropriate actions to mitigate these risks.
 - c) *Vector review and update its relevant policies, procedures and practices with respect to cables, and cable joints installed in air.*
 - d) *Transpower incorporate learnings from the Penrose cable fire into asset management practice, including design standards. Include mitigation of risks from failures of cable joints in open air.*
- 10.6 The investigation has recommended that the following actions are undertaken:
- a) *design a new permanent solution at the Penrose substation*
 - b) *construct the solution*
 - c) *inspect all areas on the Vector network where there are multiple cables in open air, including Transpower, and third party substations, assess the consequence of failure, and identify actions to mitigate risks identified from the inspections*
 - d) *inspect all critical Transpower substations to identify cable joints in air, assess the consequences of failure, and identify actions to mitigate risks identified from the inspections*
 - e) *complete all actions identified to mitigate the risks*
 - f) *Vector amend its maintenance schedules to include inspections of all open air cable installations*
 - g) *review and amend Vector policies, procedures and practices that deal with cable system design, installation and maintenance*
 - h) *review and amend Transpower asset management standards that deal with cable system design, installation and maintenance.*

Vector's and Transpower's actions from Learning 2

- 10.7 The investigation has recommended that:
- a) *Vector review and update its risk management framework, and risk identification processes*
 - b) *Transpower incorporate lessons from the Penrose cable fire into risk review processes.*
- 10.8 The investigation has recommended that the following actions are undertaken:
- a) *Vector review and amend its asset risk management framework*
 - b) *Vector amend its procurement processes and contracts to request suppliers to make Vector aware of any significant issues with product failures*

- c) *Vector create a dedicated role within its networks business focused on managing asset risk identification and management processes*
- d) *Vector continue to develop its assessment of asset risk profiles to ensure the criticality of assets is considered*
- e) *Vector review risk identification processes across the Vector group to ensure any learnings from the incident are applied*
- f) *Transpower review the scope of risk studies, including HILP event studies, to ensure coverage of assets owned by connected parties on Transpower land.*

Vector's and Transpower's actions from Learning 3

10.9 The investigation has recommended that:

- a) *Vector update its standard operating procedures to apply key learnings from the incident*
- b) *Transpower update its standard operating procedures to apply key learnings from the incident.*

10.10 The investigation has recommended that the following actions are undertaken:

- a) *Vector update its standard operating procedures for locating faults on feeders with cable sections installed in air*
- b) *Transpower review its communications and existing arrangements with the NZ Fire Service, to identify opportunities for improvement*
- c) *Vector review its communications and existing arrangements with the NZ Fire Service, to identify opportunities for improvement.*

Vector's and Transpower's actions from Learning 4

10.11 The investigation has recommended that:

- a) *Transpower and Vector review contractual terms and management processes at points of connection to ensure key learnings from the incident are incorporated*
- b) *Transpower improve its business process for assessing and approving customer requests for access and occupation of Transpower land*
- c) *Transpower establish an on-going process to provide assurance about the status and condition of customer assets on Transpower land and the potential risks to the grid.*

10.12 The investigation has recommended that the following actions are undertaken:

- a) *Transpower and Vector review contractual terms and management processes at points of connection*
- b) *Transpower review the business process for assessing and agreeing to customer requests for access and occupation of Transpower land. Ensure that a risk assessment is part of the process*
- c) *Transpower establish an on-going process to provide assurance about the status and condition of customer assets on Transpower land and the potential*

risks to the national grid. This process is to focus on critical sites, and to include agreement of risk mitigation plans with customers.

Vector and Transpower have started work to improve resilience

10.13 The final Vector and Transpower report, received by the Authority on 5 November 2015, states that the following improvements have already been completed, or are in progress:¹³³

- *At Penrose a permanent solution for cables damaged in the fire has been designed and agreed between Transpower and Vector. The replacement cables will be installed in fire segregated ducts along two independent routes.*
- *This work will be carried out in conjunction with a separate Transpower project to install a new indoor 33 kV switchroom. The timeframe for completion of this work is June 2016 and is determined by a need to co-ordinate with the indoor switchroom project. Tenders have been let for this work.*
- *Transpower and Vector have each undertaken surveys of their sites to identify situations where failure of cables in air could lead to significant consequences. These surveys have not identified any issues of immediate concern. However, at several Transpower sites, interim risk mitigations for cable joints have been implemented as a precautionary measure.*
- *Vector has developed action plans based upon its site surveys and prioritised these. Works on all critical (priority 1) sites have been completed.*
- *Improvements to risk identification and review processes are underway within both organisations, together with enhancements to relevant asset management standards and operating practices.*
- *Vector has amended its operating procedures for locating faults on feeders with cable sections installed in air, and has commenced training of staff.*
- *Transpower has developed a process for a comprehensive review of Access and Occupation schedules to update the records of customer assets on Transpower land, and evaluate the risks associated with those assets. This process has commenced. The documentation updates and risk reviews for the most critical sites are scheduled to be completed within 12–18 months.*

10.14 The Vector and Transpower report states that “*Transpower and Vector will track progress on actions through established internal processes*”. The Vector and Transpower report provides details of Vector’s and Transpower’s internal assurance processes.¹³⁴

¹³³ Vector and Transpower report, section 10.

¹³⁴ Vector and Transpower report, section 10.

10.15 An update on progress with implementing the above actions was provided to the Authority by Transpower and Vector on 23 October 2015. The progress report is attached at Appendix D.

11 The Authority's recommendations

- 11.1 The Authority considers that the recommendations and actions proposed by the investigation are sound and must be implemented to achieve improved supply resilience.
- 11.2 As the inquiry was conducted in parallel with the investigation, some overlap of the recommendations has occurred. The Authority intends that its recommendations should support the recommendations made in the Vector and Transpower report and the CCI report. The Authority's recommendations also include timeframes for completion of key actions and provide for the monitoring of progress towards achieving them.
- 11.3 Many of the recommendations are relevant to all electricity lines businesses.

Recommendations relating to the Minister's first question

Recommendation 1 – Lessons from the Penrose incident must be shared with industry stakeholders

- 11.4 The detailed background, failure mechanisms and key lessons of the Penrose fire have potential values for other electricity lines businesses. The Authority recommends that Vector and Transpower share the findings of this inquiry and the investigation with other electricity lines businesses.
- 11.5 Where barriers exist to the sharing of information, Vector and Transpower must tell the Authority about the nature of the barriers and the limitations placed on information sharing.

Recommendation 2 – Supply-critical components should be given higher risk management priority than non-critical components, even if the probability of occurrence is low

- 11.6 The Authority recommends that Vector reconsiders how it prioritises risks for its asset management programme so that it gives priority to supply-critical network components. Vector should undertake this review immediately and implement recommendations on improvements before 31 March 2016.
- 11.7 As discussed in section 5 of this report, Vector has previously given priority to overhead components of its network.¹³⁵ However, failure of supply-critical network components can have the most significant impact on customers and Vector should give a high priority to identifying and managing those failures, even if the probability of such failures may be low.

¹³⁵ Section 6.1.3 of Vector's 2013 Asset management plan states that "work on developing a CBRM framework for Vector's electricity assets commenced during FY11, focusing on overhead line assets".

Recommendation 3 – The particular characteristics of each asset must be considered in determining the risk profile of the asset

- 11.8 The Authority recommends that Vector and Transpower review their fire risk mitigation standards and asset management policies to better align with the key characteristics of specific installations. Vector and Transpower should undertake this review immediately and implement recommendations on improvements before 31 March 2016.
- 11.9 For example, a Transpower standard exists that considers fire risk in cable basements but it does not anticipate other in-air installations (ie in-air cable trenches) that have essentially the same characteristics and pose similar risk profiles.

Recommendation 4 – In-air cable joints must be identified and the associated fire risk mitigated

- 11.10 To address explicitly the risk of fire ignition from cable joints, the Authority recommends that Vector and Transpower review their standards for existing power cable joints in in-air situations. For new installations, joints in in-air situations should be avoided where practicable. Vector and Transpower should undertake this review immediately and implement recommendations on improvements before 31 December 2015. The Authority understands that Vector and Transpower have already initiated programmes in line with the above recommendation.
- 11.11 A number of relatively low-cost fire mitigation solutions have been identified by the investigation in its survey of electricity lines businesses. These options should be fully considered and, where appropriate, implemented.

Recommendation 5 – Asset boundaries require improved management between asset owners to ensure clear division of responsibility

- 11.12 The Authority recommends that Vector and Transpower pay greater attention to formalised asset management practices at all boundaries where assets connect to the grid. Vector and Transpower should undertake an immediate review of their asset management policies and implement recommendations on improvements before 31 March 2016.
- 11.13 If the findings from the review indicate a systematic issue beyond Penrose substation, the Authority recommends that Vector and Transpower undertake a comprehensive review of asset management practices at all points of interconnection between their networks. In addition, Transpower should review asset management practices at all network asset boundaries.
- 11.14 The SRC emphasised that collaborative risk assessment is a difficult but important undertaking, and that lessons regarding collaborative risk assessment will be applicable in a variety of utility settings.

Recommendation 6 – Access and occupation arrangements must be reviewed and complied with

- 11.15 All of Transpower's access and occupancy arrangements and procedures through which third parties are allowed to locate assets and equipment at important substations must be fully reviewed and include a periodic compliance

review. Transpower should undertake this review immediately and implement recommendations on improvements before 31 March 2016.

- 11.16 The Authority recommends that Transpower reviews its arrangements regarding access and occupancy, and compliance with those arrangements. Transpower should undertake this review immediately and implement recommendations on improvements to its standard contract before 31 December 2015. The Authority recognises that completion of individual contracts between Transpower and its customers may take some time to complete and some form of prioritisation may be required.
- 11.17 The inquiry found that the arrangements, through which Transpower had provided Vector with access to locate its cables in the Penrose trench were not well understood by either Vector or Transpower. For example, important schedules recording the cables in the trench were inaccurate and had not been updated, and approvals for locating additional cables in the trench had not been documented. These issues must be addressed and corrected in the review.

Recommendation 7 – Planning standards should be reviewed by Vector to ensure the standards are appropriate

- 11.18 The Authority recommends that Vector reviews its network planning standards with respect to the definition of a single credible contingency event relevant to the multiple power cables co-located within close proximity. Vector should undertake this review immediately and implement recommendations on improvements before 31 March 2016.
- 11.19 Thirty-eight power cables supporting 19 supply-critical circuits co-located within an in-air trench was a primary risk factor in the Penrose fire incident. The cable trench was effectively a single contingency risk for the 19 supply-critical circuits. Such supply-critical circuits should have had at least one level of redundancy inherent in the network design.
- 11.20 Included in the lengths of power cables were 11 kV power cables that Vector managed using a 'run to failure' maintenance approach. Locating 'run to failure' cables in an in-air situation in close proximity to other assets that have a higher standard applied to them was a critical factor in extent of supply disruption that resulted from the Penrose fire. Vector must reconsider the application of its network planning standards for these situations.
- 11.21 The SRC's advice included recommending that risk owners compare their existing assets against their present-day design standards with any deviation raising a flag for further investigation.

Recommendation 8 – Future State of the Network reviews should be re-scoped to ensure the reviews are effective

- 11.22 Vector and the AECT should review the scope of the biennial State of the Network reviews to ensure that the reviews achieve what was intended, and that any limitations are fully understood.
- 11.23 The Authority recommends that the scope of future State of the Network reviews include supply-critical network components, and an assessment of how the associated risks are being managed.

- 11.24 Vector and the AECT should undertake the review immediately and include recommendations on improvements in the 2016 State of the Network review and report.

Recommendation relating to the Minister's third question

Recommendation 9 – An independently peer reviewed, post-event safety review must be undertaken to identify improvement opportunities

- 11.25 An early post-event review involving Vector, Transpower and NZFS should have taken place. The lack of such a review has raised, at a late stage in the inquiry, important questions about communications and safety management during and after the fire. Resolution of inconsistencies between the perspectives of Vector, Transpower and NZFS could reveal important lessons and opportunities for improvement in emergency management procedures.
- 11.26 The Authority notes that, in the final stages of this inquiry, Transpower has said that it is considering a safety review that will bring together Vector, Transpower and NZFS in a review of the safety and inter-agency aspects resulting from the Penrose fire.
- 11.27 The Authority considers that the review must include engagement with relevant field and office personnel from Vector, Transpower and NZFS, especially the onsite personnel involved on 5 October 2014. The results must be widely disseminated with relevant stakeholders. This review will provide opportunities to consider and improve safety and fire control management for emergency responses involving high-voltage electrical facilities.
- 11.28 The Authority recommends that the safety review be externally peer reviewed by an appropriate independent safety authority and the outcomes publicised by 31 March 2016.

The actions must be completed

- 11.29 For customers to have confidence in the reliability of their electricity supplies, the Authority considers it important that:
- a) Vector and Transpower afford a high priority to reporting progress towards completion of the recommendations
 - b) there is transparent external monitoring of the progress achieved towards implementing the remedial actions identified in the investigation and in this inquiry.
- 11.30 The Authority recommends that Vector and Transpower submit to the Authority for approval an implementation programme by 31 December 2015. After the plan is approved, Vector and Transpower should submit progress reports to the Authority every six months until all actions have been completed (the monitoring period). Vector and Transpower should engage with the Authority during the monitoring period as may be required by the Authority from time to time.
- 11.31 The Authority will monitor progress made towards completion of the recommended improvement actions and will report to the Minister if there are any deviations from the implementation programme.

12 Glossary of abbreviations and terms

Act	Electricity Industry Act 2010
AECT	Auckland Energy Consumer Trust
AEPB	Auckland Electricity Power Board
AMP	Asset Management Plan
AMS	Advanced Metering Services
Authority	Electricity Authority
CBD	Central Business District
CBRM	Condition-based Risk Management
CCI	Cable Consulting International Ltd
Code	Electricity Industry Participation Code 2010
EHV	Extra high-voltage
EOC	Vector's Electricity Operations Centre
GIS	Geographic information system
GXP	Grid Exit Point
HILP	High impact, low probability
ICP	Industrial and Commercial Installation Control Points
ICT	Information and communication technologies
kV	Kilovolts (= 1000 volts), a unit of electrical voltage
Minister	Hon Simon Bridges, the Minister of Energy and Resources
MBIE	Ministry of Business, Innovation and Employment
MW	Megawatt, a unit of electrical power
MWh	Megawatt-hour, a unit of electrical energy
MTBF	Mean time between failures
MVA	Megavolt-ampere, a unit of electrical power
NGOC	Transpower's National Grid Operations Centre
NZFS	New Zealand Fire Service
PE	Polyethylene
PILC	Paper insulated, lead covered, a type of high-voltage power cable
RAE	Restricted Areas Entry
SAIDI	System Average Interruption Duration Index
Supply-critical	An attribute of a component, or a combination of components, in the supply system where failure of that component or components would result in a major supply interruption.

TOU	Time of Use
Transpower	Transpower New Zealand Limited
Vector	Vector Limited
VoLL	Value of Lost Load
XLPE	Cross-linked polyethylene, a type of high-voltage power cable

13 References quoted and inquiry engagement with Vector and Transpower

References

- 13.1 Vector and Transpower have provided to the Authority a suite of documents and reports at various times throughout the inquiry.
- 13.2 The references listed below are the documents that have been directly quoted in this Authority report.

Joint Transpower/Vector references

Transpower New Zealand Limited and Vector Limited, <i>Penrose Substation Fire – 05 October 2014 – Investigation Report</i> , undated, the final version of which was provided to the Authority on 5 November 2015
Transpower New Zealand Limited and Vector Limited, <i>Penrose Substation Fire – 05 October 2014 – Summary of Protection Operations report</i> , 22 May 2015

Transpower references

Transpower New Zealand Limited, <i>Station security – procedures TP.SS 07.40</i> , Issue 13, February 2012
Transpower New Zealand Limited, <i>Standard Maintenance Procedure – Fire Service Site Familiarisation (SI0045) SMP No: 02.41.025</i> , Issue 2, 19 November 2013
Transpower New Zealand Limited, <i>Penrose Substation High Impact Low Probability (HILP) Event Study</i> , June 2013, Report No: NP573
Transpower New Zealand Limited, <i>Penrose substation fire 05 October 2014 – History of Penrose substation</i> , 3 February 2015, working draft version 1
Transpower New Zealand Limited, <i>Transpower ACS Power Cables Fleet Strategy, TP.FS 04.01, Issue 1</i> , October 2013
Transpower New Zealand Limited, <i>Asset Management Practices: Penrose Cable Fire Investigation</i> , May 2015

Vector references

Vector Limited, <i>Penrose Substation Fire – 05 October 2014 – Customer Management</i> , Issue 1, 10 March 2015.
Paragon Health & Safety Consultants, <i>Occupational Hygiene Assessment – Penrose Substation</i> , 25 November 2014
Auckland Energy Consumer Trust, <i>Electricity Network Review – Request for Proposal 2010</i>
Vector Limited, <i>Penrose Substation Fire – 05 October 2014 – Summary of Protection Operations report</i> , 22 May 2015

General references

Cable Consulting International Limited, <i>Investigation into a Fire in a Cable Trench in Penrose Substation</i> , 3 November 2015
Edif ERA, <i>Analysis of Samples Taken From Cable Trench at Penrose Substation</i> , August 2015
Electricity Engineers' Association, <i>Guide to Electrical Safety for Emergency Services Personnel</i> , Second Edition, Issue 1, April 2009 ISBN; 0-473-11349-X

Electricity Engineers' Association, <i>Guide to Electrical Network Safety for Emergency Services Personnel</i> , Third Edition, May 2015 ISBN: 978-0-473-32447-6
New Zealand Fire Service, <i>Fire Investigation Report</i> , 11 August 2015 (final)
Electricity Authority, <i>Investigation into the Value of Lost Load in New Zealand - Report on methodology and key findings</i> , 23 July 2013
Letter from Director, Office of the Chief Executive, NZFS to Manager Market Monitoring, Electricity Authority, 15 September 2015
Letter from Director, Office of the Chief Executive, NZFS to Manager Market Monitoring, Electricity Authority, 20 October 2015
Letter from Hon Simon Bridges, Minister of Energy and Resources, to Dr Brent Layton, Chair of the Electricity Authority, 7 October 2014

Engagement with Vector and Transpower

- 13.3 The Authority's inquiry team has met with Vector and Transpower representatives to discuss the Penrose fire event on several occasions.
- 13.4 The meetings labelled 'workshops' below included discussion of a range of topics relevant to the progress of the investigation and the inquiry.
- 13.5 The main meetings were as follows:
- a) 14 November 2014 – initial meeting to coordinate investigation and inquiry activities
 - b) 28 November 2014 – a site meeting held at Penrose substation to provide site familiarisation and observe post-fault activities and initial investigation topics
 - c) 19 December 2014 – workshop 1
 - d) 10 February 2015 – workshop 2
 - e) 8 April 2015 – workshop 3
 - f) 27 May 2015 – meeting to discuss lessons and recommendations
 - g) 16 June 2015 – meeting to discuss Vector external communications
 - h) 4 August 2015 – workshop 4
 - i) 28 August 2015 – second site visit to Penrose substation to view the status of repairs and meet afterwards at Vector's Auckland offices for workshop 5
 - j) 13 October 2015 – meeting at Electricity Authority offices between officials to discuss Vector and Transpower submissions on the Authority's draft report
 - k) 14 October 2015 – meeting at Transpower offices between the Chief Executives of the Authority, Vector and Transpower to discuss Vector and Transpower's submissions on the Authority's draft report.
 - l) 9 November 2015 – draft Authority report considered by the Security and Reliability Council, included a Vector and Transpower presentation

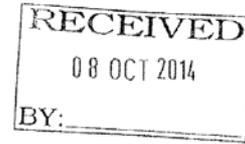
Appendix A The Minister's letter

A.1 A copy of the Minister's letter to the Authority is reproduced below.



Office of Hon Simon Bridges

MP for Tauranga
Minister of Energy and Resources
Minister of Labour
Associate Minister for Climate Change Issues



7 October 2014

Dr Brent Layton
Chair
Electricity Authority
PO Box 10041
Wellington

Dear Brent

The fire at the Penrose sub-station on 5 October which caused a power outage affecting around 85,000 households and businesses in parts of Auckland was a significant event. Many thousands of homes and businesses were left without power for over two days causing significant disruption and cost.

This raises questions about the reliability of power supply. It is therefore important there be a full inquiry so the public can be confident that risks of power supply interruption are adequately managed.

I am writing to request, under section 18 of the Electricity Industry Act 2010, that the Authority undertakes an inquiry of the Penrose outage and report its findings to me.

The Authority should work with all parties involved to address the following questions:

1. What caused the loss of supply or contributed to it, including potentially systemic factors such as risk management systems, asset health monitoring and maintenance practices, network design, and regulatory incentives and controls?
2. What fire hazard mitigation systems were in place; and did they operate as intended?
3. What actions were taken during the course of the outage in respect of:
 - a. ensuring the safety of people and equipment?
 - b. communicating with affected and interested parties (including emergency services) about the impact of the event and timeframes for restoration of supply?
 - c. mitigating the loss of supply and expediting restoration?
4. What the estimated economic impact of the outage was on customers?

5. What actions will be taken or are recommended, as a result of the outage and subsequent investigations, to improve the resilience of power supplies and management of outages?

I also request that the scope of the inquiry includes any policy implications and, because of this, that the Ministry of Business, Innovation and Employment be kept fully informed throughout the process of the inquiry.

Yours sincerely

A handwritten signature in black ink, appearing to read 'S Bridges', with a long horizontal line extending to the right.

Hon Simon Bridges
Minister of Energy and Resources

Appendix B Timeline of events

B.1 The following timeline of events has been compiled from several references. These are:

- (a) the Vector and Transpower report
- (b) the CCI report
- (c) the NZFS report

Table 4 – Timeline of events

Duration [Stage 1]	Duration [Stage 2]	Time	Source	Event
T1 = 0:00		4/10/14 23:21	EOC	Remuera K10 trips - Stage 1 starts
2:00		5/10/14 1:21	EOC	manual reclose of Remuera K10, immediately tripped
2:11		5/10/14 1:32	CCTV	light smoke observed adjacent to 33 kV switchgear building
2:43		5/10/14 2:04	NGOC	unusual alarms noted at Penrose substation
2:46		5/10/14 2:07	EOC	Carbine #2 protection blocked due to failed pilot cable
2:48		5/10/14 2:09	NGOC	substation maintainer dispatched to Penrose
2:49		5/10/14 2:10	NGOC	T11 trips, then 4 x 33kV feeder trippings over the next 5 minutes
2:56		5/10/14 2:17	NZFS	a substation neighbour reports hearing 3 loud explosions at the substation
2:56		5/10/14 2:17	NZFS	NZFS dispatches fire appliances and notifies NGOC
3:00		5/10/14 2:21	NGOC/EOC	more pilot cable failures and 33/22 kV transformer trippings
3:02		5/10/14 2:23	NGOC	notified EOC that a number of assets had tripped and explosions reported to NZFS
3:05	T2 = 0:00	5/10/14 2:26	NZFS	first NZFS appliance arrives at Penrose gate (2nd arrived at 2:28 am) - Stage 2 starts
3:11	0:06	5/10/14 2:32	CCTV	pronounced smoke & light reflections (fire) observed
3:20	0:15	5/10/14 2:41	Transpower	maintainer meets NZFS onsite and opens perimeter security gate; NZFS personnel enter substation
3:23	0:18	5/10/14 2:44	EOC	more cable circuit trippings over next 4 minutes
3:29	0:24	5/10/14 2:50	NGOC	notified EOC that all 33 kV equipment would need to be de-energised
3:34	0:29	5/10/14 2:55	NZFS	message logged that the fire appeared to be in an oil-filled underground cable
3:37	0:32	5/10/14 2:58	NGOC	switching operations commence to de-energise 33 kV and T10; completed at 3:17 am
3:41	0:36	5/10/14 3:02	NZFS	commenced bringing in foam equipment
3:56	0:51	5/10/14 3:17	NGOC	switching operations complete (19 CBs opened) - all 33 + 22 kV equipment de-energised
4:01	0:56	5/10/14 3:22	Transpower	notified NZFS that equipment is de-energised near the 33 kV building area
4:11	1:06	5/10/14 3:32	NZFS	NZFS commences firefighting on the cables exiting the cable trench near the 33 kV building
4:11	1:06	5/10/14 3:32	CCTV	dense smoke and free fire observed
4:13	1:08	5/10/14 3:34	Transpower	Transpower Regional Services Manager arrives, locates in the NZFS command vehicle
4:13	1:08	5/10/14 3:34	Transpower	notified NZFS not to go past the transformers into the 220 kV switchyard because it is energised
4:14	1:09	5/10/14 3:35	Transpower	Transpower queries whether there is any backfeed from the Vector network. Fire fighting is temporarily suspended.
4:17	1:12	5/10/14 3:38	EOC	advises NGOC that there are no backfeeds into the 33 kV system
4:19	1:14	5/10/14 3:40	Transpower	Transpower Regional Services Manager advises EOC that Vector cables are on fire in the cable trench
4:29	1:24	5/10/14 3:50	Transpower	Transpower Senior Maintenance Manager arrives at site
4:34	1:29	5/10/14 3:55	NZFS	message logged that power confirmed isolated, 2 x foam deliveries in use
5:00	1:55	5/10/14 4:21	Vector	Transpower Regional Manager advised Vector GM Network Operations that cable trench containing Vector cables is on fire
5:05	2:00	5/10/14 4:26	Transpower	Transpower manager requests complete shutdown of the 220 kV switchyard
5:09	2:04	5/10/14 4:30	Vector	oil mechanic shuts off oil flow into oil-filled cables
5:09	2:04	5/10/14 4:30	NGOC	commences switching to shut down the 220 kV switchyard
5:14	2:09	5/10/14 4:35	NGOC	switching operations complete (4 x CBs opened)
5:14	2:09	5/10/14 4:35	NZFS	request for hazardous guideline for "hydro treated naphthenic distillate"
5:16	2:11	5/10/14 4:37	NGOC	advises NZFS that the 220 kV switchyard is de-energised
5:16	2:11	5/10/14 4:37	NZFS	NZFS enters 220 kV switchyard area to continue fire fighting
5:24	2:19	5/10/14 4:45	Vector	oil mechanic shuts off oil flow into St John's (4:45 am) and Westfield (5:00 am) cables
5:26	2:21	5/10/14 4:47	NZFS	logged situation report: 2 fires, 33 kV switchgear building fire contained, fire in cable trench & firefighting not commenced because not confirmed as being isolated
7:24	4:19	5/10/14 6:45	NZFS	fire contained
8:39	5:34	5/10/14 8:00	NZFS	flooded trench to cool the contents
10:36	7:31	5/10/14 9:57	NZFS	site control handed back to Transpower; NZFS remained on standby - Stage 3 starts

Appendix C Methodology for determining the economic cost of the electricity supply outage to customers

- C.1 To estimate the total amount of unserved energy as a result of the outage, it was necessary to make some assumptions due to the limited information available. Hence, several different approaches were taken yielding a range of estimated results.
- C.2 The total lost load is initially broken down into four Vector customer categories. The lost load is then re-assigned to the four customer groupings for which VoLL multipliers are available so that the total cost of non-supply can be estimated.
- C.3 The following data sources were available:
- (a) Half-hourly GXP load for Penrose 33 kV and 22 kV and other nearby GXPs
 - (b) Half-hourly load for Industrial and Commercial (I&C) customers with Time of Use (TOU) meters
 - (c) Half-hourly load and customer category for customers with Advanced Metering Services (AMS) (advanced) meters (approximately 17 per cent of the remaining customers in the affected area)
 - (d) Monthly load and customer type for all Installation Control Points (ICPs) in the affected area (ie, the area normally supplied from the Penrose 33 kV and 22 kV GXPs).
- C.4 The Vector database classifies customers according to four categories as follows:
- (a) Residential
 - (b) Business
 - (c) Industrial and Commercial (non-TOU)
 - (d) Industrial and Commercial (TOU).
- C.5 VoLL multipliers have been sourced from a report prepared by the Electricity Authority. The report provides \$/MWh VoLL multipliers for the following four customer groupings:
- (a) Residential
 - (b) Small non-residential (< 200,000 kWh per annum)
 - (c) Medium non-residential (200,000 to 1,000,000 kWh per annum)
 - (d) Large non-residential (> 1,000,000 kWh per annum).
- C.6 The following three approaches were taken:
- (a) Method 1: Compare GXP loads on affected days with corresponding days in neighbouring weeks (Penrose 33 kV and 22 kV only).
 - (b) Method 2: Compare GXP loads on affected days with corresponding days in neighbouring weeks (Penrose 33 kV and 22 kV as well as neighbouring GXPs to which load was transferred during the outage).

- (c) Method 3: Compare ICP loads on affected days with corresponding days in neighbouring weeks where half-hourly data is available and extrapolate over the affected area.

C.7 In all cases, TOU data for I&C customers was used directly.

VOLL multipliers \$/MWh

Residential	\$ 11,980
Small non-residential	\$ 56,815
Medium non-residential	\$ 27,992
Large non-residential	\$ 3,906

Estimated cost of non-supply

Customer group	Method		
	Based on Penrose GXP volumes	Based on Penrose and neighbouring GXP volumes	Based on available individual customer metered volumes
Residential	\$ 15,401,215	\$ 7,677,016	\$ 11,973,289
Small non-residential	\$ 36,063,111	\$ 19,070,178	\$ 26,834,430
Medium non-residential	\$ 15,320,679	\$ 14,309,842	\$ 14,763,539
Large non-residential	\$ 5,713,028	\$ 5,706,634	\$ 5,709,570
Total	\$ 72,498,033	\$ 46,763,670	\$ 59,280,828

Method 1: Compare GXPs only

C.8 The following steps were taken in the analysis:

- (a) Estimate the normal total Penrose GXP load for each day of the week by averaging total Penrose GXP loads for corresponding unaffected days of the week over the period 28 September through 21 October 2014.
- (b) For the I&C TOU category, estimate the normal (ie, the counterfactual) load for each day of the week by averaging the metered loads for corresponding unaffected days of the week over the period 28 September through 21 October 2014.
- (c) Assign the remaining normal total Penrose GXP load for each day of the week, after deducting the normal I&C TOU load, to the other three customer categories (Residential, Business and I&C non-TOU) according to proportions derived as follows:
 - (i) Aggregate total metered ICP loads for the months of September and November 2014 into the four customer categories.
 - (ii) Estimate the percentage of weekly I&C TOU load that normally falls on each day of the week based on unaffected days over the period 28 September through 21 October 2014.
 - (iii) Assume the percentage of weekly I&C non-TOU load that normally falls on each day of the week is the same as for I&C TOU load.

- (iv) Estimate the percentage of weekly residential load that normally falls on each day of the week based on available residential AMS data for unaffected days over the period 28 September through 21 October 2014.
- (v) Estimate the percentage of weekly business load that normally falls on each day of the week based on available non-residential AMS data for unaffected days over the period 28 September through 21 October 2014.
- (vi) Assign total load for each customer category from paragraph (i) to each day of the week using the percentages from paragraphs (ii) through (v).
- (vii) Calculate the normal ratios of the Residential, Business and I&C non-TOU loads for each day of the week from paragraph (vi).
- (d) Obtain total Penrose GXP load for each day of the outage (Sunday 5 October through Tuesday 7 October 2014).
- (e) Obtain total I&C TOU load for each day of the outage (Sunday 5 October through Tuesday 7 October 2014).
- (f) Calculate percentage of I&C TOU load served on each day of the outage from (e) and (b).
- (g) Initially estimate total I&C non-TOU load for each day of the outage using the percentage of load served from I&C TOU data.
- (h) Initially estimate total Residential load on each day of the outage using the percentage of load served from available residential AMS data.
- (i) Initially estimate total Business load on each day of the outage using the percentage of load served from available non-residential AMS data.
- (j) Scale the initial estimates of Residential, Business and I&C non-TOU loads for each day of the outage so that the sum of the four categories matches the total GXP load from (d).
- (k) Calculate total load not served for each customer category by subtracting estimated actual loads from estimated normal loads (ie, subtracting (e) and (j) from (b) and (c)).
- (l) For each of the three non-residential customer categories (ie. Business, I&C non-TOU and I&C TOU), calculate the percentage of the load which falls into each of the three non-residential VoLL groupings (ie. small, medium and large), based on 12 months of metering data.
- (m) Split the total load not served for non-residential customer categories into small, medium and large using the percentages from paragraph (l) above.
- (n) Apply the VoLL multipliers to each VoLL grouping to obtain estimated cost of non-supply.

Method 2: Compare GXP loads for Penrose and neighbouring GXPs

C.9 The following steps were taken in the analysis:

- (a) Same as Method 1.

- (b) Same as Method 1.
- (c) Same as Method 1.
 - (i) Obtain total Penrose GXP load for each day of the outage (Sunday 5 October through Tuesday 7 October 2014), same as Method 1.
 - (ii) Estimate the normal GXP load for PAK0331, ROS0221 and MNG0331 (the neighbouring GXPs to which load was transferred during the outage) for each day of the week by same method as for Penrose.
 - (iii) Obtain GXP load for each day of the outage for PAK0331, ROS0221 and MNG0331.
 - (iv) Augment total Penrose GXP load for each day of the outage with the amount by which PAK0331, ROS0221 and MNG0331 were above average (ie, $1 + 3 - 2$).
- (d) Same as Method 1.
- (e) Same as Method 1.
- (f) Same as Method 1.
- (g) Same as Method 1.
- (h) Same as Method 1.
- (i) Scale the initial estimates of Residential, Business and I&C non-TOU loads for each day of the outage so that the sum of the four categories matches the augmented total Penrose GXP load.
- (j) Same as Method 1.
- (k) Same as Method 1.
- (l) Same as Method 1.
- (m) Same as Method 1.

Method 3: Compare ICP loads and extrapolate

C.10 The following steps were taken in the analysis:

- (a) Same as Method 1.
- (b) Same as Method 1.
- (c) Same as Method 1.
- (d) (this step not required)
- (e) Same as Method 1.
- (f) Same as Method 1.
- (g) Same as Method 1.
- (h) Same as Method 1.
- (i) Same as Method 1.
- (j) (this step not done – ie, category load estimates were not scaled to match GXP load)

- (k) Same as Method 1 except that load not served for any customer category on any day is limited to non-negative values (this had a minor effect on Residential and Business load on the last day of the outage (Tuesday 7 October).
- (l) Same as Method 1.
- (m) Same as Method 1.
- (n) Same as Method 1.

**Appendix D Transpower and Vector update on progress with
implementing actions October 2015**

23 October 2015

Transpower/Vector Progress Update on Implementation of Actions arising from the joint investigation

Progress on each of the actions identified to implement the recommendations arising from the joint investigation is outlined in the table below. This update is at 23 October 2015.

ACTION	STATUS
1 Design a new permanent solution at the Penrose substation.	Completed
2 Construct the solution.	Underway and on track to be completed by June 2016 in conjunction with a project to convert the 33kV outdoor switchyard to an indoor switchroom. Tenders for the duct installation are currently being assessed. Tender documents for the cable installation are being prepared. Removal of damaged cables is complete and the trench is being cleaned in preparation for the installation of ducts.
3 Inspect all areas on the Vector network where there are multiple cables in open-air, including Transpower and third party substations,	Completed

<p>assess the consequences of failure and identify actions to mitigate risks identified from the inspections.</p>	
<p>4 Inspect all critical Transpower substations to identify cable joints in air, assess the consequences of failure, and identify actions to mitigate risks identified from the inspections.</p>	<p>Completed</p>
<p>5 Complete all actions identified to mitigate the risks.</p>	<p>Vector – All high priority (phase I) mitigation work has been completed. One phase II site is yet to be completed due to co-ordination with a separate project. All lower priority works are in progress and expected to be completed by 30 June 2016.</p> <p>Transpower - At several Grid Exit Points, the connected customer has undertaken to implement interim risk mitigations, such as the application of intumescent paint or sandbags to cable joints in air. Some sites have already been finished, and progress with the remainder is being followed up, to ensure all identified work is completed.</p>
<p>6 Vector amend its maintenance schedules to include inspections of all open-air installations.</p>	<p>Completed</p>
<p>7 Review and amend Vector policies, procedures and practices that deal with cable system design, installation and maintenance.</p>	<p>Two key standards relating to cable joints in air have been updated. Some additional work is underway for remaining updates.</p>
<p>8 Review and amend Transpower asset management standards that deal with cable system design, installation and maintenance.</p>	<p>Scoping of this work has commenced.</p>
<p>9 Vector review and amend its asset risk management framework.</p>	<p>In progress</p>
<p>10 Vector amend its procurement processes and contracts to request suppliers to make Vector aware of any significant issues with product failures.</p>	<p>In progress.</p>

11	Vector create a dedicated role within its networks business focussed on managing asset risk identification and management processes.	Completed
12	Vector continue to develop its assessment of asset risk profiles to ensure the criticality of assets is considered.	In progress
13	Vector review its risk identification processes across the Vector group to ensure any lessons from the incident are applied.	In progress
14	Transpower review the scope of risk studies, including HILP event studies, to ensure coverage of assets owned by connected parties on Transpower land.	Scope for HILP risk studies has been amended. Work is proceeding to define and implement improved processes for identification, communication and assessment of risks at sites. This will include coverage of assets owned by others on Transpower land.
15	Vector update its standard operating procedures for locating faults on feeders with cable sections installed in air.	Completed
16	Transpower review its communications and existing arrangements with the NZ Fire Service to identify opportunities for improvement.	A joint operational review of the incident with NZ Fire Service has been agreed. An independent facilitator is in the process of being engaged.
17	Vector review its communications and existing arrangements with the NZ Fire Service to identify opportunities for improvement.	A joint operational review of the incident with NZ Fire Service has been agreed. An independent facilitator is in the process of being engaged.
18	Vector and Transpower review contractual terms and management processes at points of connection.	In progress
19	Transpower review the business process for assessing and agreeing to customer requests for access and occupation of Transpower land. Ensure that a risk assessment is part of the process.	Scoping of this work has commenced, and will be informed by outcomes and learnings from the updating of Access and Occupation schedules outlined in the following row.
20	Transpower establish an on-going process to provide assurance about the status and condition of customer assets on Transpower land and the potential risks to the national grid. This process to	Transpower has developed a process for a comprehensive review of Access and Occupation schedules to update the records of customer assets on Transpower land, and evaluate the risks associated with those assets. This

focus on critical sites, and to include agreement of risk mitigation plans with customers.

process has commenced. The documentation updates and risk reviews for the most critical sites are scheduled to be completed within 12-18 months

Appendix E Security and Reliability Council advice to Authority Board Chair

E.1 The SRC is a statutory body set up under the Act to provide independent advice to the Authority on the performance of the electricity system and the system operator and reliability of supply issues.

E.2 The SRC members are:

Mike Underhill (Chair)	Chief Executive of the Energy Efficiency and Conservation Authority (EECA)
Nigel Barbour	Chief Executive of Powerco Limited
Albert Brantley	Chief Executive of Genesis Energy Limited
Barbara Elliston	Director of Elliston Power Consultants Ltd, Counties Power Limited and Easy Warm Ltd
Vince Hawksworth	Chief Executive of Trustpower Limited
Judi Jones	Electricity and Gas Complaints Commissioner
Bruce Turner	Director Commodity and Risk Trading at Fonterra
Guy Waipara	General Manager of External Relations at Meridian Energy Limited
Erik Westergaard	Chief Executive of Wellington Combined Taxis

E.3 Judi Jones excluded herself from the discussion of the Authority's report because of her role as the Electricity and Gas Complaints Commissioner in regard to claims relating to the Penrose substation fire.

10 November 2015

Dr Brent Layton
Chair
Electricity Authority
PO Box 10041
Wellington 6143

Dear Brent

Advice resulting from 9 November 2015 meeting of the SRC

The Security and Reliability Council (SRC) is tasked with providing the Electricity Authority with independent advice on the performance of the electricity system and the system operator, and reliability of supply issues.

On 4 October 2014, a fire occurred at the Penrose substation that resulted in outages to a significant number of consumers in the Auckland area. The Authority Board sought advice from the SRC on the security and reliability aspects of this event, and specifically in relation to the analysis and recommendations contained in the inquiry conducted by the Authority in response to a request from the Minister of Energy and Resources.

The SRC considered the Penrose-related material provided to it for its 9 November 2015 meeting, which comprised the Authority inquiry report, the joint investigation report prepared by Transpower and Vector and the CCI report from the cable expert. At its 9 November meeting the SRC received a presentation from Transpower and Vector representatives, including a video describing the event and the layout of the Penrose substation, and received a brief overview of the inquiry from the Authority's inquiry team. The SRC sought clarification of several issues and then discussed the Authority inquiry report without the presence of Transpower and Vector representatives. This letter is the SRC's advice arising from the discussion of that material.

Advice about the Authority's inquiry report on the Penrose event

The SRC found the inquiry report to be a thorough and clear response to the questions raised by the Minister. The SRC agrees with the inquiry report's findings and recommendations. The majority of the SRC's discussions on the report were focussed on the significance of risk management in the context of the Penrose event. The SRC has identified the following specific advice in relation to risk management that should be considered for incorporation into the final inquiry report:

- Risk identification for assets needs to take a broader *consequence-based view* as well as an event-based view. This is important to ensure critical areas for supply reliability are identified for review.
- The SRC considers that the consideration of the risks associated with the co-location of critical assets is a vital part of risk management, particularly when the asset management regime for some of the co-located assets is different from the other co-located assets. For example, the co-location of 'run to failure' assets with critical assets undermines the intended reliability of the critical assets.
- Risk identification needs to encompass the complete power system, from the consumer right through the supply chain, so that critical areas for supply reliability can be identified for review. Such an approach can help to ensure that co-located assets, and the boundaries between the assets of different industry participants, can be clearly identified for risk assessment purposes.

- Risk assessment is traditionally undertaken by individual risk owners in relation to their area of responsibility. The Penrose event underscores that *collaborative risk assessment* is a difficult but important undertaking. Transpower and Vector have learned lessons from the experience and are now pioneering collaborative risk assessment from which the broader industry could take lessons. The SRC considers that the Authority's inquiry report should highlight collaborative risk assessment as vital in the potential prevention of this event, and as a lesson to be conveyed to risk owners in a variety of utility settings.
- In relation to collaborative risk assessment, the Authority should consider recommending that Transpower be encouraged to contact all of the parties with direct connections to the national grid and propose they undertake a collaborative risk assessment using the approach that has now been undertaken with Vector. These reviews would need to be completed in a sequential and prioritised basis, so that Transpower can accommodate them amongst their other business activities. The SRC also recommends that Vector and Transpower be encouraged to share their collaborative risk assessment process and templates with other industry participants.
- Assessing the consequences of risks (regardless of the identification process) needs to account for the range of possible consequences arising from each risk, including worst possible outcomes. It is important that risk mitigation takes proper account of all the costs and benefits of reducing risk, recognising that there will be circumstances where it is better to accept the risk rather than invest further to reduce it. The SRC noted that if risk owners compare their existing assets against their present-day design standards, this may alert them to possible risks for identification.

The SRC has also identified the following general matters for consideration for incorporation into the report:

- Although the inquiry report recognises that the co-location risk at Penrose accumulated over a long period of time as more cables were added to the trench, the report could better acknowledge that the 'creeping' nature of the risk over such a long period of time makes it very hard for parties to be sensitised to it, but it is nevertheless important that they are alert to it.
- The SRC considers that there should have been a timely post-event review between Vector, Transpower and the New Zealand Fire Service so that lessons (including security and reliability lessons) could be identified while the event was still fresh.
- The SRC notes that various post-event activities have been performed well. In particular, the response of Vector and Transpower during the event, the communication with the public and media, and the subsequent implementation of actions have all been areas of success. The SRC considers that the focus of the inquiry report has naturally been driven by the focus of the Minister's terms of reference on what went wrong and the lessons to be learned, but the Authority should also emphasise the successes as it is important for consumers to have a balanced view of the outcomes of the Authority's inquiry.

The SRC also notes that the joint investigation and the inquiry report have both taken a significant length of time to reach this stage. This appears to be due to an unwarranted focus on waiting for a highly technical and definitive view of the specific cause of the fire, which was unnecessary for properly assessing the overall event in this case. For future inquiries, some latitude in the terms of reference on reporting on the specific cause of an event could greatly speed up the completion of the reports and improve public perceptions of the inquiry process.

Advice about the security and reliability implications of the Penrose event

The SRC considers that the broader lessons from this event are very valuable, not just for the electricity industry, but also for utilities more generally. In addition to the specific advice on risk assessment and the importance of effective communication provided above:

- The SRC considers that the Authority should undertake to draw the electricity industry's attention to the findings of this inquiry. This communication needs to recognise and acknowledge the challenges associated with identifying risks of this type, but should also clearly leave risk owners with the responsibility for effective risk management, rather than being directive about the sorts of mitigations that ought to be undertaken.
- The SRC considers the lessons relating to the co-location of assets do not just apply to situations such as Transpower's grid entry/exit points. Network companies and other market participants should be encouraged to review their risk management for co-located assets within their systems.
- The SRC considers that the Authority should consider whether the cost of events should include other factors such as the costs of emergency services in widespread outages.

If the Authority Board has any questions in relation to these matters, I am happy to present or respond on behalf of the SRC. There is no further advice arising from the discussion at the SRC's 9 November 2015 meeting.

Yours sincerely



Mike Underhill
Chair
Security and Reliability Council

cc SRC members, Carl Hansen (Electricity Authority)