Ausgrid

Asset Condition & Planning Summary

ACAPS4030 Low Voltage Underground CONSAC Cables (km)

March 2014

Review

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Approval

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Amendment History

Version	Comment
1	Initial version.
2	Updated following risk review (March 2014).

Disclaimer

All asset data (population, age, etc) in this document was extracted from SAP, or other asset system, on 30/06/2012, unless otherwise noted. All monetary figures are in FY2012/13 dollars, unless otherwise noted.

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This document should be read in conjunction with the 'Replacement & Duty of Care Overview' for details of common concepts and processes.

Contents

1. Executive Summary

This document provides an overview of the analysis undertaken and the decisions made to ensure the risks associated with the low voltage (LV) underground CONSAC cables are managed in an efficient, safe and cost effective manner.

From the late 1960s until the early 1990s, Ausgrid (and its predecessor organisations) installed LV underground cables that used a concentric aluminium sheath as the neutral conductor (abbreviated as ‘CON’) and solid aluminium for phase conductors (abbreviated as ‘SAC’). These cables are known within Ausgrid and the electricity industry as ‘CONSAC’ cables. These cables evolved from the original LV and HV underground ‘paper/lead’ types cables, which consisted of a lead sheath encapsulating copper conductors with paper insulation around the conductors. They ranged from single conductor designs to four conductor designs, depending on their purpose.

A total of approximately 890 kilometres of CONSAC cable was installed across the Ausgrid network area in urban locations and were predominantly used as distributor, service and street lighting mains. While these CONSAC cables are predominantly three phase cables with solid aluminium conductors, the category also includes some cables with conductor made up of strands of aluminium (‘stranded’ cable). Ausgrid has identified 28 different CONSAC cable variations in the network, spread across approximately 7,140 distributors fed from more than 4,100 distribution substations. The use of HDPE cables began in the 1980s as the first part of the distributor and underground overhead cables. The HDPE cables contain a PVC outer sheath and a high density polyethylene insulation.

There is a strong correlation (over 70 percent) between the LV cable faults that occur on the Ausgrid network every year and the presence of CONSAC and/or HDPE type cables on the LV distributors that have failed. CONSAC cable represents approximately 15 percent of Ausgrid’s total in-service LV cable length. HDPE accounts for approximately two percent of all LV cables. Ausgrid is experiencing premature condition issues with the CONSAC cable type, relating to corrosion of the concentric aluminium sheath and breakdown of the paper insulation, both of which can lead to corrective or breakdown failure of the cable.

The condition issues related to this cable have a negative impact on Ausgrid’s ability to maintain a safe and reliable distribution network. The CONSAC replacement program was implemented following electrical shocks received by customers and Ausgrid staff, caused by deterioration of the aluminium cable sheath and therefore loss of the neutral connection. The failure modes experienced on the Ausgrid network are the same as those seen with this cable in other organisations in the electricity industry, both in Australia and internationally. Reactive replacement is not appropriate to address the increasing failure rate and the associated electrical shock risks as the CONSAC cable age increases across its population.

To optimise the overall reliability, performance and safety of the electricity network, Ausgrid uses asset management strategies which are detailed in the Replacement and Duty of Care Overview document. These strategies consider the performance, condition, risk and utilisation of all electrical network assets. More specifically, to demonstrate the need for continued prudent capital funding for the replacement of CONSAC cabling, this document details the comprehensive analysis that has been undertaken on this asset group which includes age profiling, failure analysis, risk analysis, options analysis and cost benefit analysis.

CONSAC cable failure generally causes breakdowns or interruption of supply, which can have a negative impact for Ausgrid. Moisture ingress is the main cause of failure for these cables. Ausgrid has always followed a ‘run to failure’ maintenance strategy for LV cables. This means that upon failure, the cable is either repaired or undergoes sectional replacement. For CONSAC cables however, while the immediate effects of the problem are addressed with repairs, the overall condition and cause of failures is not. This means that the CONSAC cables continue to age and deteriorate which increases the failure rate of the assets.

The overall asset management strategy for these CONSAC cable is the planned replacement of all existing cables – reactive replacement will also be required following breakdown failures until all CONSAC cable is removed from the network. This strategy proposes to replace the cables at 20km per year, with further replacement required in subsequent regulatory periods. Ongoing funding for the replacement of the cables is supported by the analysis in this document.

Ausgrid recognises that the proposed level of expenditure may not be sufficient to address the projected increase in failures and that this will result in increased levels of organisational risk relating to safety and reliability. Ausgrid has made changes to our asset management system to capture the individual cable codes following cable failures to improve our understanding of which CONSAC or other cable types are having the most influence on failure rates and will target these cables as the 2015-19 period progresses as well as in subsequent periods.

The replacement sub-program listed below is required to ensure the continued management of the CONSAC cables on the Ausgrid network in a safe and reliable manner. The Regulatory Project ID covered in this ACAPS is REP_04.02.05 LV CONSAC Cable (km).

The LV CONSAC cable sub-program is a decades-long program of work, and will carry forward from the 2010-14 regulatory period. A view of the current, planned and proposed sub-programs of works is summarised below in Figure 1.

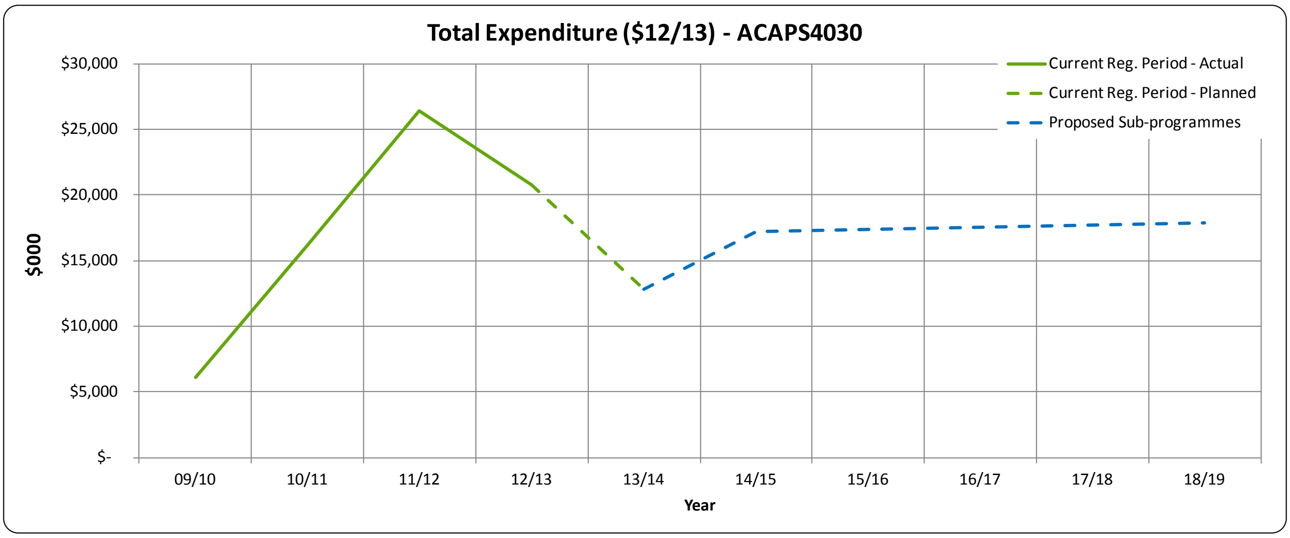

Figure 1 – ACAPS4040 Expenditure Summary

Table 1 – CONSAC actual and planned expenditure – 2010–14 regulatory period

	09/10	10/11	11/12	12/13	13/14
Total	$6,124,000	$16,232,000	$26,419,000	$20,736,000	$12,801,000

It should be noted that expenditure in 12/13 was low, and 13/14 is expected to be low, compared to previous years due to industrial issues in regard to asbestos containing materials in customer switchboards as well as parts of the Ausgrid network. This has meant that delivery projects have not been able to be completed to the point where the CONSAC cable can be completely de-energised. This is also expected to have some impact in the first two years of the 2015-19 period, but to a lesser degree. Following this, delivery levels will increase to 25km per year as business as usual.

At the completion of the 2010–14 regulatory period approximately 100 kilometres of the 890 kilometres of LV CONSAC cable that was installed from the late 1960s to the mid 1990s will have been removed from service.

The proposed program for the 2015–19 regulatory period and subsequent periods aim to systematically and efficiently manage the condition and safety risk issues related to these cables. This will be done via a sustainable program that will ultimately see all CONSAC cables removed from the Ausgrid network.

2. Asset Technical Details

2.1. Description of Asset Grouping

Figure 2 shows how LV underground cables move electricity from distribution substations via distributor cables to the point of supply for residential/business customers. They are located in areas where the electricity reticulation is primarily underground, or where they provide the connection between the underground distributor cables supplied from a distribution substation to an overhead network. LV underground cables also supply street lighting.

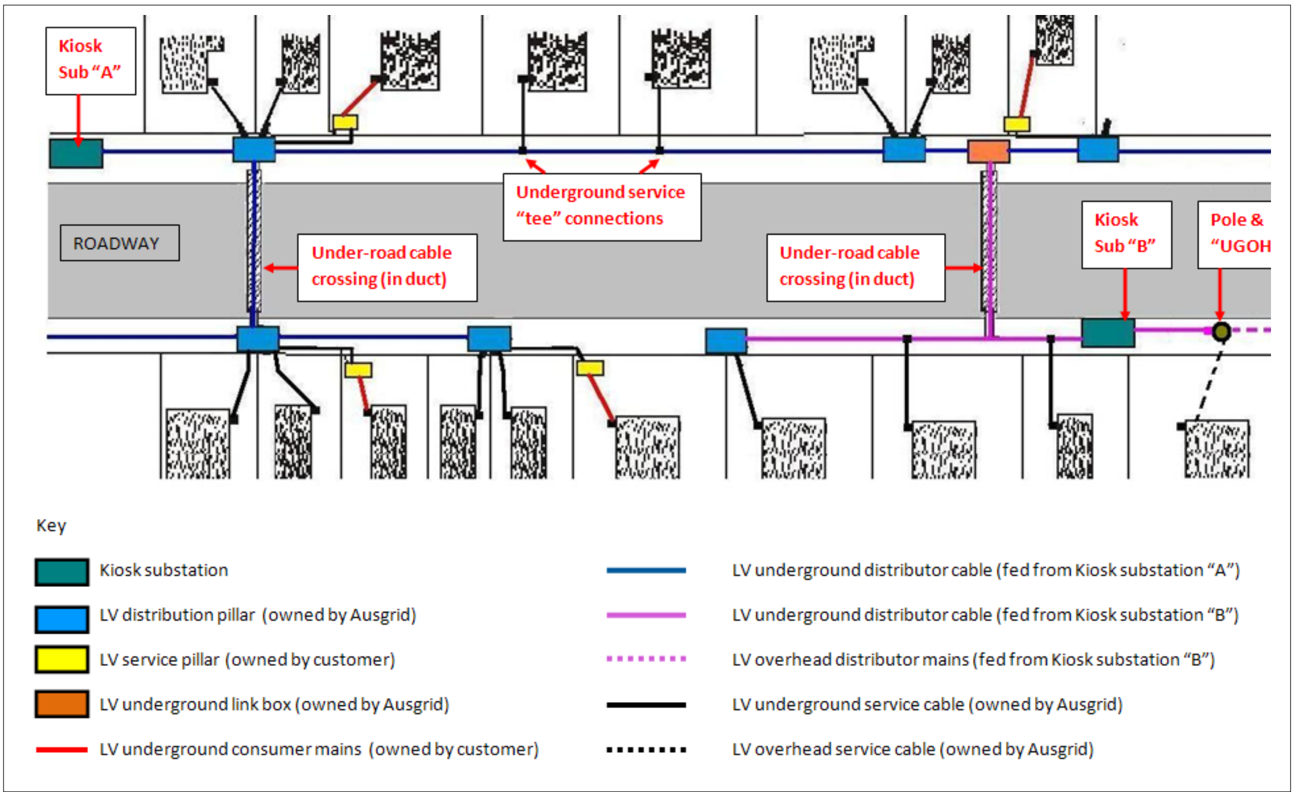

Figure 2 – Design of a typical LV underground distribution circuit with CONSAC cable

Historically, both LV and high voltage (HV) (up to 11kV) underground cables used a 'paper/lead' technology, which generally consisted of a lead sheath encapsulating copper conductors with paper insulation around the conductors. They ranged from single conductor designs to four conductor designs, depending on their purpose.

LV underground 'paper/lead' technology cables used for three phase supply generally had four copper conductors in the cable. Three of these acted as phase conductors and the fourth was used as the neutral current return path. From around the 1960s, cable manufacturers started producing LV and HV cables with aluminium conductors, instead of copper, to lower material costs. These cables were widely used in the electricity supply industry in Australia and Europe.

'CONSAC' cable is one type of LV underground cable that was developed in this era, and uses some components of the old 'paper/lead' design. CONSAC cable retained the PVC outer sheath (or 'serving'), paper insulation and predominant three conductor design (one per phase) of the 'paper/lead' cables, but substituted the lead or copper sheath with a concentric aluminium sheath. A thin layer of bitumen was applied between the PVC outer sheath and the aluminium sheath to prevent moisture migration through, and between, the PVC and aluminium sheaths.

CONSAC cable used the concentric aluminium sheath as the neutral current return path, which allowed the cable design to be changed so it only required three conductors in the cable (one per phase) instead of four conductors (three phase conductors and a neutral conductor). In most cases, CONSAC cable used solid aluminium phase conductors instead of stranded cable. Figure 3 shows a section of CONSAC cable and the components included in its design.

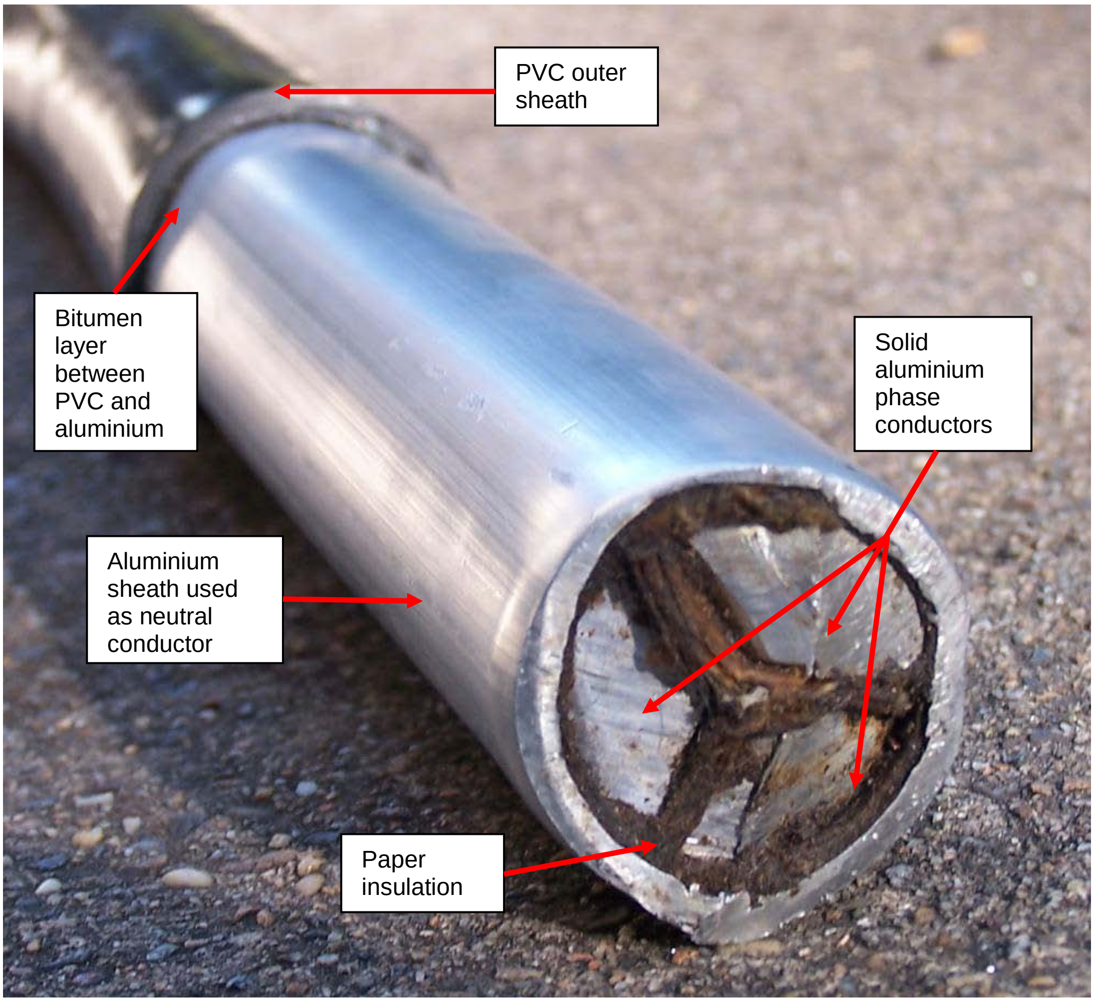

Figure 3 – A section of CONSAC cable showing its components and design

2.1.1. Use of CONSAC cable

Ausgrid (and its predecessor organisations) began installing this cable as distributor, service and street lighting mains in the late 1960s (the actual commencement date is unknown) and continued to install this cable type until the early 1990s. While the cable installed was predominantly a three phase cable with solid aluminium conductors, quantities of single phase cable and stranded cable were also installed. Approximately 890km of this cable type was installed over this period, consisting of 28 cable variations (or cable codes) from the listing of all Ausgrid cables in Network Standard NUS100 'Field Recording of Network Assets'.

Where CONSAC was used as distributor cable, initially it was connected from the distribution substation LV board to pillars or underground link boxes along the circuit and then through underground service cable 'tee' connections to individual premises. The cable was also used for street lighting supplies and as underground to overhead (UGOH) connections. Underground service cable 'tee' connections connect the service cable from premises directly to the distributor cables. Using these connections means that a distributor cannot be readily separated into smaller portions when isolating for switching or safe work requirements, so more customers need to be interrupted for this work. The use of aboveground pillars as per current designs allows the distributor to be more readily separated into smaller sections when switching, resulting in fewer customers being affected when work is required on the distributor.

Instead of being installed in conduits as per modern standards, the cable was predominantly buried directly in the ground, except where ducts were used for underground road crossings and sometimes under driveways. This design was considered a low-cost installation due to the lower cost of the aluminium cable and the limited installation of ducts, which further reduced material costs. The use of service 'tee' connections (as opposed to installing an aboveground pillar) further reduced material and labour costs. These designs were installed at a lower relative capital cost than installations in conduits as per modern standards, but the ongoing operations costs of this design have been higher than for current design standards, for a number of reasons:

- Direct burying of cables has a negative effect on cable longevity because of moisture ingress and ground movement damage, leading to 'galvanic' sheath corrosion and reduced insulation resistance of the paper insulation. The use of CONSAC cables as UGOH connections also allows moisture ingress through the aboveground connection to overhead mains, causing overhead cable deterioration.

- The use of the aluminium sheath as the neutral conductor and its connection to an earth constitutes an 'earthed' situation. This means that any work on the cable has to be done with that part of the circuit de-energised, in order to mitigate the electrical safety risk. Because service 'tee' connections were originally used to avoid the cost of a pillar, the length of distributor that needs to be de-energised for work can be much greater than would be required for modern circuit designs using pillars. With the modern design, only the part of the distributor between pillars has to be isolated.

- Cable failures require isolation of the distributor, testing to locate the fault, excavation at the failure location, repair of the cable, switching the cable back into service and reinstatement of the ground cover. In many cases when testing is carried out to locate faults, multiple fault locations are identified, caused by the electrical stresses on the paper insulation during fault conditions. This then necessitates further isolation along the distributor to locate the additional faults, which increases repair costs. With modern designs, splitting the distributor for fault finding and restoration of supply is made much easier by the use of pillars, which allow the distributor to be more easily 'sectionalised' to isolate faults.

- Reinstatement costs vary from minimal in residential grass covered areas to significant in paved shopping centres or customer premises. When ducts are installed, as in the modern design, cable installation or jointing can be done in existing ducts and pits so there are no reinstatement costs.

- Reactive repairs effectively lead to the incremental replacement of sections of CONSAC cable, rather than complete replacement along the distributor or between pillars. This results in multiple repair costs compared to a one-off CONSAC planned replacement cost, and does not address the issue of the increasing average age and failure rate of the CONSAC cable population.

- Direct burying of cables means installation of new cables requires re-excavation of the cable route or the establishment of a new cable route. Generally re-excavation of an existing cable route can only be done with the circuit de-energised because of the electrical safety risks, resulting in higher repair or replacement costs compared to 'greenfield' locations in, for example, a new residential development, where the site is not yet connected to the network so there are no costs associated with switching, planned interruptions to customers, etc. A new cable route may be a compromise on the optimum location because of the existence of other underground services. This may increase trenching, traffic control and reinstatement costs, especially if the new route needs to be located in a road or where a significant number of other services are located.

2.1.2. Use of HDPE cable

In the 1980s the first part of the distributor and UGOH cables were installed using LV single phase aluminium cables with a PVC outer sheath and high density polyethylene (HDPE) insulation instead of CONSAC cable – this type of cable is referred to within Ausgrid as ‘HDPE cable’.

HDPE cable also experiences condition related performance issues; the combination of HDPE and CONSAC cable represents the highest replacement priority in regard to LV cables. A range of other replacement sub-programs associated with CONSAC replacement work may be conducted (and funded) in conjunction with the replacement of any section of CONSAC cable:

- LV HDPE cable – see document ‘ACAPS4031 Low Voltage Underground HDPE Cables (km)’.
- LV UG link boxes - see document ‘ACAPS4040 Distribution Mains Reactive Unit Replacement.
- Steel round pillars – see document ‘ACAPS4040 Distribution Mains Reactive Unit Replacement’.
- LV UG service termination boxes – see document ‘ACAPS4040 Distribution Mains Reactive Unit Replacement’’.
- LV Underground Services – see document ‘ACAPS4040 Distribution Mains Reactive Unit Replacement’.

2.2. Asset Population

CONSAC cable lengths are recorded in the Ausgrid Geospatial Information System (GIS). A total of 28 individual types of cable (or cable codes) have been identified as being of a CONSAC type, with reference to the listing of all Ausgrid cables in Network Standard NUS100 ‘Field Recording of Network Assets’. These cable codes are used to plan and monitor CONSAC cable replacement.

The 28 codes were selected mostly based on a cable description with the following parameters:

- 415 volt cable with paper insulation (‘P’).
- Aluminium neutral (‘AL (N)’) – one type with wave-wound concentric aluminium neutral is also included.
- 3 phase solid aluminium conductor (‘AL3’ and ‘SAC’) – seven types with stranded conductor are also included.

At the start of the FY2012/13, there was approximately 795km of cable identified as CONSAC still in service. This is spread across approximately 7,140 distributors fed from more than 4,100 distribution substations. The average length of CONSAC cable per distributor is 111.3 metres. Over 4,600 of these distributors also have HDPE cable on the distributor. The tables below provide some key statistics.

Table 2 – In service CONSAC length by cable usage

Distributor Cable	Street Lighting Cable*	Service Cable	Total Length
730.8 km	34.5km	29.7km	795.0km

**In the past, street lighting was mostly supplied by dedicated street lighting cables fed from a control point. CONSAC street lighting cables were generally installed adjacent to CONSAC distributor cables. With current design standards, street lights are individually connected to the distributor cables by a connection in a pillar instead of using a dedicated street lighting cable. Any replacement of CONSAC distributor cable will include replacement/removal of street light cables; however, but the cost of doing this will be negligible compared to replacement with dedicated street lighting circuits/cables.*

Table 3 – In service CONSAC length by region

Central Coast	East	Lower Hunter	Newcastle	North	South	Upper Hunter
42.8km	167.7km	21.1km	0.2km	208.5km	354.5km	0.1km

Table 4 – Number of LV distributors containing CONSAC cable by region

Central Coast	East	Lower Hunter	Newcastle	North	South	Upper Hunter
204	1468	70	4	1951	3445	1

Table 5 – In service CONSAC length by cable code

Cable Code	Cable Code Description	Total Length
2037	415V 26 AL3 P AL(N) Z/SAC	35.1km
2038	415V 25 AL3 P AL(N) Z/SAC	13.1km
2043	415V 39 AL3 P AL(N) Z/SAC	2.3km
2044	415V 50 AL3 P AL(N) Z/SAC	1.9km
2062	415V 97 AL3 P AL(N) Z/SAC	3.0km
2063	415V 95 AL3 P AL(N) Z/SAC	5.5km
2068	415V 129 AL3 P AL(N) Z/SAC	16.1km
2069	415V 129 AL3 P AL(N) DT J/SAC	0.6km
2095	415V 194 AL3 P AL(N) Z/SAC	116.4km
2096	415V 185 AL3 P AL(N) Z/SAC	172.2km
2099	415V 258 AL3 P AL(N) Z/SAC	1.5km
2108	415V 240 AL3 P AL(N) Z/SAC	0.2km
2126	415V 65 AL3 P AL(N) Z/SAC	5.3km
2130	415V 323 AL3 P AL(N) Z/SAC	9.6km
2131	415V 300 AL3 P AL(N) Z/SAC	285.6km
2132	415 300 AL3 XQ BR AL(N) Z/SAC	1.8km
2133	415V 300 AL3 P AL(N) Z/SAC	0.8km
2134	415V 297 AL3 P AL(N) Z	0.1km
2135	415V 323 AL3 P AL(N) Z	109.1km
2138	415 323 AL1 P AL(N) Z	0.5km
2186	415V 129 AL3 P AL(N) Z	9.2km

Cable Code	Cable Code Description	Total Length
2187	415V 120 AL3 P AL(N) Z/SAC	0.7km
2195	415V 161 AL3 P AL(N) Z/SAC	0.4km
2196	415V 185 AL3 P AL(N) Z	1.0km
2198	415V 258 AL3 P AL(N) Z/SAC	0.1km
2219	415V 194 AL3 P AL(N) Z	2.3km
2253	415V 97 AL3 P AL(N) Z	0.6km
2347	415V 300 AL3 P AL(NW) Z + 185 AL1 XQ Z	0.1km

2.3. Asset Age Data

For LV underground cables and other linear assets, asset information (including cable code, length and age) is recorded in the Ausgrid GIS. Prior to the implementation of GIS, cable and jointing records were recorded in 'field books' (similar to a surveyed plan) which recorded the physical location of the cable or joint, the cable or joint type and the date of any cable or jointing work carried out. The transfer of hard copy field book recordings into the GIS began in approximately 2002, with a priority in regard to accuracy placed on HV assets over LV assets (because HV involves fewer assets and it was therefore quicker to compile this information).

The data that was entered into GIS is generally accurate in relation to cable code and length, although records are still updated when data errors are found during cable work in the field. Continued data cleansing is required in regard to cable ages, as can be seen from the CONSAC age distribution in Table 6 below,

As CONSAC cable was installed between the late 1960s and the early 1990s, there is no cable over 60 years old (which is the standard life of the cable). The fact that this is not reflected by the age data from the GIS, which suggests a weighted average age for CONSAC of 40.33 years, shows that much of the commissioning date information is inaccurate. The CONSAC cable age distribution shown in Figure 4 reflects these data issues, in that anything shown as more than approximately 45 years old at the end of the 2012 financial year (that is, with a commissioning date prior to 1968) is likely to be an error.

Table 6 – Asset population age statistics

Asset category	Weighted average age	Standard life	% over standard life
Distribution Mains LV Underground - CONSAC	37.6 years	60 years	0.0 %

Data correction of CONSAC commissioning dates currently occurs when inaccuracies are identified during business-as-usual activities such as fault repairs and project planning. In some cases, the CONSAC cable commissioning dates may not be able to be accurately determined because field book recording of cable installation and jointing may not have been carried out. In these cases a pseudo commissioning date will be applied, based on other relevant data such as substation commissioning dates, or based on the average age of the distributor.

HV and LV cables have a standard life of 60 years. While history has shown that this is generally appropriate for paper/lead type cables using copper conductor, from failure experience to date it is not the case for CONSAC and some other LV cables that use aluminium in the cable structure/design. The reasons for this are further explained in section 3, but it is likely that the standard life expected for aluminium cables is optimistic.

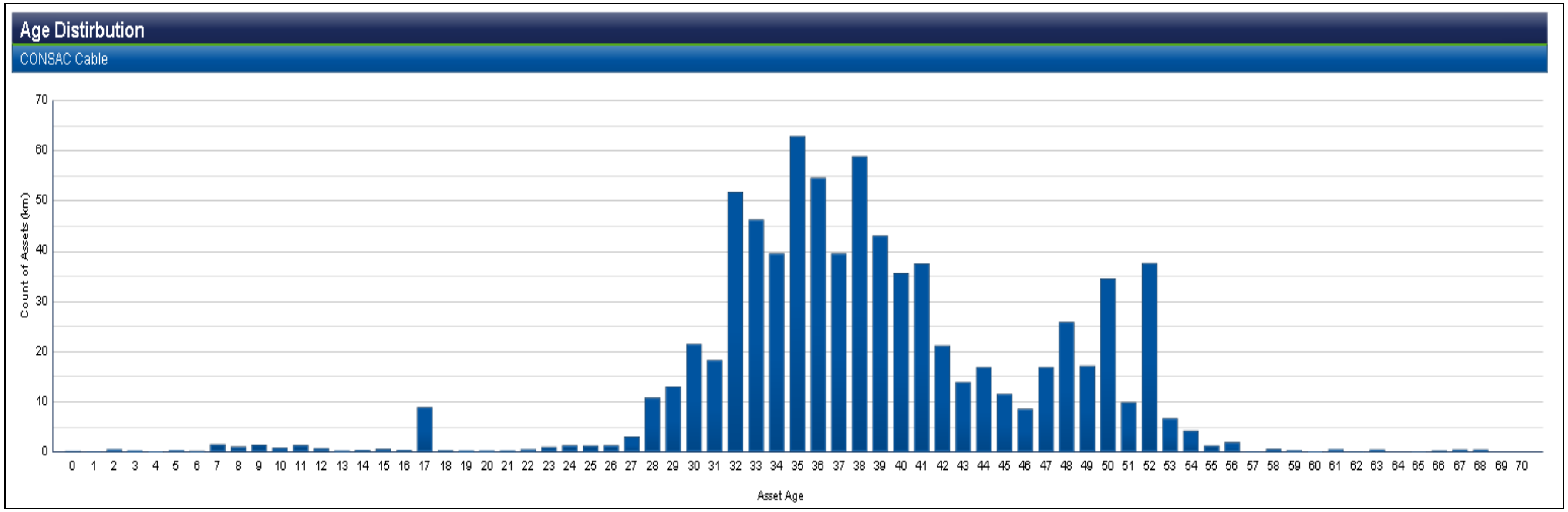

Figure 4 – Age distribution of in service CONSAC cable

3. Maintenance & Failure Data

3.1. Maintenance Strategy & History

Ausgrid has always followed a ‘run to failure’ maintenance strategy for LV cables, although planned inspections are carried out on pit lids and above ground components of the LV cable system (for example, line inspection and thermal inspections of LV pillars). Generally, the safety consequences to Ausgrid staff or the general public are higher for aboveground LV cable system components than for underground components and it is this consequence that drives the requirement for an inspection task. Planned maintenance on LV cables is not carried out because of the cost associated with planning distributor/customer outages, jointer and testing staff resource constraints, the requirement to dismantle joints/terminations and the lack of a repeatable test method that truly indicates the condition of LV cables. The ‘run to failure’ maintenance strategy for LV cables means that, upon failure, the cable is either repaired or undergoes reactive sectional replacement at the point of failure, depending on the cable condition. Ausgrid has not carried out a maintenance requirements analysis for LV cables because it continues to follow this ‘run to failure’ strategy for these assets.

While this approach of repair or reactive replacement of short lengths following failure is appropriate for LV cables in general, for CONSAC cable it has meant that while the immediate effects of deterioration are addressed, the overall cause of these failures – the inherent design of the cable – is not. The overall population of CONSAC continues to age and deteriorate with an increasing failure rate. At current replacement rates, removal of all CONSAC will take more than 40–50 years.

3.2. Failure History

The failure modes that affect CONSAC cable are predominantly caused by moisture ingress, which creates safety or reliability risks. The failures generally cause breakdowns, meaning that an interruption of the distributor occurs and the result is a loss of supply to customers. Ausgrid had a number of high profile LV cable failures in the Bondi Beach area in 2005 that were directly attributable to CONSAC cable failures. Failures requiring corrective work are usually only found when work is carried out while a cable is de-energised for other work. The main CONSAC cable failure modes are:

- Galvanic corrosion of the aluminium sheath as shown in Figure 5, and moisture ingress through PVC sheath damage or joints/terminations.

Figure 5 – A section of CONSAC showing corroded aluminium sheath

- Reduced insulation resistance of the insulating paper (Figures 6 and 7) caused by moisture ingress through damage/corrosion of the aluminium sheath or joint, circuit overloading or mechanical fatigue (during jointing).

Figure 6 – A section of CONSAC showing deteriorated paper insulation (caused by moisture ingress)

Figure 7 – A section of CONSAC showing a failed joint

- Increased resistance in the neutral current return path, caused by loss of the aluminium sheath through corrosion, or by age degradation of the soldered neutral connection at the cable termination.

- Failure of service ‘tee’ connections due to poor workmanship, corrosion and moisture ingress.

- Failures at the ‘4 to 1’ joints between CONSAC distributor cables and HDPE cables.

The failure outcomes of CONSAC cable condition issues are summarised in Table 7 below. The part/failure/cause information for CONSAC cables (drawn from notifications raised in SAP for CONSAC work) is shown in Figure 8.

Table 7 – Summary of outcomes of CONSAC cable condition issues

CONSAC Failures and Causes	Corrective Failures	Breakdown Failures
Degradation of the aluminium sheath due to galvanic corrosion	×	
Paper insulation degradation due to moisture ingress, overloading or mechanical fatigue.	×	
Corrosion of aluminium conductor due to moisture ingress allowed by sheath/insulation degradation	×	×
Phase to earth and/or phase to phase leakage currents due to paper insulation degradation	×	×
Customer shocks or voltage complaints due to aluminium sheath degradation/loss of neutral	×	
Customer shocks or voltage complaints due to service 'tee' connection degradation	×	×

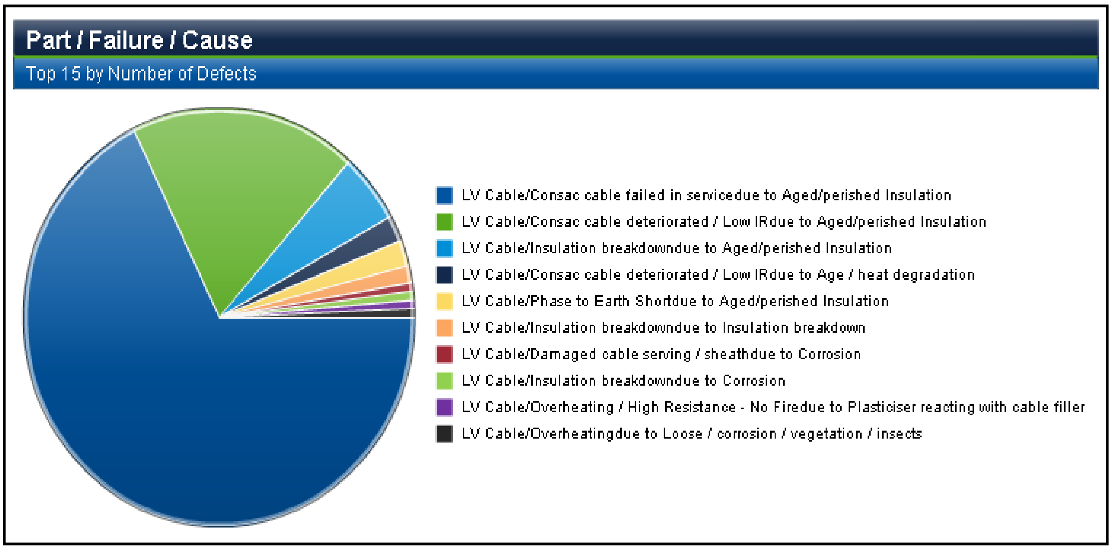

Figure 8 – CONSAC Part/failure/cause comparison

3.2.1. Corrective failures

CONSAC cable failures other than breakdowns may be identified when jointing work is carried out for other reasons, for example, cable diversions, replacements, load growth projects or new customer connections. When jointing is carried out on LV cables, a test will be conducted to measure the insulation resistance (IR) between phase conductors, the neutral sheath and earth before an LV cable or joint is put into service. IR is essentially a check to make sure the cable is safe to be switched on; it can only be performed on de-energised cables.

Low IR in CONSAC cable usually indicates deterioration of the paper insulation caused by overloading, moisture ingress through joints/terminations or mechanical damage/fatigue during jointing. Deterioration of the paper insulation may also be caused by degradation of the aluminium sheath, which allows entry of moisture. However, an IR test is not able to determine sheath condition. If sheath deterioration is suspected (e.g. in the case of a low IR result where there is no other evidence of deterioration), the fault location will need to be identified by Ausgrid Network Test staff and the location excavated to determine the exact cause of the low IR. Network Test staff often identify multiple fault locations in the section of cable being tested.

Failures requiring corrective work may also be identified through customer electrical shock reports or voltage complaints. As CONSAC cable deteriorates, the ability of the cable to pass current through it without leakage decreases. While deterioration of the paper insulation of a phase conductor may result in voltage complaints or damage to customer equipment caused by low or unbalanced voltages, deterioration of the neutral cable is of greater concern because it is the return path for the alternating current (AC) supply and a fault may result in electrical shocks. The flow of neutral currents for customer installations and for an LV distributor is shown in Figures 9 and 10[1].

Neutral conductor deterioration

A distribution network is a balanced system in which all the phase current that leaves a source of supply (for example, a kiosk substation) returns to the source of supply. When the distribution network is in good condition, current returns to the source of supply via the neutral conductor. When CONSAC is used as the distributor or customer installation service cable, the aluminium sheath is the neutral conductor. The phase current from the source (shown as 'Active' in Figure 9) goes into the installation via the service fuse and meters, travels through appliances as they are used and then returns to the source of supply. The earth connection is used as a safety feature to make sure that if there is a short circuit between a phase and earth, the circuit breaker or fuse in the customer installation operates to disconnect the fault. An example of this is when a person inserts a knife into a toaster, causing a phase to earth fault – if there is no earth connection, the circuit breaker or fuse will not operate and the person is likely to receive an electrical shock because their body becomes the current return path.

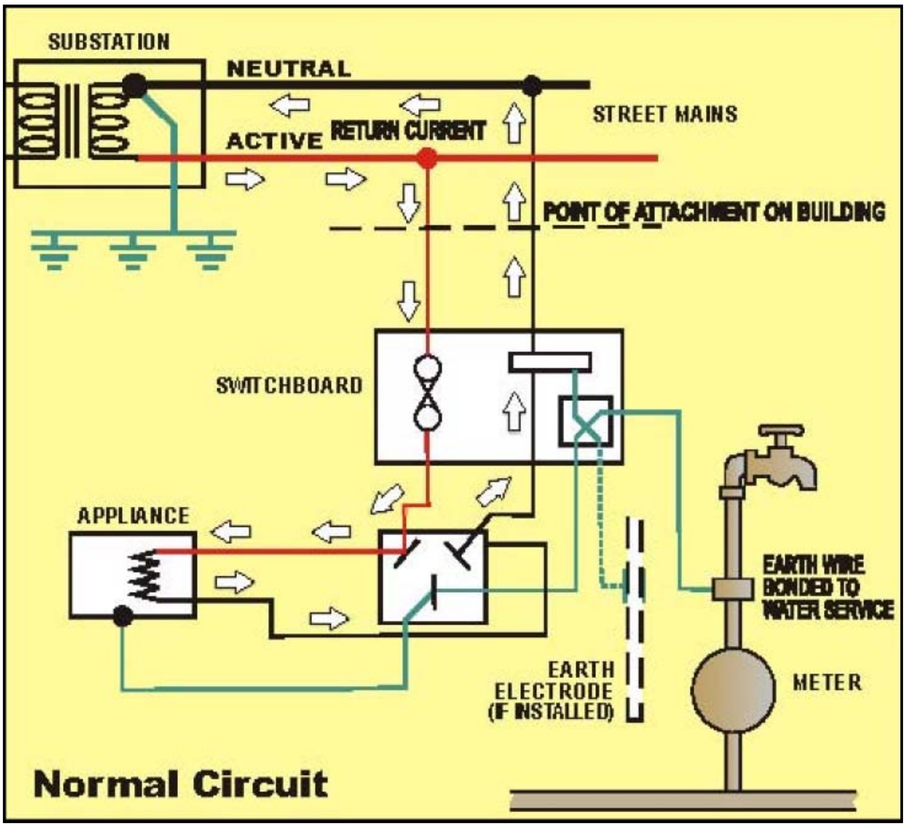

Figure 9 – Neutral current flow with neutral current return path in good condition

If the aluminium sheath of the CONSAC distributor or service cable deteriorates or fails, there is an increase in the electrical resistance of the neutral current path back to the source of supply. When this occurs, the phase current will find an alternative return path; this is usually through the customer's earthing connection or water pipes. This current flow is shown in Figure 10. The customer's earth connection is usually made to an earthing stake; however, it may simply be a connection to a metallic water pipe (as is the case for installations connected to the electricity network before the mid 1970s). These earth connections are not maintained by Ausgrid and therefore their condition is unknown.

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[1] Source – Sydney Water Plumbing Safety Information - 'Risk of electric shock from metallic water service pipes', http://www.sydneywater.com.au/Publications/FactSheets/PlumberInformationRiskOfElectricShock.pdf.

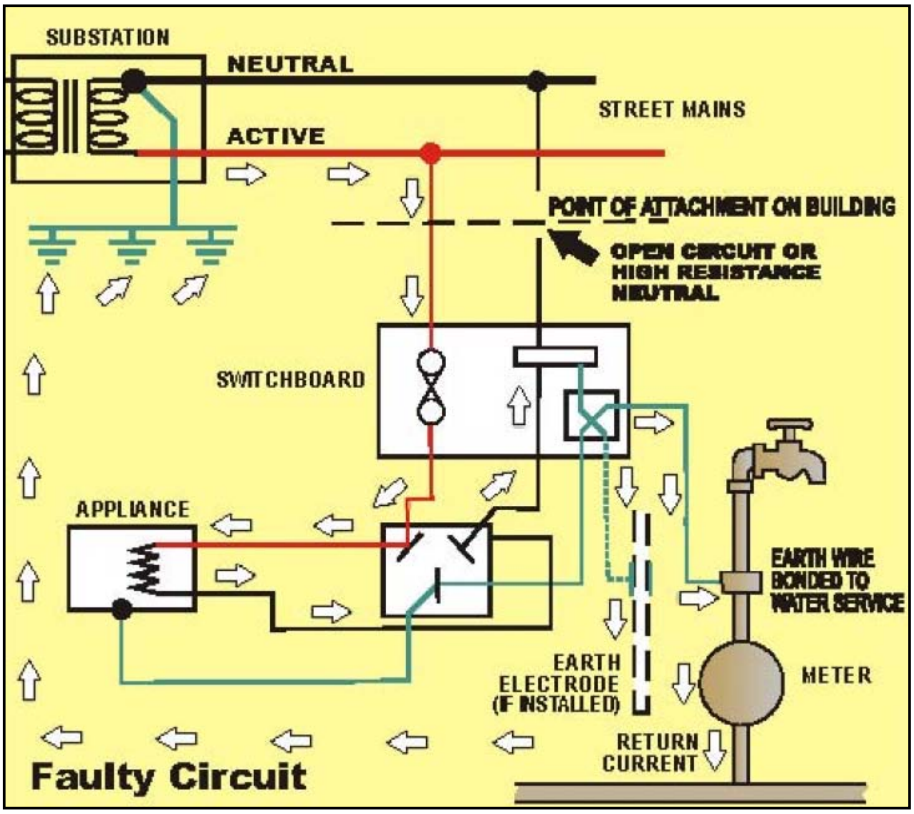

Figure 10 – Neutral current flow with a faulty neutral current return path

Current passing through a customer's earthing connection can cause voltage complaints due to voltage unbalance; it also can create an electrical safety risk due to a voltage rise on appliances and water pipes/taps. This will result in a customer receiving an electrical shock in the shower or kitchen, and can be fatal. The CONSAC cable replacement program commenced in 2004, following a number of (non-fatal) shock incidents reported by Ausgrid customers and staff in a housing development at Singleton Heights. CONSAC had been widely used in the development and was found to have sheath corrosion and deterioration of paper insulation and neutral connections.

The use of water pipe as the earthing point for customer installations is a concern for Ausgrid, because when a metal water pipe fails, it is often replaced with a plastic pipe. While modern customer installation standards require that each installation has an earthing stake and a connection to a water pipe to earth the installation, earlier customer installations only required a connection to a water pipe to provide earthing of the installation. The result is that there are some cases in which the only source of earthing (the metal pipe) has been removed and no other earthing provision installed.

When a metal water pipe fails, modern practice by most water utility companies is to install plastic pipe sections as a replacement. Plastic pipe sections reduce the extent of the 'earthing grid' that metal water pipes provide for customer installations and the LV network. If CONSAC cable is used as the underground service to an installation where the earthing is provided only by a water pipe, the likelihood of an electrical safety risk increases if the CONSAC sheath is in poor condition and the neutral return current is searching for an alternative route via a metal water pipe that no longer exists. Ausgrid, in conjunction with Sydney Water, has a 'Neutral Integrity Testing' program in place to test customer installation earthing after planned water pipe replacement, to ensure that the installation is safe following the replacement of metal water pipes with plastic pipes. The costs for this program are shared between Ausgrid and Sydney Water.

There have been 64 failure notifications for corrective work raised for CONSAC cable in the last three years. This translates to approximately 2.7 corrective failures per 100km per year. It is likely that the level of corrective failures has been under-reported in SAP, for instance, in cases where failures are identified – and repairs are made – in the course of other works. Improvements have been made to SAP to allow better data capture.

3.2.2. Breakdown failures

Breakdown failures of CONSAC cable are caused either by the failure of the aluminium sheath, or by deterioration or mechanical damage of the paper insulation. In either case, the IR between the cable phase conductors and the neutral sheath is reduced and electrical leakage occurs. This leakage further degrades the aluminium sheath and the paper insulation until it causes a breakdown failure. Breakdown failure of the cable blows the distributor fuse at the distribution substation, resulting in an interruption to all customers fed by that distributor.

Aluminium sheath failure

The presence of a PVC outer sheath will limit the corrosion of the aluminium sheath as long as it fully covers the sheath, is not damaged and is not affected by moisture. Historically, a small length of the PVC outer sheath has been removed when joints are needed or when a cable is terminated. The aluminium sheath is usually covered with epoxy putty and tape or a lead wipe at joints to provide a barrier between the aluminium sheath and the soil, but this does not always cover all of the exposed aluminium sheath. Age degradation now being seen on the epoxy putty indicates that previously covered sections of the sheath are now exposed or are allowing moisture ingress, allowing galvanic corrosion to occur. Galvanic corrosion is possibly accelerated where CONSAC cable is direct buried in salty environments, for example, close to the ocean. The LV cable failures experienced in the Bondi Beach area in 2005 may have been exacerbated by the salt environment.

Galvanic corrosion of the aluminium sheath is caused by direct contact with other metals (in joints or in soil) and moisture. The rate of degradation is determined by the soil characteristics. This issue was first identified by the then Sydney County Council in the late 1970s and documented in Technical Standard TS1160 ‘Joint Sleeves’, an extract of which is included in Appendix A. Investigations of failed CONSAC cable at that time revealed that sheath corrosion is accelerated when there is a voltage present between the metals. As the aluminium sheath of CONSAC cable is used as the neutral return path, there is always some voltage between the sheath and earth wherever the PVC outer sheath is missing or deteriorated and corrosion is likely to occur.

Paper insulation deterioration or mechanical damage

When the aluminium sheath is corroded to the point that moisture can migrate through it, the moisture ingress reduces the IR of the paper insulation, which in turn allows leakage currents to occur between phase conductors or between a phase conductor and neutral. This results in minute burns to the paper insulation, further compromising the integrity of the paper insulation until a breakdown failure occurs. Again, breakdown failure of the cable blows the distribution substation fuses supplying that distributor, and supply to customers on that distributor is interrupted.

Overloading of CONSAC cables can also cause breakdown failures. Overloading stresses the cable and can cause overheating or burning of the paper insulation, which causes it to become brittle. This is particularly the case where the paper insulation is mechanically damaged or fatigued during installation or installed in such a way that it exceeds its bending radius.

All cables have a bending radius that needs to be considered when it is laid or terminated. Any cable can be thought of as similar to a garden hose – when a garden hose if bent beyond its natural curve it will collapse or ‘kink’, and this will limit or stop the flow of water because the diameter of the hose is now smaller. This ‘kink’ results in a higher resistance to the flow of water. The same thing occurs with CONSAC cable from an electrical point of view: when it is bent beyond its bending radius the conductor or sheath can be kinked. This increases the electrical resistance of the conductor at that point, causing heating. The paper insulation can also be crushed or stretched, which lowers its IR. Both types of damage cause electrical weaknesses in the cable that are then stressed during overloads or when a fault passes through any section of cable (‘through-faults’). Over time these weaknesses lead to breakdown failures.

Although the majority of CONSAC type cables consist of a solid aluminium conductor, some use stranded aluminium conductor. Stranded aluminium conductor is more susceptible to corrosion than solid conductor. As the conductor corrodes, its cross-sectional area increases. This puts pressure on the paper insulation, causing it to degrade or tear as the conductor expands. This insulation degradation allows electrical leakage currents to occur between phases or from a phase to earth and can lead to either failure of the cable.

Sixty percent of recent breakdown failures have occurred at the 4 to 1 joints (that is, joints that connect four single phase cables to one 3 phase cable) between CONSAC distributor cables and HDPE UGOH cables. The aboveground sections of CONSAC or HDPE cable are more susceptible to moisture ingress due to degradation of the materials used to seal the cable where it connects to the overhead wires. The moisture ingress travels down the cable to the joint, causing corrosion and failure of the joint, which then blows the distributor fuse at the distribution substation, resulting in an interruption to all customers fed by that distributor.

There have been 163 breakdown failure notifications raised for CONSAC cable in the last three years. This translates to approximately 6.8 breakdown failures per 100km per year. It is likely that the level of breakdown failures has been under-reported in SAP, partly because the failure may be recorded simply as a ‘cable fault’ rather than specifying ‘CONSAC’. Improvements have been made to SAP to allow better data capture and Ausgrid has established a process to capture the GIS cable code for all cable failures.

4. Investigations Undertaken

4.1. CONSAC Cable Testing Method

An investigation was undertaken in 2011 to develop a CONSAC cable testing method that would reliably assess the condition of the aluminium cable sheath. While IR checks are carried out with any CONSAC cable jointing work, these are only a rudimentary assessment of the condition of the paper insulation and provide little ability to judge the condition of the aluminium sheath. It was hoped that a successful testing method would assist in determining CONSAC cable condition, so that replacement could be prioritised where needed.

Ausgrid's Distribution Engineering Mains Services (DEMS) undertook literary research on testing of CONSAC cables but found little information about testing of this cable type. DEMS therefore developed and trialled some in-house test methods. The trial focused on testing of CONSAC service cables, since the replacement of services to residential/business customers is costly and onerous in terms of planning (customer outage negotiation, especially in mixed residential/commercial precincts), resourcing (jointer shortages) and reinstatement of customers' property to existing condition.

The testing procedures that were trialled involved applying 240 volts between the active conductor and the aluminium sheath with a controlled current, and measuring the voltage drop at the terminals. Another test carried out was the current split test where the active current was compared to the neutral and earth current at the incoming supply at the customer's installation to determine the condition of the neutral connection.

Testing was carried out at approximately 50 installations. It was found that the testing methods being trialled could not reliably confirm the integrity of the aluminium sheath of the CONSAC service cable. The reason for this is related to the construction of the CONSAC cable and its aluminium sheath: as long as there is a section of continuous aluminium sheath between the source and the customer installation, there is a path for neutral return current – it is only in cases where the aluminium sheath is electrically broken around the total diameter of the sheath that failure will be detected. In addition, where a service was connected by a service 'tee' connection, the service had to be cut to carry out the testing, requiring a commitment to either join a new cable to the existing CONSAC service cable or replace it.

4.2. Meter Based Monitoring

As part of its metering procurement strategy, Ausgrid is investigating the use of electricity meters that monitor the integrity of the neutral connection as a method of mitigating the electrical safety risk associated with deterioration of the aluminium sheaths in CONSAC cables. While these meters may be available under the next meter procurement exercise which commences in FY2015/16, they are not expected to have been installed to an extent that they provide risk mitigation for the whole CONSAC cable population in the short term but localised benefits are expected to become apparent from their installation. If these meters are applied at locations supplied by CONSAC cable, and if this risk mitigation strategy is successful, replacement of the CONSAC cable may be able to be deferred.

5. Risk Assessment

5.1. Consequences of Asset Failure

The consequences of failures of CONSAC cable will depend on factors such as the location of the cable, the length of CONSAC cable on a distributor, the number of customers connected at the time of failure and the length of time that customers are without electrical supply due to CONSAC failure. The consequences may include:

- Electrical shock or death of Ausgrid employee or a member of the public due to loss of the neutral current return path. Electrical shock not causing death requires electrocardiogram (ECG) monitoring of affected person.
- Damage to customer appliances or electrical installations due to loss of neutral current return path or voltage fluctuations.
- Loss of economic productivity due to lengthy or repetitive interruptions to electricity supply to customers.
- Disruption to traffic and pedestrian flow during reactive repairs of CONSAC cable, particularly in commercial or industrial precincts.
- Liability for damages due to injury or death, appliance or installation repairs, loss of economic productivity or reliability of electricity supply.
- Adverse publicity related to injury or death, appliance or installation damage, loss of economic productivity or reliability of electricity supply (as occurred with failures at Bondi Beach).

The consequence inputs into the Replacement Program Risk Quantification Model are summarised below. The consequence severity levels are as defined in Figure 6.7 of the Maintenance Requirements Analysis Manual (AM-STG-10005).

Table 8 – Risk Quantification Model inputs – consequences

	Safety	Environmental	Damages/Liability	Adverse Publicity
Consequence Level	Moderate - 3 (Note 1)	Insignificant - 1	Minor - 2 (Note 2)	Minor - 2 (Note 3)
Probability of outcome upon Breakdown failure	10%	1%	10%	10%

Table 9 – Risk Quantification Model inputs – load at risk

	Supply
Individual asset load at risk (MVA)	0.26
Probability of load loss upon breakdown failure	100%
Average time to repair	120 hours
Average time to restore load	8 hours

Notes:

1. *Consequence of electrical shock due to requirement that affected person must attend medical facilities to have an electrocardiogram (ECG) test done to ensure that their heart rhythm has not been disturbed by the electric shock. It is assumed that there is a 10 percent chance (1 every 10 years) that an Ausgrid employee, customer or person working in a trench in the vicinity of a live and deteriorated CONSAC cable will receive an electric shock.*
2. *Consequence level is due to the expectation that, as the condition of the CONSAC further deteriorates, there is likely to be an increase in the number of electrical shocks. It is assumed that there is a 10 percent chance (1 every 10 years) that court proceedings will occur due to these electric shocks.*
3. *Consequence level is due to the expectation that, as the condition of the CONSAC is a known issue for Ausgrid, if an injury results in court proceedings it is expected that this will be reported in the local media. It is assumed that there is a 10% chance (1 every 10 years) that adverse publicity will occur due to these electric shocks caused by CONSAC cable deterioration.*

5.2. Probability of Asset Failure

As explained in section 3.1, a maintenance requirements analysis has not been undertaken for LV cables because Ausgrid adopts a 'run to fail' strategy for these assets. LV cable corrective or breakdown work notifications in SAP are used to monitor cable performance. LV cable failure notifications for the 2009/10, 2010/11 and 2011/12 financial years were analysed to determine failure rates. Although cable failure rates are likely to vary slightly over time, this represents a short period of analysis given the quantity of LV cable on the Ausgrid network. Analysis of SAP notifications for failures of LV cables shows that approximately 40 percent of the LV cable failures can be attributed to CONSAC cable and a further 30 percent to HDPE cable.

Further analysis of these failures notifications has identified that:

- Corrective failures occur at a rate of 2.7 per 100km per year.
- Breakdown failures occur at a rate of 6.8 per 100km per year.
- An average of 90 metres of CONSAC cable was replaced in response to breakdown failures to remove all CONSAC cable from the affected distributor.
  (Note: the [physical] average of 90 metres replaced per breakdown failure does not align with the average [mathematical] length of CONSAC per distributor of 111 metres. The difference is due to the fact that the ***average length replaced*** *has been determined from failure notifications and is the average of actual replacement lengths. The* ***average length per distributor*** *is calculated by dividing the total length of CONSAC on the Ausgrid network by the number of distributors that contain CONSAC cable.)*
- For distributors with multiple CONSAC failures, subsequent failures occur on average 131 days (0.36 years) after the initial failure when all of the CONSAC cable is not replaced on the distributor.
- The average age of the CONSAC cable at the time of failure is 44.2 years.

The extrapolated likely failure rate of these assets is discussed in more detail in section 8, in the context of program timing.

Improvements have been made in SAP and to the process for capturing the GIS code of failed cables to assist in the prioritisation of replacement of CONSAC cable and other cable types and to improve Ausgrid's understanding of which cable types experience breakdown failures.

5.3. Risk Matrix

Table 10 – Existing risk levels associated with CONSAC corrective and breakdown failures

CONSAC Failure	Hazard	Likelihood	Consequence	Risk
Degradation of the aluminium sheath due to galvanic corrosion	Partial loss of electrical supply/voltage unbalance. (Note 2)	Likely	Insignificant	**B1**
Degradation of the aluminium sheath due to galvanic corrosion	Electric shock in customer installation due to loss of neutral conductor. (Note 3)	Possible	Moderate	**C3**
Degradation of the aluminium sheath due to galvanic corrosion	Electrocution/fatality in customer installation due to loss of neutral conductor. (Note 3)	Rare	Catastrophic	**E5**
Degradation of the aluminium sheath due to galvanic corrosion	Electric shock injury to Ausgrid employee, ASP or civil contractor (Note 1)	Unlikely	Moderate	**D4**
Paper insulation degradation due to moisture ingress, overloading or mechanical fatigue.	Loss of electrical supply (Note 2)	Almost Certain	Major	**A4**
Corrosion of aluminium	Partial loss of electrical	Likely	Insignificant	**B1**

CONSAC Failure	Hazard	Likelihood	Consequence	Risk
conductor due to moisture ingress allowed by sheath/insulation degradation	supply/voltage unbalance. (Note 2)			
Phase to earth and/or phase to phase leakage currents due to paper insulation degradation	Electric shock injury to Ausgrid employee, ASP or civil contractor (Note 1)	Possible	Moderate	**C3**
Phase to earth and/or phase to phase leakage currents due to paper insulation degradation	Loss of electrical supply (Note 2)	Almost Certain	Major	**A4**
Customer shocks or voltage complaints due to service 'tee' connection degradation	Partial loss of electrical supply/voltage unbalance. (Note 2)	Likely	Insignificant	**B1**
Customer shocks or voltage complaints due to service 'tee' connection degradation	Electric shock in customer installation due to loss of neutral conductor. (Note 3)	Possible	Moderate	**C3**
Customer shocks or voltage complaints due to service 'tee' connection degradation	Electrocution/fatality in customer installation due to loss of neutral conductor. (Note 3)	Rare	Catastrophic	**E5**

Notes:

1. *Electric shock to an Ausgrid employee, contractor or accredited service providers (ASPs) could occur in a cable trench or at a cable termination due to leakage currents causing earth potential rise. Any electric shock has the potential to cause a fatality. As the cables are laid in the public domain, Ausgrid cannot not always ensure that only staff or ASPs are working near the cables, so 'civil works contractors' (anyone who may dig or work in a trench) are also at risk.*

2. *Electrical leakage currents due to CONSAC aluminium sheath degradation or deterioration of paper insulation may result in either voltage unbalance between phases (corrective failure) causing voltage complaints, or in loss of supply when the cable degradation reaches the point of breakdown failure.*

3. *Loss of the neutral connection to a customer installation (due to loss of the aluminium sheath or failure of a service neutral 'tee' connection) can lead to electrical shocks occurring in the customer installation – many customers report this to Ausgrid as experiencing 'tingles'. If the neutral conductor of a distributor deteriorates, the risk of electrical shocks is then present on all customer installations connected to that distributor. Each of these incidents has the potential to cause a fatality due to electrocution.*

5.4. Risk Driver Identification

CONSAC risk is primarily associated with duty of care risk exposure due to past and potential future electrical shock incidents, although asset performance risk is also present due to increasing failure rates.

The following risk drivers, in order of descending priority, are applicable to earthing related activities:

1. **Asset performance** associated with degradation of network assets that are intended to maintain the safety and reliability of the LV network. Increasing failures rates due to degradation of the aluminium sheath and paper insulation will lead to an unsustainable number of cable faults.

2. **Duty of Care** requirement to minimise the risk of electrical shocks/electrocution caused by leakage currents from cables with deteriorated aluminium sheath/paper insulation, or by aluminium sheath corrosion resulting in the loss of the distributor neutral conductor/customer installation neutral connection.

3. **Compliance** requirement to ensure that the Ausgrid distribution network provides a safe supply of electricity in accordance with Electricity Supply (Safety and Network Management) Regulation 2008.

6. Risk Reduction Options Analysis

6.1. Risk Reduction Options

Because of the physical design of CONSAC cable and way it was installed, it cannot be inspected in a cost-efficient way, its condition cannot be repeatedly and accurately tested or measured, and it cannot be modified or refurbished. As such, the risk reduction options considered for analysis all require some extent of failed cable replacement.

The options analysed are discussed below. The assumptions used for this options analysis are as follows:

- Each distributor on which CONSAC is located is unique. Each has different lengths of CONSAC and other cable. To assist options analysis, an average length of CONSAC cable per distributor was determined to allow comparison. This average length (111.3 metres) was calculated by dividing the total length of CONSAC cable by the number of distributors on which it is located. The calculated average length was then 'rounded down' to 111 metres for this options analysis.

- If a cable failure is to be repaired, it is assumed that where the cable has failed, a two-metre section of cable will be cut out (one metre each side of the failure location) to allow jointing of a new section of cable into the distributor. Lengths beyond this are considered as 'replacement'.

6.1.1. Option 1 – Do nothing

This is a 'run to failure' strategy. Under this option, when CONSAC cable experiences a breakdown failure, only two metres of new cable is 'pieced in' to replace the failed section. This option requires no additional excavation beyond that required to identify the fault location. This option will result in two additional LV joints on the distributor cable (either side of each failure) which, over the length of the distributor, could result in more than 100 additional LV joints being installed before all CONSAC cable is removed from a distributor of average length of 111 metres. No spare ducts will be laid during repairs.

6.1.2. Option 2 – Reactive replacement (10 metres per failure)

This option is similar to the 'do nothing' strategy except that when CONSAC cable experiences a breakdown failure, a longer 10 metre section of new cable is 'pieced in' to replace the failed section. This option involves additional excavation beyond that required to identify the fault location. This option will result in two additional LV joints per 10 metre section of new cable installed. Over the length of the distributor, this could result in up to 20 additional LV joints before all CONSAC cable is removed from a distributor of average length of 111 metres. Aboveground pillars could be installed and spare ducts could be laid for each 10 metre section excavated, which would lower the cost of future repairs or network augmentation, since further excavation would not be required for that location.

6.1.3. Option 3 – Reactive replacement (30 metres per failure)

This option is similar to the Option 2 except that when CONSAC cable experiences a breakdown failure, 30 metres of new cable is 'pieced in' to replace the failed section. This also involves additional excavation beyond that required to identify the fault location. Thirty metres is approximately the width of two typical urban properties. This option will generally result in aboveground pillars being installed at each end of the new cable, and installation of the cable in ducts. One or more spare ducts will also be installed, to take advantage of the low marginal material cost of installation while the trench is excavated. Installation of spare ducts and pillars means that future excavation is not required and restoration of supply following failures on the remaining lengths of CONSAC is simpler and quicker.

6.1.4. Option 4 – Planned replacement

This option is for the replacement of all CONSAC cable on a distributor. The priority of replacement will be determined in accordance with a risk ranked priority list of all distributors that include CONSAC cable. Under this option CONSAC cable will also be replaced on a distributor if it experiences a breakdown failure or when other work is required at its location and there are cost benefits in replacing the CONSAC cable in conjunction with that work. Aboveground pillars and spare ducts will be installed with this replacement.

6.1.5. Option 5 – Reactive replacement of all CONSAC only following breakdown failure

This option is similar to the Options 1, 2 and 3 except that when CONSAC cable experiences a breakdown failure, all of the CONSAC cable on the distributor is replaced. This option was considered but was not carried forward for further analysis because design and implementation of a CONSAC replacement project for a whole distributor could take up to two years. During this time, additional failures on the distributor could be expected, as outlined in Options 1, 2 and 3 above. Reactive replacement would therefore result in other planned work being continually delayed while reactive replacements were carried out.

Reactive replacement of CONSAC cable will occur under Option 4, but it will be considered as ‘planned’ replacement following repair of the initial breakdown failure, and then only when full replacement is identified as necessary.

6.1.6. Options analysis – advantages and disadvantages

Table 11 – Risk reduction options analysis – advantages and disadvantages

Option	Advantage	Disadvantage
1. Do nothing (run to failure)	When CONSAC cable experiences breakdown failures, only two metres of new cable is ‘pieced in’ to replace the failed section of HDPE cable, so there are no capital costs as this would be considered operations expenditure. No excavation is required to replace the two metres of cable beyond that required to identify the fault location.	CONSAC cable is only replaced when failures occur. The remainder of the CONSAC on the distributor may be in a deteriorated condition but will not be replaced until it fails. Further reactive costs will be required for reactive replacement of remaining CONSAC cable when it fails. Reactive replacement disrupts planned work for the constrained number of jointer resources. Failures are occurring at an increasing rate due to known condition issues with CONSAC, creating an increased safety risk and more disruption to planned work. Each failure results in two additional LV joints on the distributor (at each failed location) which, over the length of the distributor, could result in more than 100 additional joints being installed before all CONSAC is removed. Joints have potential for future failures as they are connected to CONSAC cable which is aged and potentially also in a deteriorated condition. No spare ducts will be laid during repairs; therefore, any future failures or network augmentation will require further excavation (and costs). With 795km of CONSAC installed on more than 7,000 distributors, replacement of all CONSAC could take more than 100 years to complete if only two metres of cable is replaced with every failure.
2. Reactive replacement (10m per failure)	Requires a smaller number of additional joints on the distributor compared to repairing failed CONSAC. Installation of pillars allows for easier sectionalising of the distributor for future failure repairs or other work. The marginal material cost of installing ducts while the trench is excavated is low. Installation of ducts means that future excavation would not be required on that section of the distributor.	CONSAC cable is only replaced when failures occur. The remainder of the CONSAC on the distributor may be in a deteriorated condition but will not be replaced until it fails. Further reactive costs will be required for reactive replacement of remaining CONSAC when it fails. Reactive replacement disrupts planned work for the constrained number of planning, design and jointer resources. Failures are occurring at an increasing rate due to known condition issues with CONSAC, creating an increased safety risk and more disruption to planned work. This option involves additional excavation and higher costs beyond that required to identify the fault

Option	Advantage	Disadvantage
		location. With 795km of CONSAC installed on more than 7,000 distributors, replacement of all CONSAC would require more than 79,000 failures to occur and could take up to 100 years to complete if only 10 metres were replaced per failure.
3. Reactive replacement (30m per failure)	Involves a smaller number of additional joints on the distributor compared to repairing failed CONSAC or replacement with 10m sections. Installation of pillars allows for easier sectionalising of the distributor for future failure repairs or other work. The marginal material cost of installing ducts while the trench is excavated is low. Installation of ducts means that future excavation would not be required on that section of the distributor.	CONSAC cable is only replaced when failures occur. Reactive replacement disrupts planned work for the constrained number of planning, design and jointer resources. Failures are occurring at an increasing rate due to known condition issues with CONSAC, creating a greater safety risk and more disruption to planned work. This option involves additional excavation and costs beyond that required to identify the fault location. With 795km of CONSAC installed on more than 7,000 distributors,, replacement of all CONSAC would require more than 26,000 failures to occur and could take up to 100 years to complete if only 30 metres were replaced per failure.
4. Planned replacement (Proactive replacement prior to failure)	Replace all CONSAC on a distributor prior to failure in accordance with a risk-ranked list based on known condition issues. Reduced number of breakdown failures. Planned replacement allows appropriate planning intervals for the replacement work – including negotiation with customers, Councils and road authorities – to reduce the cost and impact on the community of the work. Planned replacement assists in the effective allocation of constrained planning, design and project delivery resources. CONSAC replacement can be undertaken with other planned work (for example, HDPE cable replacement) to reduce planning, design and project costs, as well as disruption to the community. The marginal material cost of installing ducts while the trench is excavated is low. Installation of ducts means that future excavation would not be required.	CONSAC cable will still experience failures due to known condition issues but this will decrease as planned replacement progresses. Reactive replacement will still disrupt planned work but this will decrease as planned replacement progresses. Failures are occurring at an increasing rate due to known condition issues with CONSAC. Planned replacement will expedite reduction of safety risk. Reduction in failures/safety risk is reliant on the level of annual planned replacement. Risk-ranked replacement prioritisation will not be exact; therefore, some CONSAC may be replaced before other CONSAC that is in worse condition. With 795km of CONSAC on the distribution network, replacement of all CONSAC could take 26 to 40 years to complete (based on replacement of between 20km and 30km per year).

6.2. Options Costing

The net present value (NPV) model was used to compare costs associated with the various options, based on an average length of 111 metres of CONSAC cable on an LV distributor. The cost assumptions used to calculate the lifecycle costs of the various options in the NPV model were:

- The consequence of failure cost, as per the Risk Quantification Model, was $496,847.
- The planned replacement cost was $732.30 per metre, with a reactive mark up of 33%. This average planned unit cost was calculated by averaging the expenditure ($ per km) against closed CONSAC cable replacement projects from the Ausgrid CAPEX dashboard.
- An assumed subsequent failure every 0.36 years following initial CONSAC failure was determined from analysis of SAP notifications where multiple CONSAC cable breakdown failures had occurred on the same distributor.
- Maintenance costs are negligible between the various options so they were not included.

The cost of Option 1 included 56 instances of CONSAC failure, including failure costs and the replacement of two metres of CONSAC cable with each failure. These failures occur over the coming 40 years with repetitive failures every 0.36 years. As the cable is, on average, 37.6 years old as at 1 July 2012, this would make the cable over 60 years old when the last portion is replaced.

The cost of Option 2 included 11 instances of CONSAC failure, including failure costs and the replacement of 10 metres of CONSAC cable. These failures occur over the coming four years with repetitive failures every 0.36 years.

The cost of Option 3 included four instances of CONSAC failure, including failure costs and the replacement of 30 metres of CONSAC cable. These failures occur over the coming one and a half years with repetitive failures every 0.36 years.

The cost of Option 4 included the planned replacement cost of 111 metres of CONSAC cable, prior to failure.

A sensitivity analysis was undertaken on the following cost inputs into the NPV model:

- Unit rate for planned and reactive replacement.
- Cost of the consequence of failure.
- The average age of CONSAC cable at time of failure.
- The average timeframe between CONSAC failures on the same distributor.

This sensitivity analysis indicated that the lowest lifecycle cost option was influenced by all inputs, but was not significantly dependent on any one in particular.

6.3. Risk Assessment of Options

A separate sensitivity analysis was undertaken to determine the impacts of various levels of planned replacement on the expected number of failures on the remaining CONSAC cable. An annual fault growth rate of 14.8 percent was calculated from the failure information, but this was modified to 10 percent as a more conservative value. This analysis and explanation for modifying the fault growth rate is included in section 8.1.

This analysis shows that, when the modified 10 year annual average fault growth rate of 10 percent is applied, replacement of 40km or less per year will result in an increase in the number of CONSAC cable faults for at least the next 12 years. The graphs in section 8.1 also show that if there is no planned replacement (as per Options 1, 2 and 3), the number of faults is projected to double over the next 10 years.

For an asset currently demonstrating premature condition and safety issues, Options 1, 2 and 3 present unacceptable safety, reliability and asset sustainability risks. For Option 4, the level of planned replacement will affect the number of future failures and their associated safety, reliability and asset sustainability risks. More than 60km of cable needs to be replaced each year to have an immediate effect on reducing the number of projected cable failures.

Under Option 4, up to 20km per year of CONSAC cable is replaced. This will lead to an increase in failures, which will result in an increasing number of reactive replacements also under Option 4. Planned replacement will be undertaken in accordance with a risk ranked priority. The risk ranking is determined by factors including age, number of interruptions on a distributor and total length of the distributor. In addition to this, reactive replacement costs are generally 33 percent more than planned replacement costs. With 20km of CONSAC cable replaced annually over the 2015–19 regulatory period it would take more than 30 years to replace the total population of CONSAC cable under this option.

Table 12 is an assessment of the risk reduction options. The existing risk level is for the total CONSAC cable population in its current condition. The resultant risk level (ie, after the option is applied) is the expected level of risk after 10 years of application of the risk reduction option.

Table 12 – Risk assessment of options

	Existing Risk			Risk After Option Applied (10 years)		
Option	Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Do nothing	Possible	Major	C4	Likely	Major	B4
Reactive replacement (10m/failure)	Possible	Major	C4	Likely	Major	B4
Reactive replacement (30m/failure)	Possible	Major	C4	Likely	Major	B4
Planned replacement	Possible	Major	C4	Possible	Moderate	C3

6.4. Cost Benefit Analysis of Options

Figure 11 below shows the NPV model output for the four options. This is extracted from 'ACAPS4030 NPV Spreadsheet - 20130617 CONSAC v7.xlsm'. The model is based on a discount rate of 10 percent. Alternative discount rates of 8 percent and 12 percent are also shown for comparison

Option	NPV		
	Discount Rate - 2%	**Discount Rate**	Discount Rate + 2%
Do Nothing - Replace 2m lengths (Multiple)	$ (11,185,768.58)	$ (8,457,830.70)	$ (6,566,979.65)
Reactive - Replace 10m lengths (Multiple)	$ (3,070,039.09)	$ (2,678,776.94)	$ (2,344,159.70)
Reactive - Replace 30m (Multiple)	$ (1,205,354.33)	$ (1,070,686.20)	$ (952,897.45)
Planned Replace	$ (55,220.65)	$ (50,448.56)	$ (46,117.97)

	Using current Discount Rate
According to this analysis, the recommended option to take is	$ (50,448.56)
This option is highlighted in green.	
	Using Discount Rate + 2%
According to this analysis, the recommended option to take is	$ (46,117.97)
This option is highlighted in light green.	
	Using Discount Rate - 2%
According to this analysis, the recommended option to take is	$ (55,220.65)
This option is highlighted in light green.	

Figure 11 – NPV model output – CONSAC cable lifecycle costs for Options 1–4

NPV analysis of the various options shows that the recommended option is Option 4 – Planned Replacement, since it incurs the lowest lifecycle costs for managing CONSAC cable. This option allows replacement of CONSAC cable to be carried out methodically and with less impact on customers and the community. Methodical replacement also allows efficient allocation of constrained resources across all areas of work.

Planned replacement will result in a modern design LV underground distribution network that is readily modified for maintenance or other work because of the installation of aboveground pillars in place of service 'tee' connections. It will also provide capacity for future network augmentation without having to re-excavate cable routes and disrupt customers or traffic.

6.5. Preferred Option

The preferred option for managing CONSAC cable, as suggested by the NPV analysis, is Option 4 – Planned Replacement. It is proposed to replace approximately 20km per year (average over the 10 year period), although it is also recognised that this rate will not address the average age or expected breakdown failures of the CONSAC population. Further replacement will be required in subsequent regulatory periods.

7. Current Program Summary

The current replacement programs described in this section are relevant to the program of work being proposed in this document for the 2015–19 regulatory period.

7.1. LV CONSAC Cable (REG_ID - REP_04.02.05)

The current LV CONSAC Cable program precedes the proposed program of works detailed in this document. This replacement program was created around 2004, following the high number of electrical shocks experienced in the Singleton Heights area, and was subsequently expanded to cover all Ausgrid regions. This program is mostly for planned CONSAC cable replacement but also allows for reactive replacement following cable failures. Planned replacement of HDPE cable may also be undertaken in conjunction with this work where efficiencies can be gained by combining the work to optimise resource availability or requirements for trenching/cable relocation.

Combining HDPE cable replacement with CONSAC cable replacement on a distributor has the effect of removing all poor condition LV cable from that distributor, with the result that safety and reliability risks are reduced. Where appropriate, many delivery projects for CONSAC have included replacement of HDPE cable or other replacement work on the distributors.

The scope of this program has been reduced from approximately 80km per year to approximately 20km per year, to reflect a realistic level of deliverability.

7.2. Low Voltage HDPE Cable (REG_ID - REP_04.02.06)

The Low Voltage HDPE Cable program is another existing LV cable replacement program similar to CONSAC and is referenced in this document because there is a high correlation between the distributors where CONSAC cable is located and the distributors where HDPE cable is located (approximately 4,500 distributors).

The original replacement program was still in development at the time of the 2010–14 regulatory submission and therefore the scope of work for that period is very small (approximately 17km of HDPE cable over the period). Distribution Guideline DG103 makes reference to specific Sydney County Council cable supply contracts, which were thought to be the only HDPE cables likely to suffer the condition issues now being experienced. In reality, after further analysis of GIS cable codes and network faults it has been established that other County Councils (Brisbane Waters, Mackellar and St George) that were merged to form part of Ausgrid also installed HDPE cables, and that these display the same condition issues as the Sydney County Council HDPE cable.

Table 13 – HDPE actual and planned expenditure – 2010-14 regulatory period

	09/10	10/11	11/12	12/13	13/14
Total	$303,000	$559,000	$1,745,000	$1,056,000	$928,000

8. Proposed Program

8.1. Program Timing Development

Any time that a cable failure occurs at any voltage on the Ausgrid network, Ausgrid's 'Network Test' team is given the task of identifying the location of the cable fault so that it can be excavated and repaired. This team has been recording the voltage of the failed cables to be tested for more than 20 years in the Sydney area.

Analysis was undertaken of their test records to obtain a high level understanding of what trend is occurring at the different cable voltage levels. This analysis was primarily undertaken to determine the impact of LV CONSAC and HDPE cables on the Ausgrid network but other benefits were recognised while preparing the 2015-19 regulatory submission.

Figure 12 shows the number of cable fault location tests carried out by Ausgrid's Network Test for high voltage, low voltage and street lighting cables during the past 20 years.

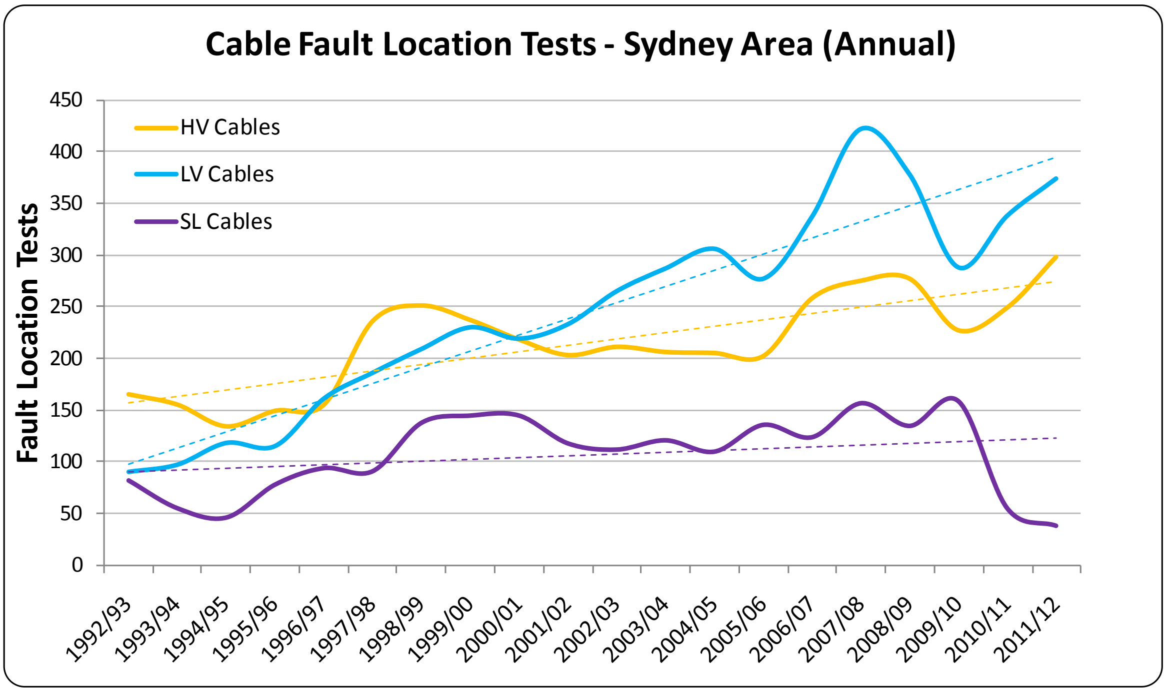

Figure 12 – Cable fault location testing performed by Network Test staff – Sydney area

This analysis demonstrates that failures on LV and HV underground cables are increasing, but LV cables are increasing at a higher rate than HV cables. It was thought that these increases may be driven by rainfall. Ten years of rainfall data was obtained from the 'Bureau of Meteorology' (BOM) website for the Sydney area, and the average rainfall was found to be approximately 800mm per annum over this 10 year period. This rainfall data was then compared to the cable fault location information and is shown in Figure 13.

The first impression obtained from the graph in Figure 13 is that there is a high correlation between rainfall and LV and HV underground cables failures. Street lighting cable fault location testing has tapered off since the beginning of 2009-10, and this could be explained by a change in the work process as jointing staff now do the location testing for these cable failures instead of the Network Test staff.

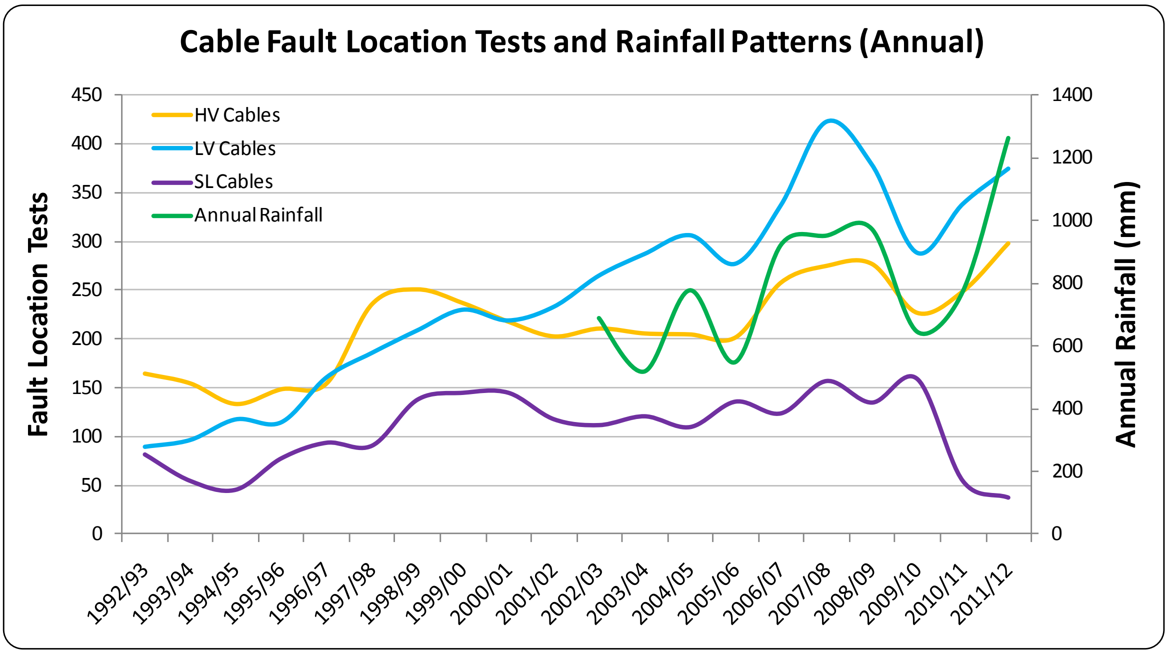

Figure 13 – Cable fault location testing performed by Network Test staff compared to rainfall

The analysis shows that increases in rainfall invariably mean there will be an increase in HV and LV underground cable faults. This is usually due to moisture penetrating or saturating the soil and then, ultimately, the cable. This moisture can enter the cable structure through deteriorated joints or corroded/damaged cable screens. Penetration of moisture through these components causes deterioration of the electrical barrier that the cable insulation provides between phases or between a phase and earth. This results in a failure of the LV cable due to electrical leakage currents either from a phase to another phase or from a phase to earth.

Since the start of FY2009-10, analysis has been undertaken to determine whether distributors that have experienced an interruption due to an LV cable fault had CONSAC or HDPE cables installed on that distributor. Monthly extracts are taken from the Ausgrid GIS system to monitor the removal of these cable types from the LV network. A monthly extract from the Ausgrid Interruptions Database is also used to determine which LV distributors have experienced an LV cable fault. These two extracts are compared to gain a view of how many of the distributors with cable faults also have CONSAC or HDPE cable on the distributor. The results of this analysis are shown in Figure 14.

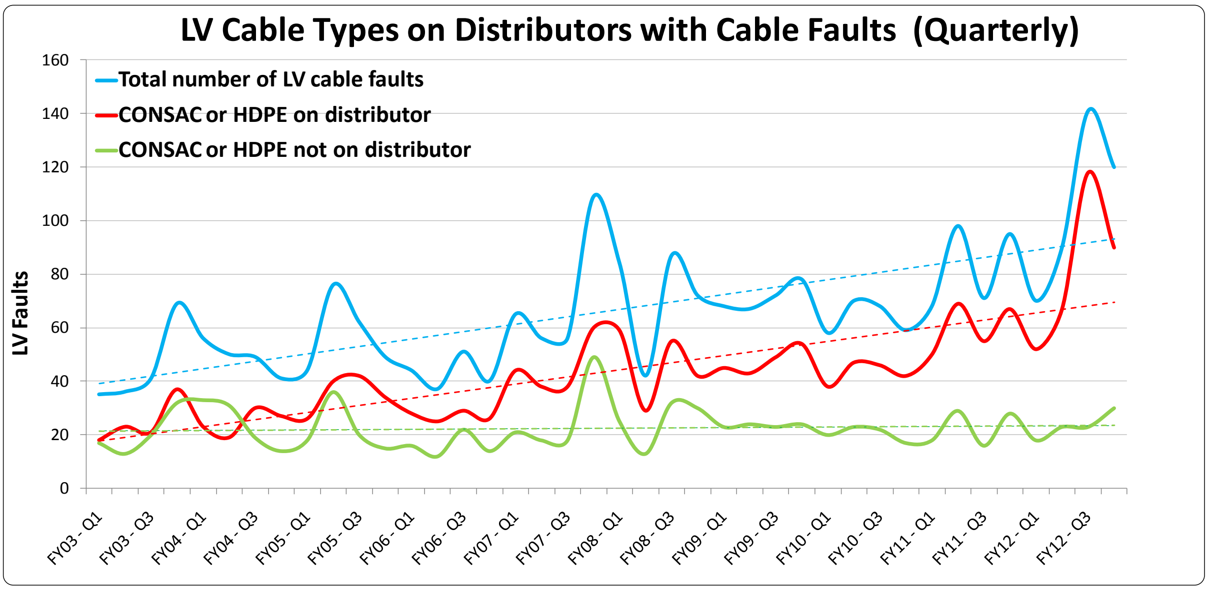

Figure 14 – Quarterly interruptions due to LV cable faults and presence of HDPE or CONSAC cable on distributor

There is a strong correlation between the LV cable interruptions that occur on the Ausgrid network every year and the presence of CONSAC and/or HDPE cables on the LV distributors that have failed. In FY2002-03, approximately 55 percent of interruptions due to LV cable faults occurred on distributors with CONSAC and/or HDPE cable in the circuit. This percentage has generally increased since then – during FY2011-12, more than 70 percent of interruptions were on distributors with CONSAC and/or HDPE cable types. By contrast, there has been almost zero growth over the 10 year period in the trend of LV cable faults on distributors that do not have CONSAC and HDPE cable present on the distributor.

To improve understanding of which CONSAC cable types are causing this increasing failure rate, Ausgrid staff now record the individual cable code of all failed cables or cable joints in SAP. This information will be used to further prioritise CONSAC cable replacement, by allowing Ausgrid staff to select the location of the specific CONSAC cable types that are causing the highest number of failures and remove them from service as a priority through replacement or network redesign.

As information in regard to the specific cable code of a failed cable is not available for past cable failures, a separate sensitivity analysis has been undertaken based on 10 years of interruptions data to determine the possible effects of various average annual planned replacement lengths of CONSAC cable on future reactive replacement requirements. It should be noted that this analysis has been undertaken on failures related to interruptions from the Ausgrid Interruptions Database, not SAP cable failure norification, because the Interruptions Database has been in use for approximately 10 years compared to four years for SAP. This sensitivity analysis has assumed that when CONSAC or HDPE cable is located on a distributor on which a LV cable fault has occurred it is one of these cable types that has caused the failure as no other information is available to prove otherwise. The following inputs and assumptions were used for this analysis:

- A growth rate of 12.5 percent per year over 10 years for LV cable faults[2].
- Where a distributor has a cable fault and both CONSAC and HDPE cable are present, it is assumed that 75 percent of failures are due to HDPE failures and 25 percent are due to CONSAC. This is because, where there are CONSAC to HDPE joints, the deterioration of the HDPE is the likely reason for the joint failure.
- A 10 year average annual count of 84 faults (0.48 faults/km) for HDPE and 91 faults (0.11 faults/km) for CONSAC is used as the baseline for fault count growth projections.
- From the above assumption, the annual growth rate for faults has been determined from analysis of 10 years of interruptions as 20.8 percent for HDPE and 14.8 percent for CONSAC over 10 years based on the assumption that if CONSAC or HDPE was on a LV distributor which experienced an interruption, CONSAC or HDPE was the cause.
- Faults which occurred prior to 2009/10 may have occurred due to CONSAC or HDPE. If the cable was replaced at that time it will no longer be included in the monthly GIS extracts that were used for this sensitivity analysis and therefore the growth rate for faults may appear to be higher over the 10 year period than they actually are. As a more conservative approach, the calculated annual growth rates of 20.8 percent for HDPE and 14.8 percent for CONSAC have been reduced by a third to allow for the possibility that past faults did involve CONSAC or HDPE but factual information has been lost due to subsequent replacement of the cable.
- An assumed reactive replacement allowance of 20 metres for CONSAC cable (mid-way between Option 2 and Option 3 in Section 6.1). Lengths greater than this are assumed to come under planned replacement.
- A reactive replacement allowance of 21.8 metres for HDPE cable following a cable fault. This is based on average length of HDPE per distributor.
- Sensitivities around current failure rates per kilometre of cable were tested for current failure rates minus 10 percent and plus five percent, 10 percent and 15 percent (Figures 15-20).

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[2] Source: Ausgrid Interruptions Database.

- Sensitivities of two-thirds of the current fault growth rate, plus and minus five percent, plus 10 percent and plus 15 percent (Figures 21-25), have been used to determine the effect of
  - differences in annual planned replacement kilometres
  - differences in the timing of reductions in reactive replacement.

The following graphs (Figures 15 to 20) show CONSAC cable fault projections with different lengths of planned replacement and different failure rates per kilometre. A baseline of zero planned kilometres is included for reference purposes. A failure rate/kilometre reduction of 10 percent has been included in the graphs for reference purposes, but this outcome is unlikely given the condition issues associated with CONSAC cable.

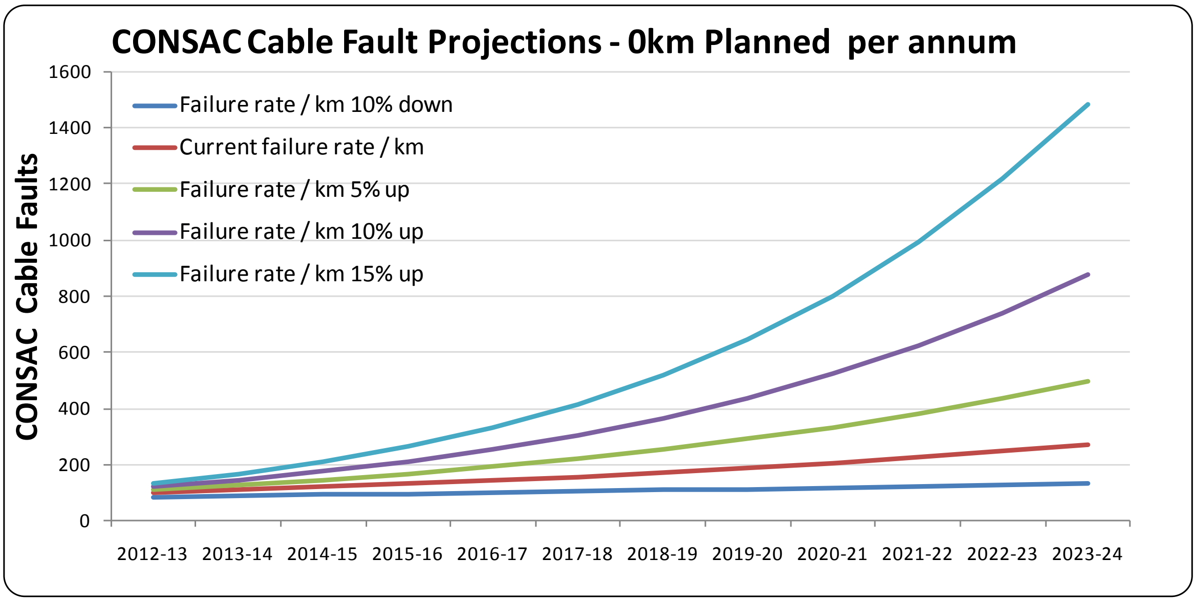


Figure 15 – Sensitivity analysis of CONSAC cable faults with no planned replacement (baseline)

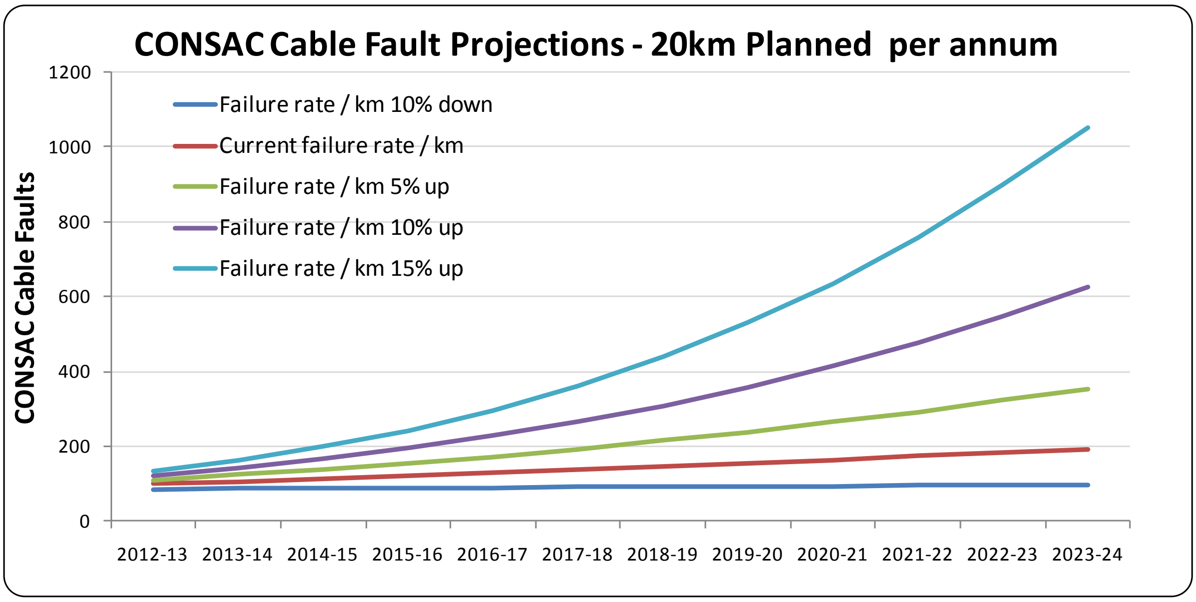


Figure 16 – Sensitivity analysis of CONSAC cable faults with 20km per year planned replacement

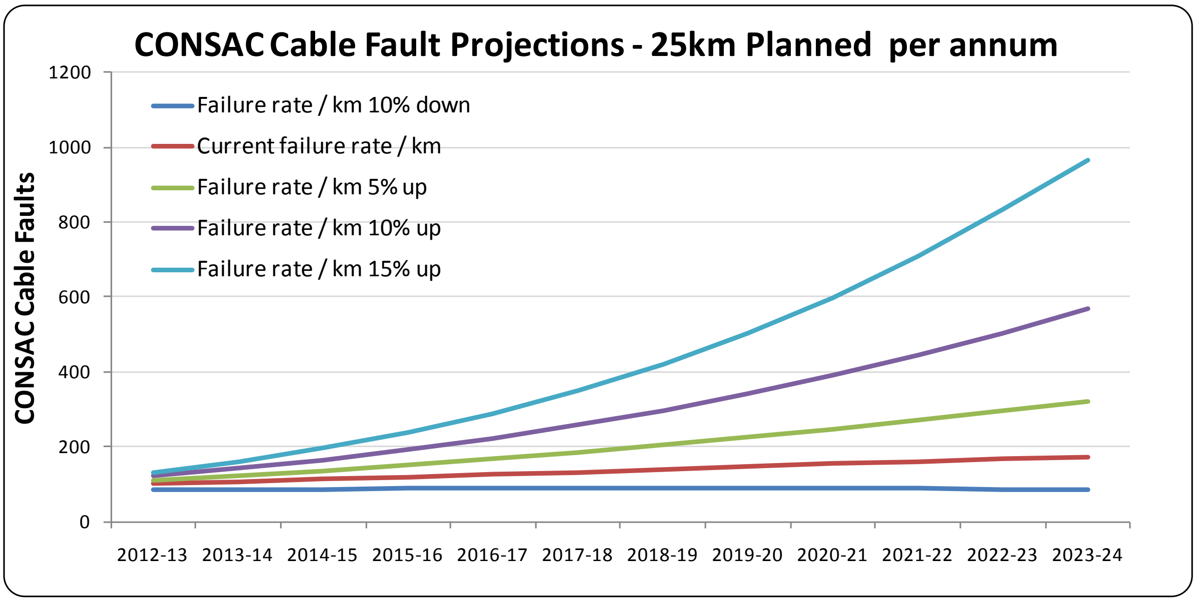


Figure 17 – Sensitivity analysis of CONSAC cable faults with 25km per year planned replacement

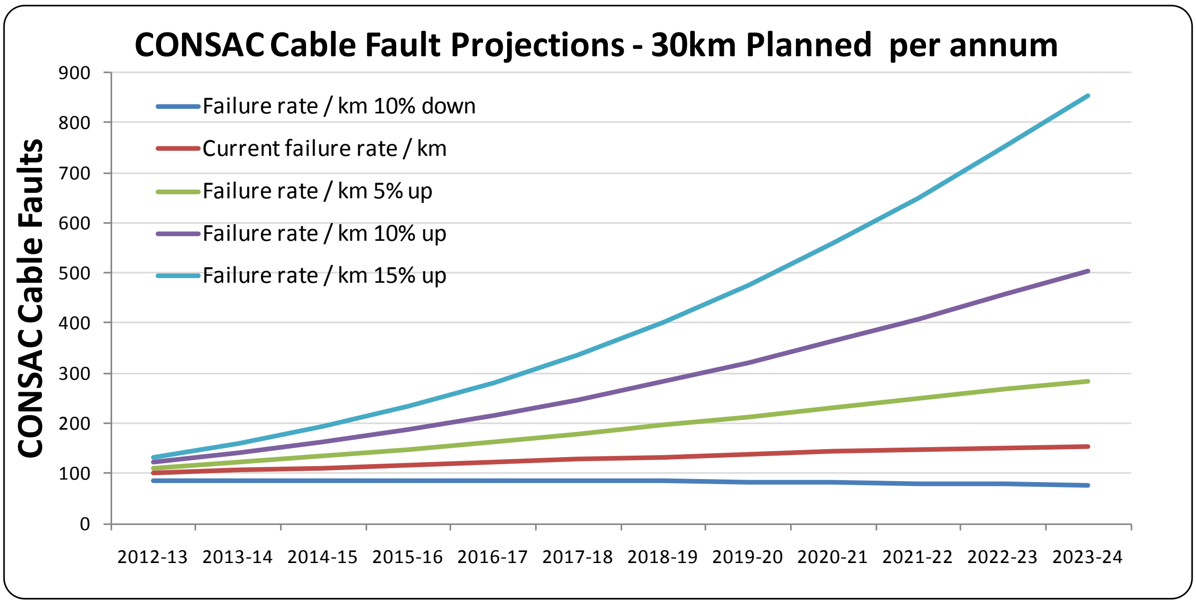


Figure 18 – Sensitivity analysis of CONSAC cable faults with 30km per year planned replacement

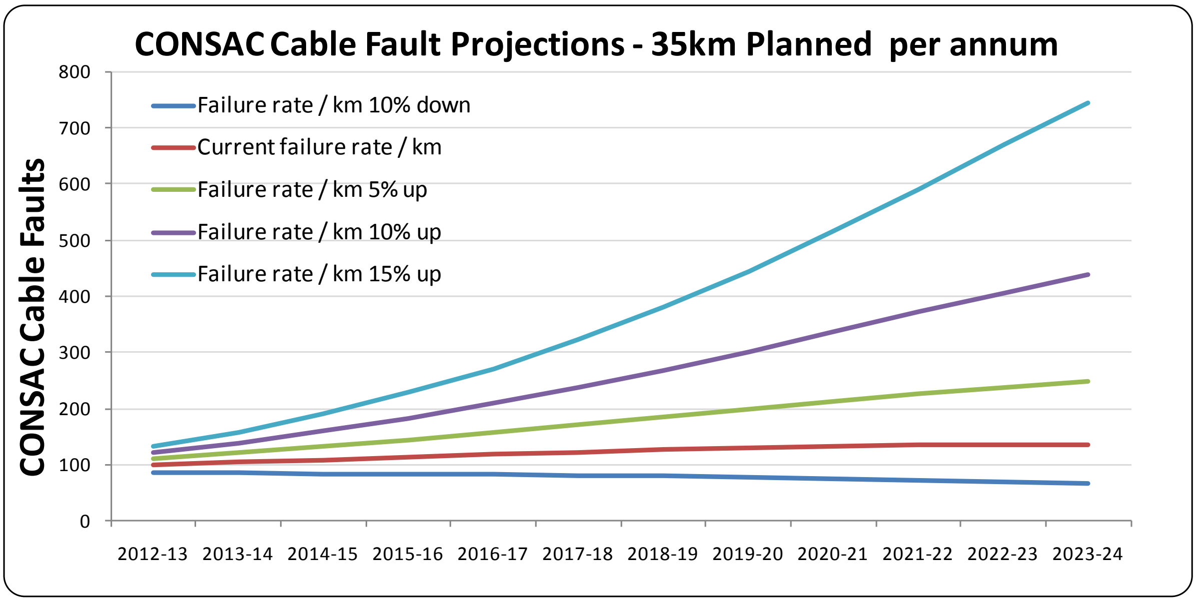


Figure 19 – Sensitivity analysis of CONSAC cable faults with 35km per year planned replacement

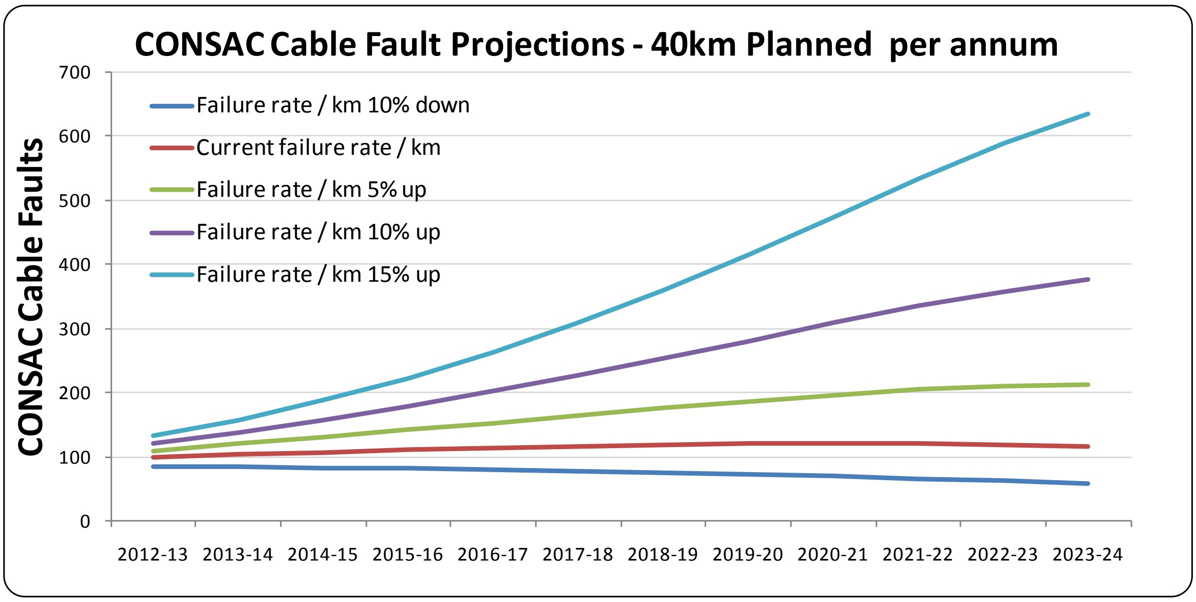


Figure 20 – Sensitivity analysis of CONSAC cable faults with 40km per year planned replacement

Figures 15 to 20 show that any planned CONSAC cable replacement of 35km per year or more will stabilise the projected number of failures in approximately 10 years based on the current growth rate in failures of 10 percent (that is, two-thirds of 14.8 percent). Any planned replacement less than 35km per year will stabilise the projected number of failures but over increasing periods.

The following graphs show projected CONSAC cable reactive replacement lengths with different lengths of planned replacement and different annual growth rates for failures. Again, a baseline of zero planned kilometres has been included for reference purposes. A fault growth reduction of five percent has also been included in the graphs for reference purposes but this outcome is unlikely given the condition issues associated with CONSAC cable.

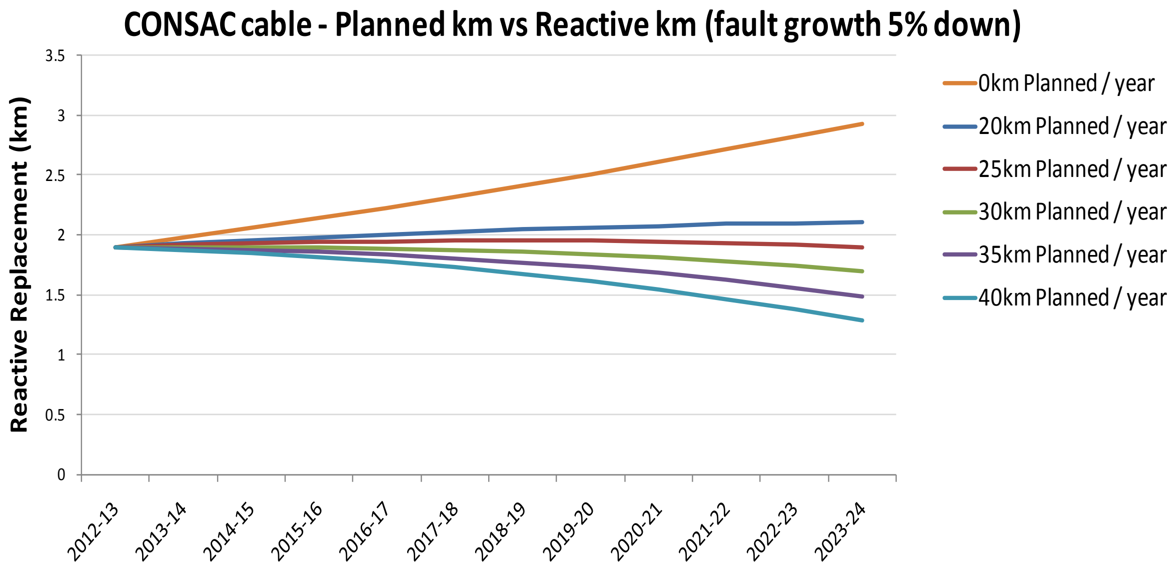


Figure 21 – Reactive replacement requirements with growth in faults per year current growth rate reduced by 5 percent

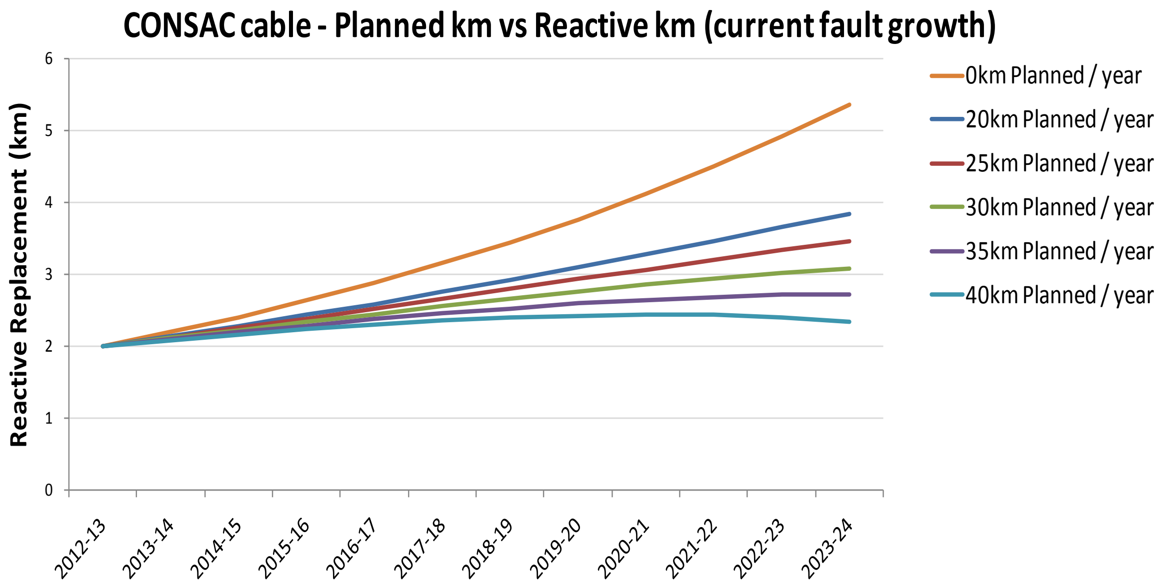


Figure 22 – Reactive replacement requirements with current growth per year in faults.

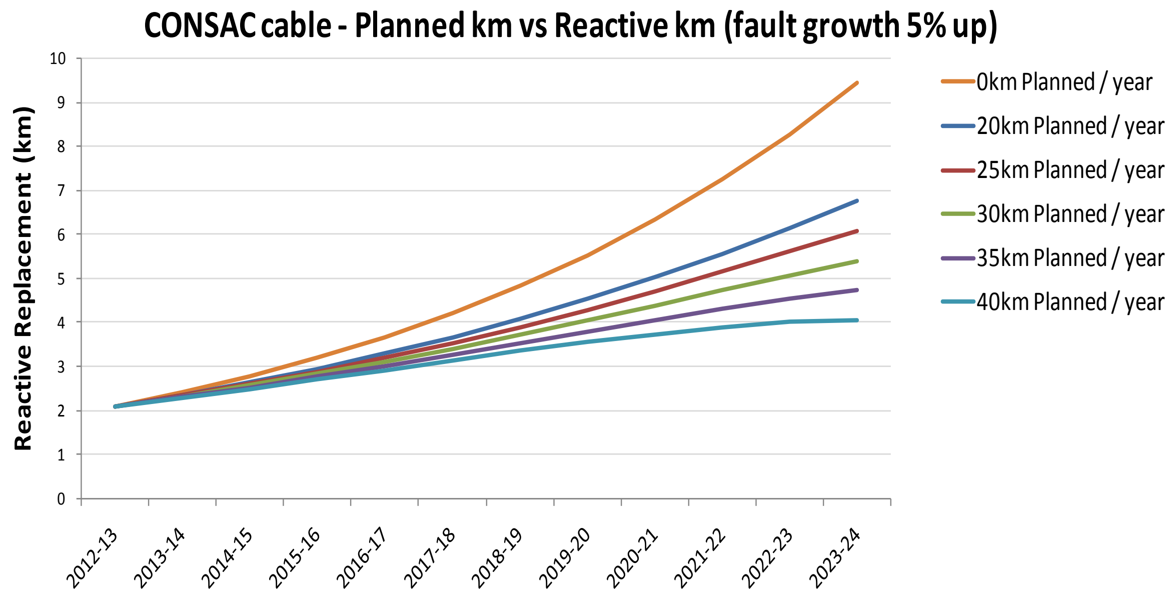


Figure 23 – Reactive replacement requirements with growth in faults per year with current rate increased by 5 percent

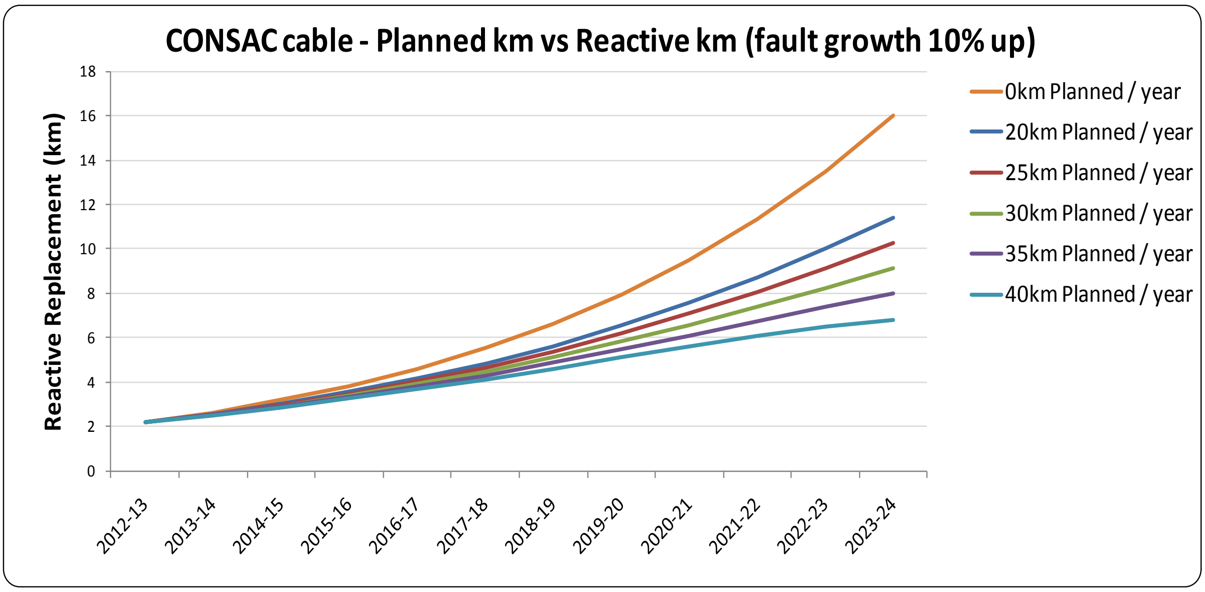


Figure 24 – Reactive replacement requirements with growth in faults per year with current rate increased by 10 percent

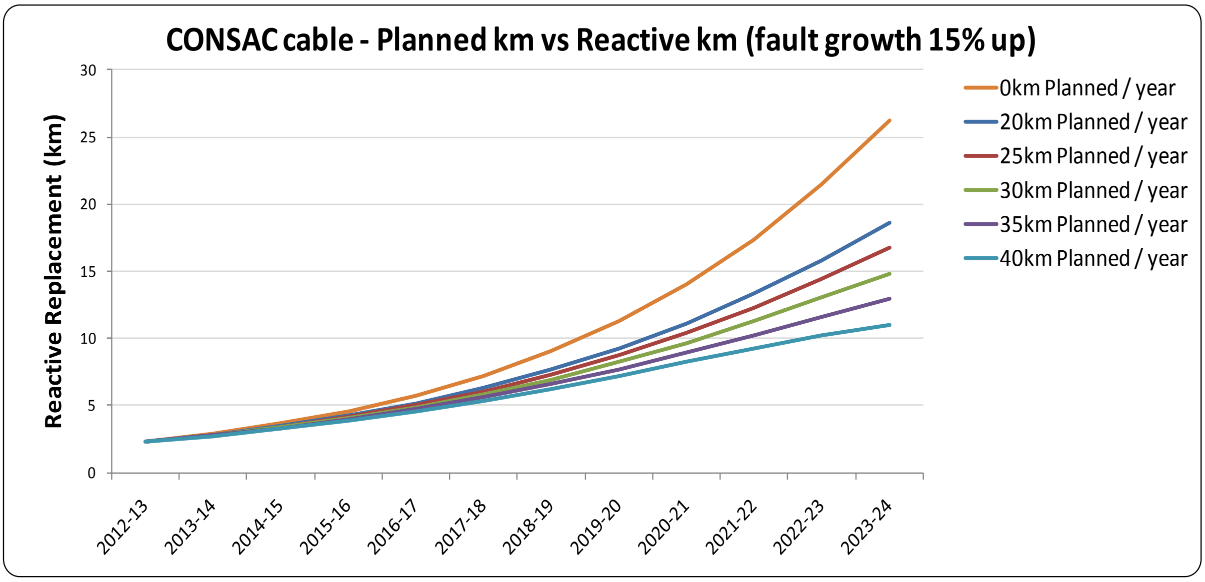


Figure 25 – Reactive replacement requirements with growth in faults per year with current rate increased by 15 percent

From Figures 21 to 25 it can be seen that any planned CONSAC cable replacement of 35km per year or more will stabilise the projected number of failures in approximately 10 years based on the current growth rate in failures of 10 percent (that is, two-thirds of 14.8 percent). Any planned replacement less than 35km per year will stabilise the projected number of failures but over increasing periods.

As a conservative investment approach, Ausgrid is proposing planned replacement of 20km per year during the 2015-19 period as well as additional reactive cable replacement as failures occur. Ausgrid recognises that the proposed level of expenditure and quantity to be replaced may not be sufficient to address the projected increase in failures and that this will result in increased levels of organisational risk relating to safety and reliability. Ausgrid has made changes to our asset management system to capture the individual cable codes following cable failures to improve our understanding of which CONSAC or other cable types are having the most influence on failure rates and will target these cables as the 2015-19 period progresses as well as in subsequent periods.

The total risk mitigated/cost ratio provided by the Risk Quantification Model is shown in Table.14.

Table 14 – Regulatory project IDs – Total risk mitigated/cost ratios

No.	Regulatory ID	Sub-program title	Ratio
1	REP_04.02.05	LV CONSAC Cable	1.33

8.2. Planning & Cost Assumptions

- There were 794.9 kilometres of CONSAC cable in service on the Ausgrid network at the start of FY2012/13.
- It is proposed to replace 114.78 kilometres over the 2010-19 period as part of this plan (both planned and reactive replacement). Further replacement will be required in subsequent regulatory periods.
- If HDPE cable is located on a distributor where CONSAC cable is being replaced, it is assumed that the HDPE cable will be replaced in conjunction with the CONSAC replacement work.
- All costs mentioned below are in FY$12/13.
- Total planned replacements over 5 years; 100 kilometres.
- The unit rate for the planned replacement of CONSAC cable is $732,300 per kilometre.

- Based on the failure data and age of these assets, projected reactive replacements have been included as shown in Table 15 below.
- Reactive replacement is based on a reactive growth rate of 10 percent per year (two-thirds of the 10 year average of 14.8%).
- Reactive replacement quantities are based on the assumption that 20 metres of cable will be replaced as the initial replacement response following a cable failure – replacement of the cable on the remainder of the distributor then becomes 'planned replacement'.
- Total reactive replacements over 5 years; 14.78 kilometres.
- The reactive mark-up for this asset group is 33 percent. This allows for the additional contract cable, traffic management and labour costs.
- The unit rate for the reactive replacement of CONSAC cable translates is $973,959 per kilometre.
- Total planned expenditure: 100 x $732,300 = $73,230,000
- Total reactive expenditure: 14.78 x $973,959 = $14,395,114
- **Total project expenditure: $73,230,000 + $14,395,114 = $87,625,114.**

8.3. Proposed Program – Quantities, Expenditure & Timing

Table 15 – Proposed LV Underground LV CONSAC Replacement Sub-program

	14/15	15/16	16/17	17/18	18/19	Total
Planned (km)	20	20	20	20	20	100
Reactive km)	2.61	2.78	2.96	3.13	3.30	14.78
Total (km)	22.6	22.8	22.9	23.1	23.3	114.78
Planned $M	14.65	14.65	14.65	14.65	14.65	73.25
Reactive $M	2.54	2.71	2.88	3.05	3.21	14.39
Total $M	17.19	17.35	17.53	17.70	17.86	87.63

Note: Variation in calculation due to rounding

Appendix A: Supporting Documentation

Item 1 Extract from Sydney County Council Technical Standard TS1160 'Joint Sleeves' (1980).

Item 2 Designs of various CONSAC joints and neutral connections

Item 1 Extract from Sydney County Council Technical Standard TS1160 'Joint Sleeves' (1980).

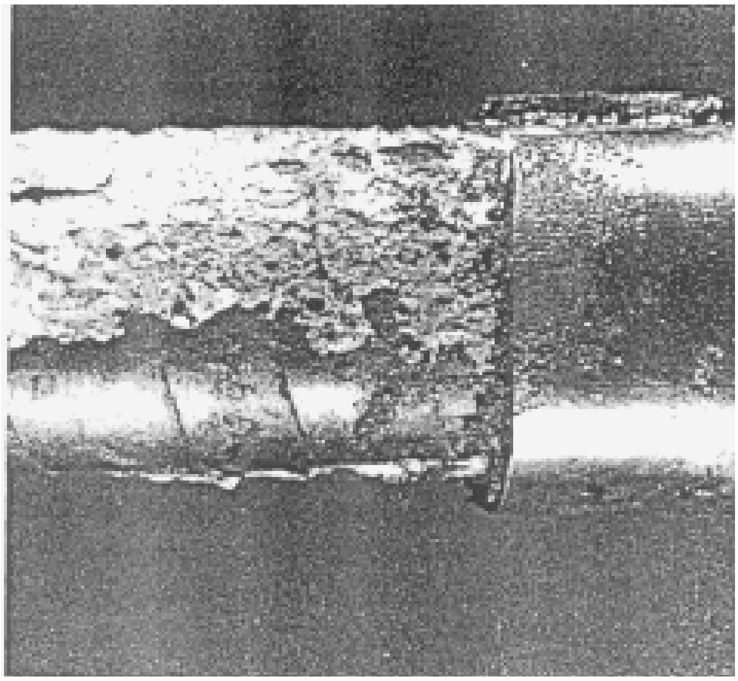
Note; this Technical standard was issued in 1980 and, as can be seen from the images, corrosion of the aluminium cable sheath had already been occurring on CONSAC cable even though it was of a relatively young population age at that time.

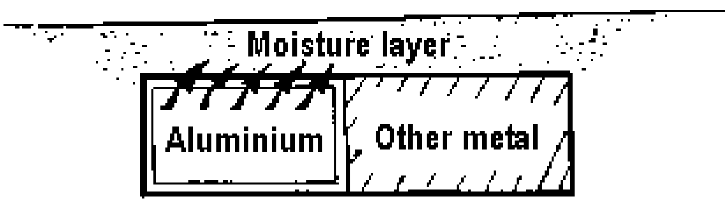
CORROSION PROTECTION OF ALUMINIUM CABLE SHEATHS

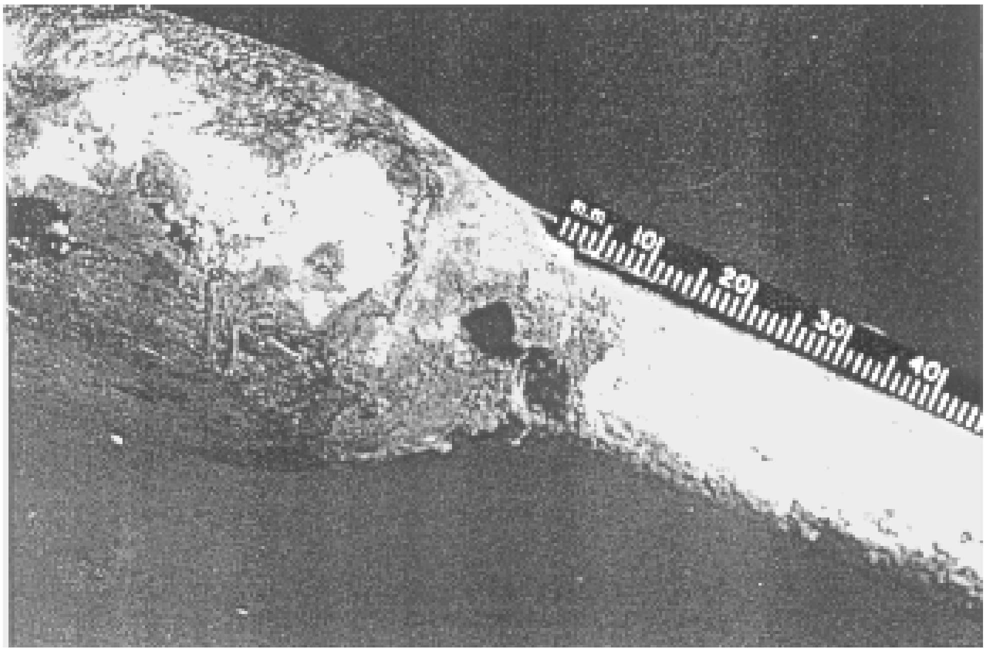
Any metallic structure (be it pipe, conduit or cable) which is buried in the ground can be subject to a variety of forms of corrosion attack.

For many years Council only used lead sheathed cables. Where necessary, these were given forms of external coating or serving, both for reasons of mechanical protection and for protection against corrosion. Basically, though, lead is a stable material with good resistance to corrosion under many circumstances. In recent years, due to changing technology and possible savings which can be obtained with some types of cable, aluminium sheathed cables have been adopted in preference to lead sheathing for widespread use by the Council. In contrast to lead, aluminium is a very active metal and particular care must be taken when aluminium is buried in the ground or installed in any situation where it could be in contact with other metals.

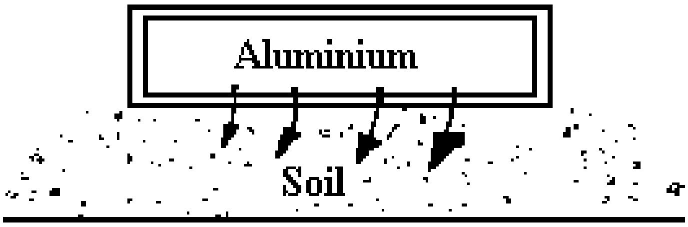
Cable Jointers and Labourers engaged in the sealing of cables must be aware of the importance of providing adequate protection for aluminium cable sheaths and must adopt correct procedures as laid down in jointing instructions and restated below. Pure aluminium exposed to air combines rapidly with oxygen to form the familiar grey coloured film on its surface. This film resists further corrosion. However, if the aluminium comes in contact with other metals in the presence of moisture, electrical (galvanic) corrosion is set up and the aluminium corrodes very quickly.



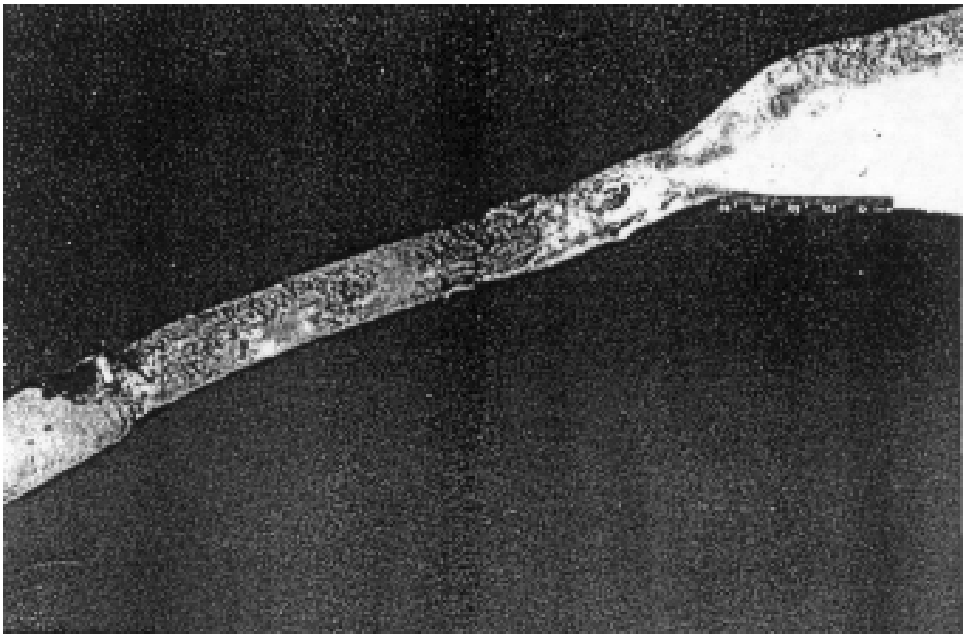




This photograph shows the corrosion that took place at the junction between a lead wipe and the aluminium sheath of a cable in a moist location. This happened in a very short time.



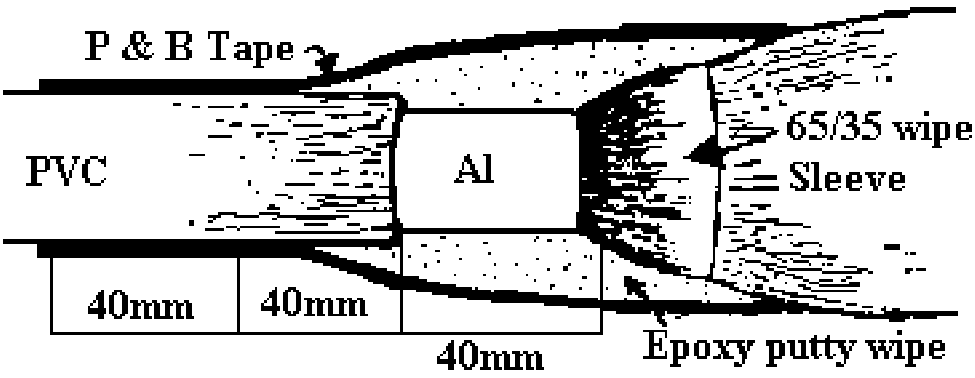
Aluminium in contact with soil behaves in a similar way. The aluminium will corrode at a rate which depends on the character of the soil. If there is a voltage on the aluminium it corrodes far more rapidly. As the sheath of L.V. cables is used for a neutral there is usually some voltage on it compared to earth and unprotected aluminium sheath will corrode at a rapid rate.



This is the effect of leaving an aluminium sheath in the ground without a protective covering.

REMEMBER: NEVER LEAVE ALUMINIUM SHEATH UNCOVERED

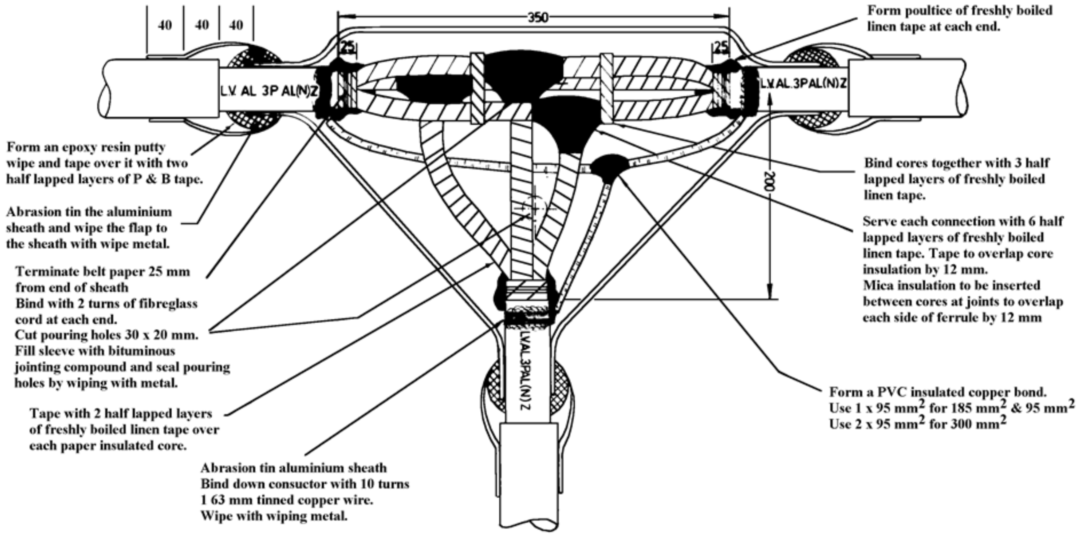
4.1 EPOXY PUTTY 'WIPES'



Jointing of aluminium sheathed cables introduces an area of possible corrosion where the aluminium is exposed to the lead sleeve. To exclude all moisture from this area, an epoxy putty wipe is made and this is then covered with two (2) half lapped layers

Item 2 Various CONSAC Joint Types From Sydney County Council Technical Standards

LV AL3PAL(N)Z to LV AL3PAL(N)Z JOINTING INSTRUCTION

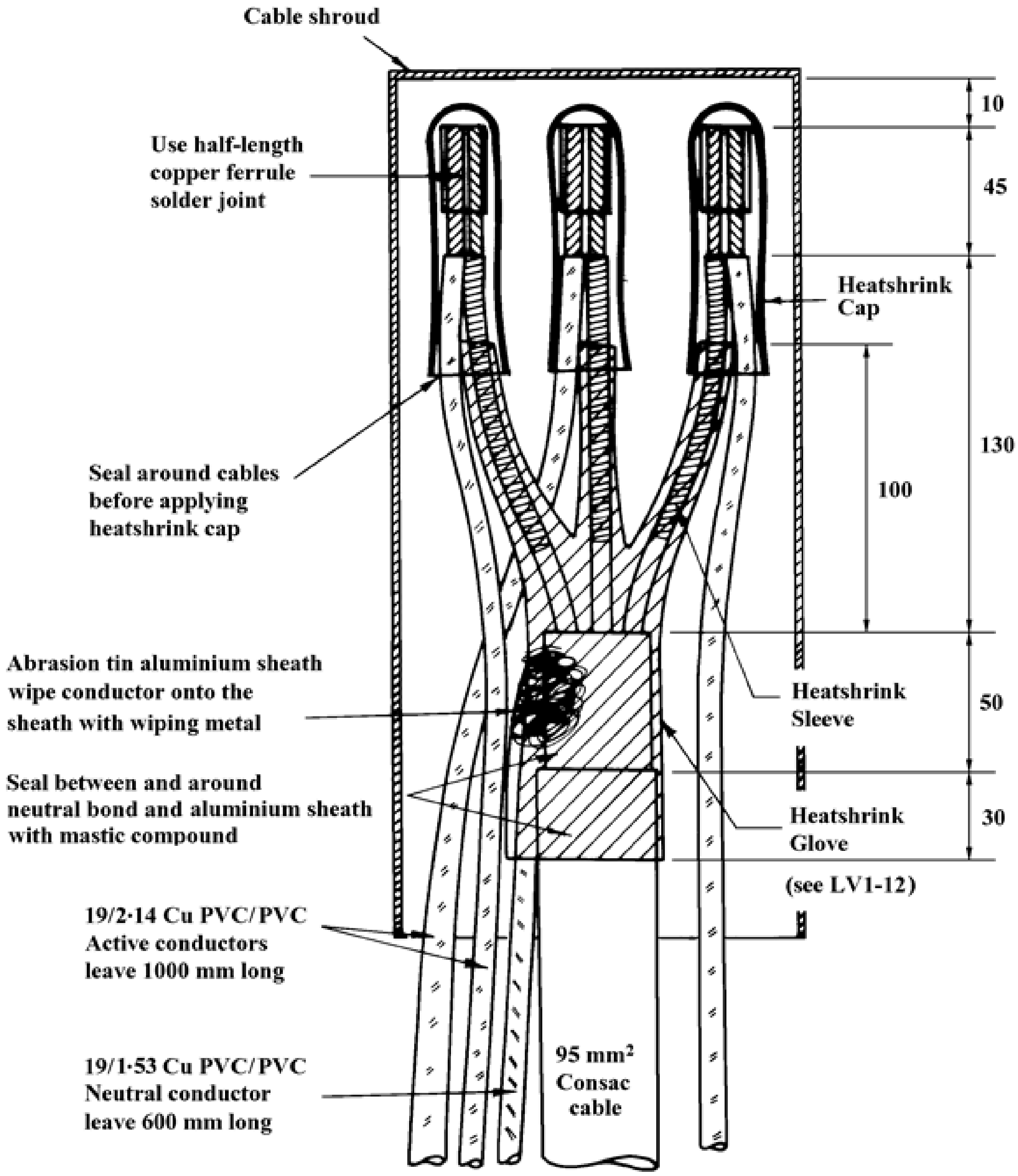


NOTES:
1. Through cable not cut.
2. Split lead 'T' flap used.
3. Seam wipe longitudinal split with wiping metal.
4. Use Code No. 8 lead sheet for 'T' flap
5. Direct laid joints are encased in bitumen filled asbestos cement troughing & covered with 'ELECTRIC BRICKS'
6. Protect the plastic heath serving with fibreglass tape while wiping of the flap to the aluminium sheath.

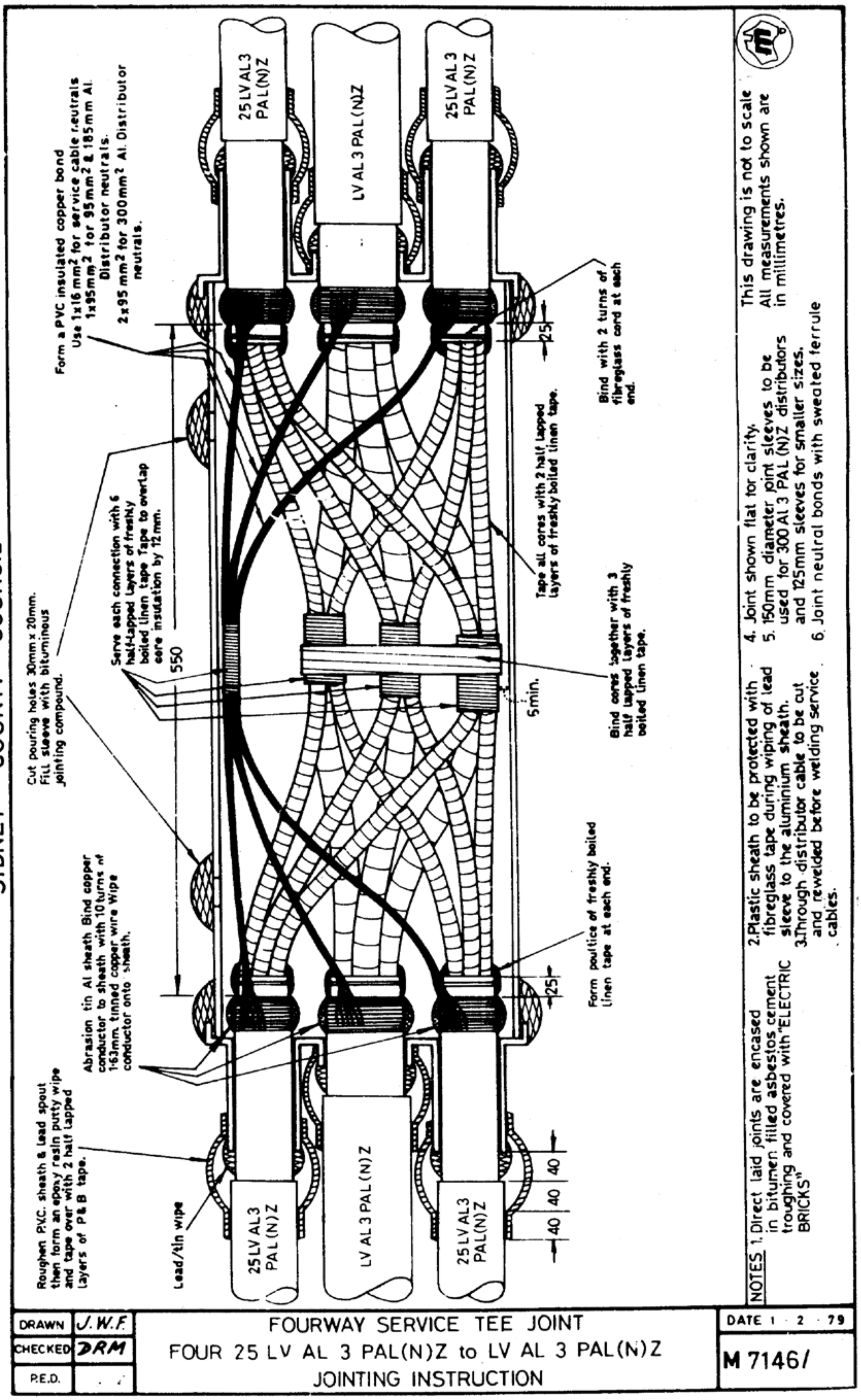
This drawing is not to scale.
All dimensions in mm.

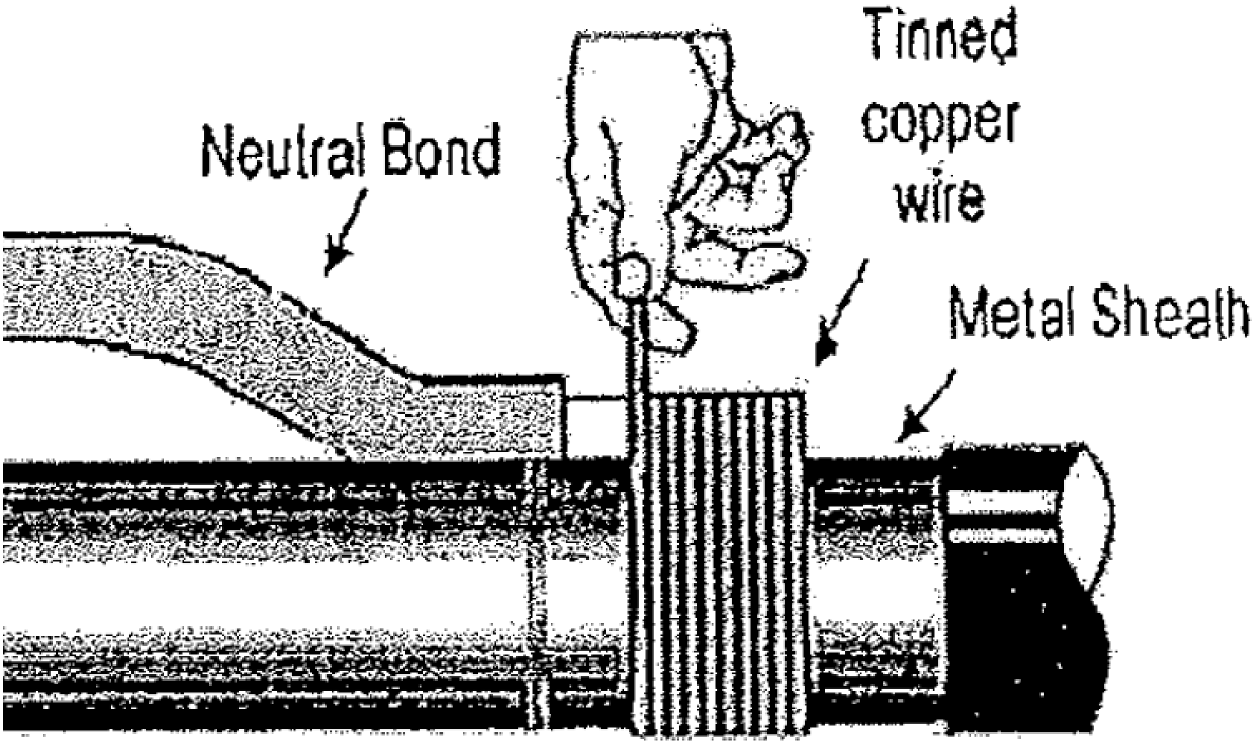
Drawing M7173/1

LV1-19 UGOH TERMINATIONS CONSAC SERVICE CABLE



Information from Technical Standard TS1203 ‘Low Voltage Lay On Tee Joints’




Neutral Bond
Tinned copper wire
Metal Sheath