GRAVELROAD

thinking beyond consulting

Report regarding Customer Access Network Architecture

08 October 2009

Table of Contents

1 Introduction 3

2 Authorship 4

3 Summary and Conclusions 5

4 Background 10

5 Main Cable in distribution Trench 14

6 IEN Cables 24

7 Fibre Joints 27

8 Change of Cable Gauge 32

9 Cable Ploughing 35

10 Cable Sheath Types 41

11 Bend Angle 44

12 Declaration 46

13 List of References 47

List of Appendices

Appendix 1 - Craig Lordan Curriculum Vitae

Appendix 2 – Received Questions

List of Figures

Figure 1 - Relative size of various pits and manholes.. 18
Figure 2 - Example routes for hauling tension calculation (Not to Scale)............................ 22
Figure 3 - Example Cable Plough.. 36

1 INTRODUCTION

1.1 This report sets out my opinion in relation to the questions contained in the Mallesons Stephen Jaques brief dated 9 September 2009 and 6 October 2009.

1.2 The questions I have been asked are included within Appendix 2 and summarised within section 3 of this document.

1.3 This report does not provide any opinion on the economics or unit costs relating to the delivery of customer access network infrastructure.

1.4 My opinions, set out in this document, are based on the material supplied, independent research and my experience in the development and operation of telecommunication networks.

2 AUTHORSHIP

2.1 I, Craig Lordan, have compiled this document in response to the brief. I am an Electrical Engineer, having graduated from Central Queensland University in 1988. I have 20 years experience within the Australian telecommunications industry and my CV is at Appendix 3. Prior to becoming a consultant, I was engaged in a number of Access Network roles within Telstra commencing in 1989 until I resigned in 2001.

2.2 During that period with Telstra, I specialised in urban and rural Customer Access Network infrastructure, including the planning, design and construction of copper, fibre and radio networks. My experience extended from hands on responsibility for individual construction projects through to long term strategic planning and budgeting.

2.3 I also completed international roles while with Telstra. These included the planning and development of customer access networks within Vietnam. Later roles with Telstra included national responsibility for the development and application of Access Network design and construction practices.

2.4 During the past seven years as a consultant, I have provided advice and support to many organisations in relation to the development and implementation of telecommunication networks. Organisations that have received and implemented my advice include existing telecommunication carriers, electricity utilities and government organisations. Recently I have spent a high proportion of my time working to plan and build alternative telecommunication infrastructure within non-carrier organisations.

2.5 I have provided advice to both Queensland electricity organisations which have successfully enabled and commercialised telecommunication infrastructure which provides competition to the existing carrier networks. Other major projects have included the completion of technical feasibility reports for the implementation of very high speed access, fibre based, networks on behalf of State and Local Governments.

3 SUMMARY AND CONCLUSIONS

3.1 My responses to the questions posed are summarised in the following paragraphs.

"Whether or not it is reasonable to assume that main network CAN cables can be housed in the same trenches that have been dug to house distribution cables in any network modelled by the Analysys model?"

3.2 I understand that the distribution trench within the Analysys cost model is selected to connect individual customer locations.

3.3 In my opinion, it is not good engineering practice to assume that all main cable network requirements can be housed in the trenches that have been provided for the distribution network. The reasons for this conclusion are set out in this report.

3.4 In my opinion, it is reasonable to assume the use of a common trench for the distribution cable network and main cable network where up to two conduits are to be installed. This would typically be in locations where only a single main cable is expected to be required.

3.5 In my opinion, the installation of main cable on a route chosen to satisfy distribution network requirements will mean that the main cable will be longer, more difficult to install, and in some circumstances the installation may not be feasible as discussed in paragraph 5.20. Further the overall cost of the network may be higher due to installation restrictions and a requirement for more cable joints than would apply for a route selected for the installation of only main cable.

3.6 Where multiple large main cables, and the associated conduits, are required, it is my opinion, that the main cable and distribution network should be constructed as separate infrastructure. For the reasons discussed in the following paragraphs the size of the infrastructure, including width and depth of the trench, required to collocate multiple main cables is not practically achievable in many locations where distribution infrastructure is installed.

"Whether or not it is reasonable not to allow for conduits to house IEN cables which are assumed to be placed in CAN trenches in any network modelled by the Analysys model?"

3.7 In my opinion, it is not good engineering practice to install Inter Exchange Network (IEN) cables within the conduits provided for the distribution or main network.

3.8 In my opinion, installing IEN cable in conduits provided for distribution or main cables will impact on the future operation of the network, due to the increased potential for damage to the IEN cable. Any such damage is likely to interrupt the delivery of services to a high number of customers.

3.9 In my opinion, a separate conduit should be provided for IEN cables, which only enters pits and manholes necessary for the jointing and hauling of IEN cables. I suggest consideration be given to minimising the distance of IEN cable to be installed by the use of separate dedicated trenches for IEN infrastructure because installing IEN cables on routes selected for distribution network adds significant distance to the length of the IEN cable.

"Whether or not it is reasonable not to allow for fibre joints in the CAN in any network modelled by the Analysys model"

3.10 In my opinion, it is good engineering practice to allow for fibre joints within the CAN as joints are required, as a minimum to facilitate the interconnection to customer lead-in cables.

3.11 The number of fibre joints should be calculated using the number and location of services to be connected, distance from each final module to customer termination and the total distance of the proposed main and distribution network.

"Whether or not it is reasonable to include the cost of fibre joints in the cost of fibre cable without knowing how many joints are required in any network modelled by the Analysys cost model?"

3.12 It is reasonable to include the cost of fibre joints within the Analysys cost model. The number of joints should be calculated on the basis of the two joint categories described in paragraph 7.16, the number of services to be provided, the length of the distribution network, type of network[1], and total number of fibres within the network.

"Whether or not it is reasonable not to allow for joints to connect copper main or distribution cables at pillars or large pair gain systems in the CAN in any network modelled by the Analysys model?"

3.13 In my opinion, at those pillars and large pair gain systems where the maximum cable size which can be installed is exceeded, a copper joint will be required.

"Whether or not it is reasonable not to include joints to connect one gauge of cable to another, in any network modelled by the Analysys model?"

3.14 In my opinion, as cables are only manufactured with one gauge within the cable, a joint will be required where one cable gauge is to be connected to another. The change from one conductor gauge to another requires the interconnection of two separate cables and this requires a joint.

"Whether or not it is reasonable not to include a pit or a manhole to house any joints used to connect one gauge of cable to another."

3.15 In my opinion a pit or manhole should be included where-ever a joint is required in the network, either for a DP or a change of cable gauge, to allow for later access to repair faults or rearrange the interconnections within the joint.

"In your view, what is the maximum number of cables it is reasonable to plough in any network modelled by the Analysys model?"

3.16 In my opinion, the maximum number of cables which can reasonably be ploughed is two cable sheaths for a single path. If the definition of a route extends to the use of both sides of a road then the maximum number that could reasonably be ploughed on a route is four, by completing two installations on opposite sides of the road.

---

[1] Type of network may be either a, PON architecture which reduces the number of fibres to be jointed in the distribution network or a architecture which includes a dedicated fibre from RAU to DP.

3.17 In my opinion it is reasonable to consider the installation of two cables simultaneously but any greater number will be restricted due to the ability to carry multiple drums of cable, and space within the plough.

3.18 The ploughing of cable is typically subject to a degree of error between the nominated and the actual alignment of the installation due to the plough being prone to shift horizontally from the planned alignment. Considering the potential for variation in alignment, it is in my opinion, not a practical approach to consider another cable plough in close proximity to an existing installation due to the likelihood of damage.

3.19 My opinion is based on the physical limitations of ploughing equipment, in particular its inability to support more than two cable drums, and the space within the plough to install multiple cables and the practical issues associated with the installation of cable by ploughing techniques which include the variation in installed alignment and the activity required to stop and restart ploughing when crossing roads or water courses.

"In your view, what is the maximum number of copper pairs and the maximum gauges of those copper pairs in a sheath to be ploughed, in any network modelled by the Analysys model"?

3.20 In my opinion, due to the space restrictions within existing cable ploughs, the maximum size cable which can be installed is protected sheath cable equivalent to 100 pair 0.64 mm, 50 pair 0.90mm or 200 pair 0.40 mm.

"Whether or not it is reasonable not to allow for protected cable in instances where cable is directly buried in the ground in any network modelled by the Analysys model"

3.21 Due to the potential for damage to the cable sheath from objects within the ground, when cable is installed without conduit, in my opinion, it is not reasonable to not allow for protected cable where the cable is to be directly buried in the ground. If unprotected cable is directly buried in the ground it is likely to result in an increase in maintenance activity to replace damaged cable.

3.22 My opinion is based on the potential risk of damage to a cable which is installed directly into the ground without a protective sheath. The standard cable sheath protects the conductors within a cable from moisture ingress but rocks and other in ground material are likely to puncture the sheath and the cables are likely to require future repair or replacement. The use of cable with a protective sheath can significantly reduce the likelihood of a cable being damaged during installation or by the environment.

"In your view, what is the maximum angle that a large nest of cables is physically able to turn without a manhole or a pit? Please set out the reasons for your view."

3.23 In my opinion, the maximum angle that a large nest of cables is physically able to turn without a pit or manhole is approximately 90 degrees. If the nest of cables is to turn more than 90 degrees a pit or manhole will be necessary.

4 BACKGROUND

4.1 Before addressing the specific questions, I provide the following comments as background information.

Typical Customer Access Network (CAN) Architecture

4.2 A CAN is typically installed with an architecture which includes points of concentration to minimise the overall infrastructure size and enhance the flexibility of how cables are used.

4.3 Starting at a termination point in the customer's premises the access network normally consists of:

a) Lead-in cable which connects the customer premises to the street network Distribution Point (DP),

b) DP – a joint in the cable network which allows for the interconnection of the lead-in cable to the distribution network cable,

c) Distribution network cable – cable which interconnects the DPs and typically a pillar,

d) Pillar – interconnection device, often above ground, which enables the connection between distribution cable and main cable. The use of pillar allows the concentration of services to a smaller number of pairs than would typically be provided in the distribution network,

e) Main cable – cable which interconnects pillars and the Remote Access Unit (RAU),

f) RAU – carrier's equipment which is connected to the core telecommunication network and provides the services connectivity for the delivery of voice and broadband services to the customer via the customer access cable network.

4.4 Typically within an urban CAN, new distribution network routes are normally dependent on the shared trench provided by the developer, and where possible are designed to optimise the route required to connect customers. The main cable network is normally considered separately with the aim to minimise the distance between the pillar and RAU.

Copper Cables

4.5 Based on the material supplied[2], I understand that the Analysys cost model assumes the provision of single trench to satisfy all requirements including distribution cable (pillar to DP), main cable (RAU to DPs) where required and in limited circumstances Inter Exchange Network (IEN) cable.

4.6 For connections between core carrier equipment locations, commonly referred to as an exchange, IEN cables are installed. IEN cables are of a higher value to carriers, due to the fact that any damage or fault in an IEN cable has the potential to impact significantly more customer services than damage to a distribution network cable or main network cable.

4.7 Based on my review of the provided material[3], I understand that all trench routes are selected by an algorithm based on connecting all DPs. If main cable is also required the number of conduits to be installed on the route is increased.

4.8 I understand that within the Analysys cost model the DPs are installed to provide connections to premises and include a joint to connect the distribution cable to the property lead-in cable. Distribution cable is typically of a size of 100 pairs or less.

4.9 In some trenches close to the RAU there is a concentration of requirements, including distribution network, multiple main cables and IEN cable on some routes which dictate the inclusion of many conduits within the trench.

4.10 When only distribution cable is required a single conduit is installed within the trench.

4.11 In the Analysys cost model the number of conduits required in the trench to select the size of access point pit to be installed.

---

[2] FLRIC report for stakeholders_Workshop Version P39

[3] FLRIC report for stakeholders_Workshop Version

Typical CAN Components

4.12 A main cable network is normally comprised of larger cables of typically 400 pairs or greater, and structured to minimise the number of joints.

4.13 Copper cables are used in telecommunication networks to provide connection between carrier’s equipment and the customer’s equipment. The usual practice is to use a pair of wires to provide this connection. Copper cables are normally referred to in terms of the number of pairs or wires which they contain (e.g. 100 pairs) and the diameter of the conductor (wire).

4.14 Various copper wire diameters (gauges) are used in the provision of telecommunication networks. Increasing the gauge of the cable extends the distance from the RAU at which customers can be connected.

4.15 There are currently three standard copper cable gauges used for new cable installations. The three copper gauges in use are 0.40 mm, 0.64 mm and 0.90 mm. Increasing the gauge of copper wire decreases the loss for every metre of the network, but increases the weight and diameter of the cable for the same number of pairs. Increasing the gauge of the copper significantly increases the cost. Due to the cost of cable, the minimum gauge of cable which will enable connection of the most distance customer is typically selected for installation.

Optic Fibre

4.16 Optic fibre cable installations are also considered in this report. Optic fibre cable consists of a number of optic fibres within a common sheath. Optic fibre cable is typically comparable in size to distribution cable, but unlike copper cables the size of the cable is normally defined by the number of fibres rather than the number of pairs as is the case for copper cables.

4.17 Unlike connections of copper wire, which can be completed very quickly with a medium level of skill, fibre splicing is significantly more difficult due to the size of the fibre (microns in diameter) and the requirement for a high level of alignment between the two fibre ends. With an electrical (copper wire) connection there is no requirement to align the two ends of the wire as the connector provides the physical link. With optic fibre the connection process requires the accurate alignment of the two fibre ends to form a connection which allows light to pass.

4.18 Two optic fibres can be joined by fusing the ends together in a special machine (fusion splicing), or by placing the fibre ends in a mechanical connector designed to maintain the alignment. Although the connector form of splicing is quicker to complete than fusion splicing, it normally exhibits a higher level of loss, and, in any case, both fibre splicing options take significantly longer to complete than copper cable jointing.

4.19 Optic fibre networks can be constructed using two basic architectures, the first is to allocate a single fibre or pair of fibres from the RAU to the customer connection which is similar to the copper network. The other option is to use optical splitters which allow for one fibre to be connected via a splitter to multiple (e.g. 32) fibres which are in turn each connected to customer premises. This architecture is commonly referred to as a passive optical network (PON).

4.20 The splitter within a PON is similar to a prism which diverges light into many paths and through the use of special terminal equipment each customer terminal has access to its own high capacity connection from the RAU. The use of PON architecture allows for a significant reduction in the number of fibres required between the RAU and the distribution network.

Trenches

4.21 When telecommunication networks are installed underground, either the cable is directly buried in the ground or conduits are installed into which the cable is hauled. Conduit is basically a pipe between two access points. An access point is a location where a pit or manhole is installed to allow the installation of cable through the conduit or the installation of joints between two or more cables, and future access to conduits or cable.

4.22 When cable is directly buried, it can be installed either by the excavating of a trench and laying the cable prior to reinstatement, or by the use of cable plough techniques.

4.23 Ploughing of cable avoids the cost of excavating a trench for the installation of cable by installing the cable directly into the ground through a plough.

5 MAIN CABLE IN DISTRIBUTION TRENCH

5.1 I have been asked:

(a) **Whether or not it is reasonable to assume that main network CAN cables can be housed in the same trenches that have been dug to house distribution cables in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please explain:**

(i) why it is necessary to house main CAN cables separately from distribution cables;

(ii) what inputs would be required, and how could they be determined, to take into account the separate housing of main CAN cables from distribution cables in the network modelled by the Analysys model.

We refer you to the trench sharing coefficient in the Analysys cost model (see CAN.xls, Access, rows 360-374). Please assume that the trench sharing coefficient reduces the amount of distribution trench in the Analysys cost model to account for the fact that two or more distribution cables may share a common route and thus should be placed in the same trench.

5.2 In my opinion, it is not good engineering practice to assume that all main cable network requirements can be housed in the trenches that have been provided for the distribution network. Rather in my opinion, it is only reasonable to use a common trench for the distribution cable network and main cable network where up to two conduits are proposed to be installed. This would typically be in locations where only a single main cable is expected to be required.

5.3 In locations where multiple main cables are required along the same route there are a number of practical physical constraints which, in my opinion, restrict the inclusion of main cables within a trench selected and provided for distribution cable requirements and thus the main cable and distribution network should be constructed as separate infrastructure.

5.4 In my opinion, the installation of main cable on a route chosen to satisfy distribution network requirements will mean that the main cable will be longer, be more difficult to install, or it may not be feasible on that route. Further the overall cost may be increased due to installation restrictions and a requirement for more cable joints than would apply just for a route selected for the installation main cable.

Installation of Main Cable

5.5 The discussion within this section is limited to the use of copper cable for both distribution and main cable installation.

5.6 The installation of main cable in trenches selected for the distribution network requires additional conduits to be installed and larger pits or manholes than would be required if only distribution cables were being installed. Where a single 100mm diameter conduit is considered suitable for distribution only network applications, many more 100mm conduits may be required to meet the requirements of a main cable network. When multiple conduits are to be installed larger pits or manholes are needed to be installed as more space is required to accommodate larger cables and joints.

5.7 The location of all types of infrastructure within footpaths or nature strips is controlled by Local Government Authorities (LGAs). Although the exact specifications of utility service alignments on the footpath or nature strip, within each LGA may vary, when compared to others, there is limited space, in terms of width and depth, allocated to the provision of each utility’s underground infrastructure. This in many cases restricts the installation of telecommunication infrastructure and will need to be considered prior to any network installation.

Manholes

5.8 I understand, from the supplied material[4], that the Analysys cost model determines the size of a pit or manhole to be installed based on the number of conduits in the trench so that it accommodates the calculated cable requirements. For a single conduit route, a P5 pit is assumed at every DP and

---

[4] Fixed LRIC Model user guide for stakeholders-Workshop Version Page 13

for routes with a requirement for 24 or more conduits the maximum size assumed within the Analysys cost model is a PF28 manhole at each DP.

5.9 A P5 pit allows for access to the underground infrastructure by an individual reaching down into the void created by the pit.

5.10 Manholes provide sufficient space for individuals to enter and undertake work on the cables whilst the infrastructure remains below the ground.

5.11 The typical sizes of the proposed pit/manholes within the Analysys cost model are shown in Table 1. Slight variations in dimensions may occur between different manufacturers.

Pit / Manhole Type	***Length (cm)***	***Width (cm)***	***Depth (cm)***
P5 Pit	65	40	63.5
P6 Pit	130	50	68
P9 Pit	210	60	90
PF12 Manhole	290	138	175
PF20 Manhole	390	180	210
PF28 Manhole	510	180	255

Table 1 Various Pit and Manhole Sizes.

5.12 A typical network layout involves designing main cable and distribution network routes separately. The installation of manholes on the main cable routes is normally restricted to locations required to enable jointing or hauling of the required main cable.

5.13 The practical outcome of the Analysys cost model's approach of installing main and distribution requirements within a common trench is, in my opinion, the installation of substantially more manholes than would be required in a typical network layout. The location of the manholes is selected based on the service connection points rather than to minimise the impact of the larger infrastructure and therefore large pits or manholes may be placed areas which are not suitable for this type of infrastructure.

5.14 It appears, based on review of the Analysys cost model documentation[5], that each DP typically supplies four demand locations. My understanding of the proposed Analysys cost model is that a single trench with DPs is to be provided, and if required, road crossings installed to service demand points on the other side of the road.

5.15 This is, in my view, a reasonable approach for a distribution network only installation. Within a typical urban environment, this approach would result in a single P5 pit approximately every two properties on one side of the street.

5.16 However, where a trench not only supports the distribution network requirements but also significant main cable requirements the Analysys cost model assumes large manholes such as PF12 or PF20 for every DP location, in order to allow for future in ground access as discussed above. This approach results in the installation of a large manhole at every two properties on one side of the street.

5.17 The installation of large manholes in numerous locations in the limited space within many footpaths or nature strips, is likely, in my opinion, to have a significant visual impact and may also impact the alignment of other services such as electricity, gas and water.

5.18 With a typical footpath or nature strip width of four to five metres a large manhole will consume a significant amount of the space available for all services. Figure 1 demonstrates the relative size of the pits and manholes assumed within the Analysys cost model.

---

[5] CAN Workbook, Sheet In.Access – Average SIOs per DP for Geotypes 1 – 7.

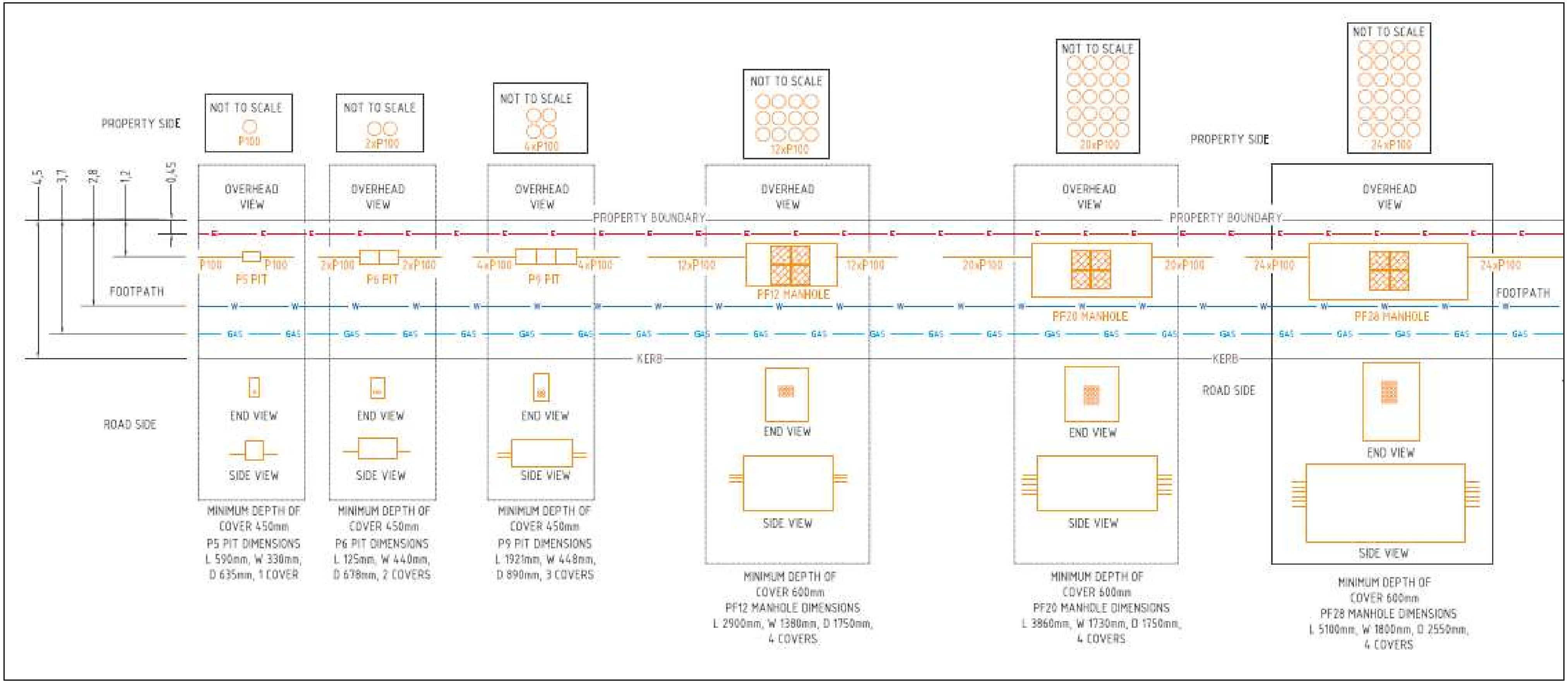

Figure 1 - Relative size of various pits and manholes

5.19 A manhole, as shown in Figure 1 is significantly larger than a P5 or P6 pit.

5.20 In my opinion, Local Government Authorities (LGAs) and other utility service providers are likely to have an issue with the installation of multiple manholes within a short distance, due to the effect on other utility services and impact on other street facilities such as walking paths. In my view the primary concern is the volume of space consumed for the installation of trench routes and manholes in areas which may have only very limited space available. If the proposed approach was to be implemented, in my opinion, approval is unlikely to be given by LGAs for the installation of all manholes.

5.21 When implementing customer access networks, property owners often oppose large manholes outside of their property. It is not possible to exclude manholes from a CAN but the minimisation of use can reduce the difficulty of installation. For example a P5 pit is less than 25% the length and width of a PF20 manhole.

5.22 In typical CAN architecture, major main conduit routes are often placed on main thoroughfares and the lower number of manholes allows for the selection of installation positions to minimise the impact on other services, property owners and street features. Placing manholes at each DP removes the ability to adjust the location of the manholes during the design of the network.

5.23 Whilst there may be a cost benefit of using a single trench which has been selected for the distribution network, there are in my opinion, stronger engineering reasons to provide a separate route for main cable, which include reducing the route distance and minimising the installation of large manholes in unsuitable locations.

Hauling Distance

5.24 The maximum hauling distance is limited by the amount of tension which a specific cable can withstand without being damaged during the hauling process.

5.25 The maximum hauling distance for a cable is dependent on a number of factors including the cable size, slope of the ground, and number of bends to be traversed along the route.

5.26 Within a distribution network the number of route changes (bends) is typically not a significant issue due to the smaller cables and the requirement for joints at DPs. Distribution networks are normally comprised of shorter lengths of cable between DPs or the pillar. In my opinion, hauling tension restrictions are unlikely to be a limiting factor in the distribution network.

5.27 However, main cable installations are likely to be impacted by maximum hauling length restrictions due to larger heavier cables which are more difficult to haul and more costly to joint. The cable weight and maximum tension which can be applied without damaging the cable are limiting factors in the installation of main cable.

5.28 Each cable has a defined limit in terms of the amount of tension which can be applied before the cable is likely to be damaged. Once the hauling limit is reached, typically a joint must be installed.

5.29 The impact of direction changes within the conduit network can be quite significant on the distance limit for the hauling of a main cable.

5.30 As the Analysys cost model selects the trench routes to optimise the connection of customer location it is, in my opinion, likely that distribution trench routes may include multiple changes of direction.

5.31 The tension which will be applied to a cable is dependent on a number of factors which include:

a) Weight of cable – dependent on the size and number of conductors within the cable

b) Distance to hauled

c) Co-efficient of friction between the two surfaces in contact

d) For hauling around a bend

  a. Radius of the bend[6]

  b. Angle of the bend (e.g. 90 deg)

---

[6] In the tension calculation, the radius of the bend has little impact on the total tension applied and in some references the radius is excluded from the equation.

c. Cumulative tension prior to the bend

5.32 The formulas which I have used to calculate the tension applied during the installation of the cable are shown below.

a) Straight Line

$T_1 = T_2 + \mu * W * L$

b) Bend

$T_1 = T_2 * \cosh(\mu*\theta) + \sqrt{}(T_1^2 + (WR)^2 * \sinh(\mu*\theta))$

Where

T1 = Tension (kg) T2 = Cumulative tension prior to bend

W = Weight of cable (kg/m)

R = Radius (m)

μ = Friction coefficient

θ = Angle of Bend

5.33 I offer the following examples to demonstrate the potential impact of bends on hauling tension.

5.34 Within the examples I have made a number of assumptions which are:

1. The cable is 400 pair 0.40 mm copper cable
2. The weight of 400 pair cable is 1.7 kg /m
3. The coefficient of friction is 50%
4. Maximum allowable hauling tension for 400 pair cable is 980kg
5. the route is level.

5.35 I have considered three conduit routes and have calculated the tension required to haul a cable along the route. The three example routes are:

1. A straight route of 500m,

2. A 500 m route with a single 90 degree bend at 250m,

3. A 500 m route two 90 degree bends and two sections of 175m and one of 150m.

All bends are assumed to be 90 degrees with a radius of 5m.

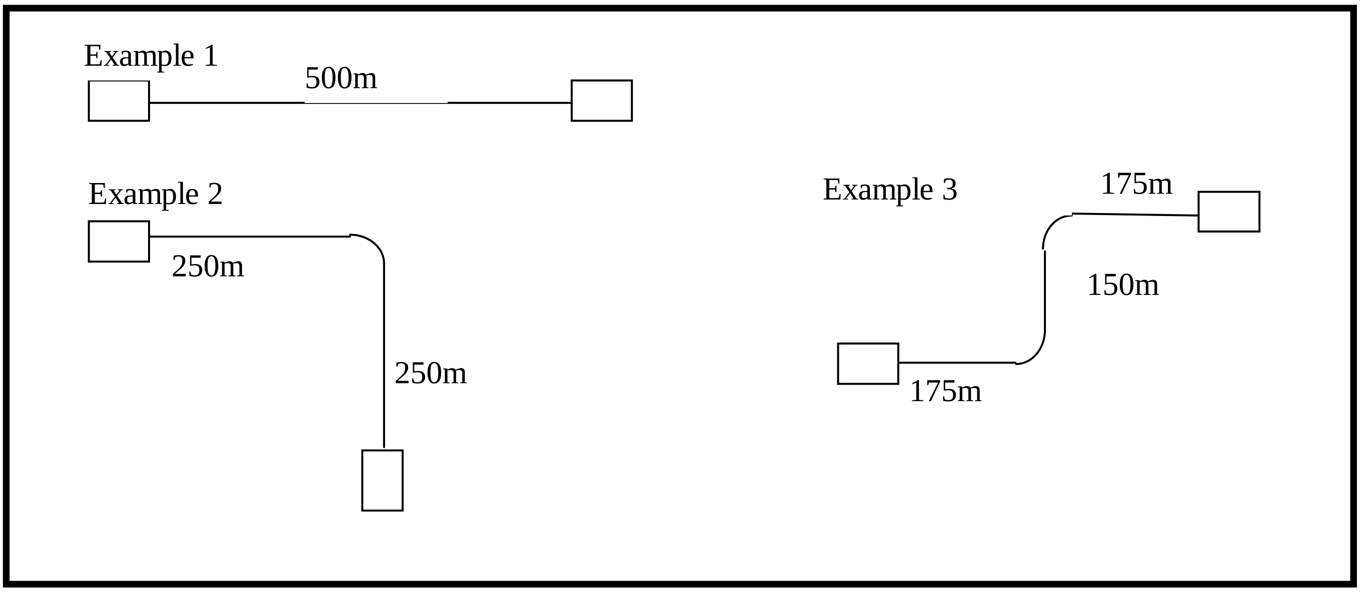

Figure 2 - Example routes for hauling tension calculation (Not to Scale)

5.36 Using the formulas in paragraph 5.32 I have calculated the hauling tension which will apply to the installation of cable along the three example routes. The results are shown in Table 2. The results of the calculations are the same for both directions of installation.

Route	Description	Calculated hauling tension
Example 1	500 m straight route	425 kg
Example 2	500 m route with single bend	707 kg
Example 3	500 m route with two bends	1,249 kg

Table 2 - Calculated tension for hauling cable.

5.37 The calculation of hauling tension for the example routes demonstrates the significant impact that changes of direction have on the hauling of cables.

5.38 Although all routes are a total distance of 500 metres, the hauling tension for example route 3 exceeds the maximum hauling tension of the 400 pair cable. For an installation on a route comparable to example 3, the length of the haul would need to be reduced to remove one of the bends so the haul tension does not exceed the limit of the cable. In my opinion, it is reasonable to assume that a trench route selected to satisfy distribution network requirements may include three or more bends within a route length of 500 m.

5.39 When a smaller diameter cable such as optic fibre is installed the distance between joints can be much greater than the maximum haul distance.

5.40 When the haul limit is reached for smaller diameter cables, the cable may be placed on the ground next to the haul point, and then it can be further hauled without the need for a joint. The typical hauling machinery used for smaller weight cables allows for the hauling of cable past the winch. Typically large cable winches do not support the continued hauling of cable once it has reached the location of the winch.

5.41 However main cables are not small diameter cables and it is not practical, due to the physical cable size and weight, to lay the cable adjacent to the manhole and continue the haul into another section. Typically a joint is required at the maximum hauling distance. In my opinion the potential trench routes selected for the distribution network will include a significant number of bends which is likely to require additional joints to be installed in the main cable network due to cable hauling tension restrictions.

5.42 In my opinion, the number and location of changes in direction within a trench route has a significant impact on the maximum length of cable which can be installed without a joint and the characteristics of each route should be considered to identify the distance between joints in the main cable network.

5.43 In my opinion, due to the expected issues with installing manholes in locations along a distribution route, the potential difficulty with hauling large cables on routes with multiple changes of direction, and the likely increase in overall length of main cable required, consideration should be given to the selection of main cable only routes where the minimisation of these factors is possible.

6 IEN CABLES

6.1 I have been asked:

6.2 **Whether or not it is reasonable not to allow for conduits to house IEN cables which are assumed to be placed in CAN trenches in any network modelled by the Analysys model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required, and how they should be determined, to take account of such conduits in the network modelled by the Analysys model.**

In addressing this question, please assume that the Analysys cost model places all IEN cable within 4 km of an exchange in a CAN trench. Further, please assume that 1, 2, 4, 6, 8 etc 100mm conduit are used in the CAN as necessary to accommodate the required number of cables provisioned for a particular CAN route.

6.3 In my opinion, it is not good engineering practice to install Inter Exchange Network (IEN) cables within the conduits provided for the distribution or main network.

6.4 In my opinion, installing IEN cable in conduits provided for distribution or main cables will impact on the future operation of the network, due to the increased potential for damage to the IEN cable. Any such damage is likely to interrupt the delivery of services to a high number of customers.

6.5 During any maintenance work on the existing infrastructure, or installation of new distribution or main cable along the route, the risk of damage, in my opinion, is increased. Additionally due to the route selection methodology it is likely that the total length of exposure to mechanical damage is increased.

6.6 In my opinion, a separate conduit should be provided for IEN cables, which only enters pits and manholes necessary for the jointing and hauling of IEN cables. I suggest consideration be given to minimising the distance of IEN cable to be installed by the use of separate dedicated trenches for IEN infrastructure because laying IEN cables on routes selected for distribution network adds significant distance.

IEN Cables

6.7 Following good engineering practice, I have assumed that all IEN cables are optic fibre cables.

6.8 As discussed in paragraph 5.40 the installation of optic fibre cable into conduits can accommodate significantly more route changes than a main's network copper cable before a joint is required, although the installation cost may be increased due to the need to start and stop hauling at more locations.

6.9 Based on my understanding of the Analysys cost model, the IEN cable, within 4 km of an exchange building, will be installed in the trench, conduit and pit network provided for the distribution network and therefore the proposed IEN path will pass through smaller pits as well as larger manholes. The smaller pits will be encountered where there is no requirement for main cable.

6.10 In my opinion, one significant issue which does not appear to be considered in the Analysys cost model is the minimisation of future damage to the IEN cables.

6.11 There are two likely causes of damage to cables within a telecommunication network. These are, mechanical impact from machines digging within the vicinity of cables and activity within conduits, pits or manholes to install new, or rearrange existing infrastructure.

6.12 The installation of IEN cable within the conduit provided for the distribution or main network increases the path distance and the subsequent higher number of pits and manholes increases the probability of damage to the IEN cable

6.13 When additional cables are installed or rearrangements are made to existing infrastructure access to the pits and manholes occurs. Whenever there is activity within a pit or manhole, or hauling of a new cable in a conduit in which the IEN cable is placed, there is the potential for accidental damage to the existing infrastructure.

6.14 In my opinion, due to the common conduits, additional route length and the higher number of pits and manholes though which the IEN cable passes within the Analysys cost model approach, the potential for damage to the IEN cable and faults impacting customers is increased.

6.15 For a telecommunication carrier, the operational security and performance of IEN cables is a significantly more important consideration than reducing the installation cost. Any proposal that increases the number of potential locations for damage should be carefully considered.

6.16 In my opinion, to achieve a higher level of operational reliability for IEN cables a separate conduit should be provided which only enters pits and manholes necessary for the jointing and hauling of IEN cable. I would also suggest consideration be given to minimising the distance of IEN cable to be installed by the use of separate dedicated trenches for IEN infrastructure where the routes selected for distribution network requirements add significant distance.

7 FIBRE JOINTS

7.1 I have been asked:

7.2 **Whether or not it is reasonable not to allow for fibre joints in the CAN in any network modelled by the Analysys model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required, and how they should be determined, to allow for fibre joints in the network modelled by the Analysys model.**

In addressing this question, please assume that the Analysys cost model uses fibre in the CAN.

7.3 In my opinion, it is good engineering practice to allow for fibre joints within the CAN as joints are required, as a minimum to facilitate the interconnection to customer lead-in cables.

7.4 The number of fibre joints should be calculated using the number and location of services to be connected, distance from each DP module to customer termination and the total distance of the proposed main and distribution network.

7.5 Jointing of optic fibre is a skilled task which requires special equipment, and can be made more difficult in a field environment by the need to exclude all foreign matter from the fibre to fibre connection.

7.6 The predominant early applications of optic fibre cable in telecommunication networks were for high value requirements which included core network links and connection to very large customers. These applications typically allowed for the minimisation of joints by capitalising on the ability to haul or plough optic fibre cable for long distances before joints were required.

7.7 The introduction of optic fibre infrastructure into the distribution network requires many access points to provide connections to multiple customer premises. Presently in the Analysys cost model, copper CAN joints are located at every DP and I would expect a similar number of connection points in a fibre distribution network.

7.8 Although the number of customer connections provided from each DP may vary between a copper and fibre distribution network the requirement for a DP remains.

7.9 The current approach, employed by telecommunication carriers, has been the deployment of optic fibre based distribution networks, using technical solutions which minimise the requirement for skilled jointing of fibre in the field.

7.10 Equipment manufacturers have developed modular solutions for DPs with pre-terminated fibre connectors to minimise the level of field optic fibre splicing and minimise the skill level of resources required to construct the network.

7.11 Available modular fibre CAN equipment includes pre-made, lead-in cables of varying lengths with connectors at both ends and distribution modules which are supplied complete with pre-terminated fibre cables for connection to the next point of concentration. Typically the pre-terminated units are limited in both the length of provided cable and number of included fibres.

7.12 Modular CAN fibre DPs should still be considered as joints, although the level of skill for installation is reduced.

7.13 The use of fibre splice joints, where fibres are spliced in the field and placed in a sealed enclosure within a pit or manhole is minimised with the provision of modular infrastructure such as described in paragraph 7.11.

7.14 A standard fibre joint is still required where DP modular joints are connected to the distribution cable. In a number of network plans which I have observed there are typically three to four DP modules connected to a fibre joint, with each DP module supplying an average of four to six customers. It should be noted that the ratio of service connections to local modules and ratio of local modules to fibre splice joint will depend on the carrier’s chosen architecture and equipment manufacturer.

7.15 DP modular access points do not require fibre splicing, but, in my opinion, should still be considered as joints in terms of modelling a network.

7.16 Therefore, in my opinion, for a fibre based distribution network, two categories of fibre joint should be included within any network cost model, modular joints for DPs and fibre slicing joints.

7.17 I have been asked:

7.18 **(d) Whether or not it is reasonable to include the cost of fibre joints in the cost of fibre cable without knowing how many joints are required in any network modelled by the Analysys cost model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain how the number of joints should be calculated and what inputs would be required to take account of the cost of those fibre joints in the network modelled by the Analysys model.**

7.19 As described in paragraph 7.15, it is my opinion that it is reasonable to allow for fibre joints within a fibre distribution network and the cost of fibre joints should be considered within the Analysys cost model. The number of joints can be calculated on the basis of the two joint categories described in paragraph 7.16, the number of services to be provided, the length of the distribution network, type of network[7],and the total number of fibres within the network.

7.20 The use of modular joints for the last access points allows for a reduction in the skill level required for construction but there is an associated cost with modular units that exceeds the cost per metre cost of cable alone. Due to the saving in labour costs, it is my expectation that the majority of cost attributable to the inclusion of local modules will be the additional cost of material for each access point (DP).

7.21 For the joints, where interconnection is provided from the DP fibre joints to the distribution network, field based fibre splicing will be required. The number of fibres to be spliced will impact the cost to complete the joint and should be determined after considering the chosen fibre network architecture, dedicated fibre pair or PON, and the average number of DPs which will be aggregated at the joint location.

7.22 Suggested parameters which may be used to calculate the number of jointing items required include:

a) A modular fibre access points for every 6 demand points provided the maximum distance to any demand point be no more than 100 metres.

---

[7] Type of network may be either a, PON architecture which reduces the number of fibres to be jointed in the distribution network or a architecture which includes a dedicated fibre from RAU to DP.

b) A distribution fibre to modular access points joint for every 4 modular access points provided each modular access point is within 120 m.

c) A distribution fibre joint for every route which exceeds 4 km between existing joints.

7.23 Based on the parameters described in paragraph 7.22 and using unit costs for modular joints, splice joint enclosures and cost per fibre spliced, in my opinion, the Analysys cost model could include the cost of fibre joints within a fibre CAN.

7.24 I have been asked:

7.25 **Whether or not it is reasonable not to allow for joints to connect copper main or distribution cables at pillars or large pair gain systems in the CAN in any network modelled by the Analysys model? If, in your opinion, it is not reasonable, please set out the reasons for your view.**

7.26 In my opinion, at those pillars and large pair gain systems where the maximum cable size which can be installed is exceeded, a copper joint will be required.

7.27 Cables are terminated within a pillar to enable the cross connection of any main cable pair to any distribution cable pair within that pillar. In the case of large pair gain systems, cables are terminated to allow the cross connection of an equipment interface to a cable pair.

7.28 The size of cable which can be installed into a pillar or large pair gain systems is limited. For a 900 pair pillar the maximum cable size is 100 pair and for a 1800 pair pillar or large pair gain system cabinet the maximum size is 200 pair.

7.29 In any circumstances where the street cable exceeds the maximum size of cable which can be installed into the pillar or pair gain system cabinet, a joint will be required to connect with a number of suitable cables.

7.30 For example, if a 400 pair main cable is to be connected to a 900 pair pillar a joint will be required between the 400 pair cable and four 100 pair cables which can then be inserted into the pillar.

7.31 Therefore, in my opinion, for every pillar and large pair gain system in the network where the maximum cable size which can be installed is exceeded, a copper joint will be required to convert the larger cable to multiple smaller cables.

8 CHANGE OF CABLE GAUGE

8.1 I have been asked:

8.2 **(e) Whether or not it is reasonable not to include joints to connect one gauge of cable to another, in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required to take account of such joints in the network modelled by the Analysys model.**

(f) Whether or not it is reasonable not to include a pit or a manhole to house any joints used to connect one gauge of cable to another. If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what further inputs are required, and how they should be determined, to take account of any pit or manhole to house any such joints in the network modelled by the Analysys model.

Joints

8.3 In my opinion, as cables are only manufactured with one gauge within the cable, it is reasonable to include joints where one cable gauge is to be connected to another. The change from one conductor gauge to another requires the interconnection of two separate cables and this requires a joint. The reasons for my opinion are included within the following sections.

8.4 There are two options for providing cable based services at a distance which exceeds the performance limit of the typical minimum cable gauge of 0.40mm. These are to use a larger gauge from the RAU through to the customer premises, or to progressively increase the conductor gauge along the route as the network extends further from the RAU.

8.5 To minimise the overall cost of delivering services along a route, option 2 above, where it is technically feasible, is to use a smaller gauge cable (e.g. 0.40 mm) for the beginning of the route and only use larger gauge (0.64 mm) at the end of the route where it is required to reach the more distant customers.

8.6 At any point within the network where the cable gauge is to be increased two different cables need to be connected.

8.7 The connection between two cables requires a joint which includes connectors for each of the wires and a housing to enclose the connectors and exposed wires.

8.8 The change in cable gauge may occur at a pillar, but this approach requires two joints to connect the two separate cables to the pillar tails.

8.9 Therefore, in my opinion, where a change in cable gauge is proposed a joint should be included within any modelling of a CAN.

Pit or Manhole

8.10 In my opinion, a pit or manhole should be included at any location where a joint is required in the network, either for a DP or a change of cable gauge, to allow for later access to repair faults or rearrange the interconnections within the joint.

8.11 If a joint is required within a copper CAN, for a change in cable gauge or for a DP, it is technically feasible for the joint to be either directly buried or housed within a pit or manhole.

8.12 In my opinion, there are practical implications which limit the direct burying joints of any type within a CAN.

8.13 The placement of joints within pits or manholes provides mechanical protection to joints and enables access for future rearrangements of the connections or fault rectification.

8.14 A high proportion of CAN faults occur within joints and access to the joint is required to undertake repair. Additionally if the fault occurs between two joints, access to the joints may be required to enable the transfer of the affected service from the faulty pair to a non-faulty pair.

8.15 In my opinion it is a prudent, and good industry practice, to provide a suitable pit or manhole to accommodate a joint which is required to facilitate a change in cable gauge.

8.16 Wherever a change in cable gauge change is proposed and the location is not at a proposed pillar or DP location, in my opinion, the provision of an additional pit or manhole should be included in the modelling of the CAN.

9 CABLE PLOUGHING

9.1 I have been asked:

9.2 **(g) In your view, what is the maximum number of cables it is reasonable to plough in any network modelled by the Analysys model? Please set out the reasons for your view.**

9.3 In my opinion, the maximum number of cables which can reasonably be ploughed is two cable sheaths for a single route. If the definition of a route extends to the use of both sides of a road then the maximum number that could reasonably be ploughed on a route is four by completing two installations on opposite sides of the road. The maximum number of cables to be simultaneously ploughed is still two.

9.4 In my opinion, the installation of more than two cables simultaneously will be restricted due to the ability to carry multiple drums of cable, and insufficient space within the plough.

9.5 The ploughing of cable is typically subject to a degree of error between the nominated and the actual alignment of the installation due to the plough being prone to shift horizontally from the planned alignment. Considering the potential for variation in alignment, it is in my opinion, not a practical approach to consider another cable plough in close proximity to an existing installation due to the likelihood of damage.

9.6 Within this section I have assumed the installation of cable is limited to public property. I have not considered the installation of network cable within private property.

9.7 In my opinion, the ploughing of cable on a route is limited by three main factors, the mechanical limitations of the installation equipment, the actions required when ploughing is not possible, for example when crossing roads or water courses, and the restricted alignments available for the installation of telecommunication cables.

Cable Ploughing Equipment

9.8 The installation of cable by ploughing uses either, a bulldozer or, a smaller wheeled machine to pull a plough through the ground.

9.9 The drum of cable to be installed is normally supported at the front of the installation machine, with the cable running across the top of the machine to the plough.

Figure 3 - Example Cable Plough[8]

9.10 The plough, attached to the rear of the machine, includes tubes through which the cable is fed from the top and exits at the rear into the trench as the plough moves forward through the earth.

9.11 The plough shape is designed to cut through the earth and the ground closes as the plough moves forward. To enable the installation of the cable, the route is often pre-ploughed (commonly known as ripping) to soften the ground prior to installation of the cable/s.

9.12 A further enhancement to cable ploughing techniques is adding vibration to the plough which is intended to aid the plough to move through the ground.

9.13 Typical plough configurations are for the cable installation tube to exit close to the base of the plough with a second tube and exit is typically provided 200 to 300 mm above the base of the plough for the installation of a guard wire or protection tape to reduce the likelihood of future damage

---

[8] Lancier Cable Vibration Mole Plough Type KV 15

9.14 Ploughing is typically used for installations where there is a significant distance proposed between joints and often where the distance from the closest RAU dictates the use of either 0.64 mm or 0.90 mm cable.

9.15 Due to the typical length of cable to be installed and the larger gauge cable which has a larger diameter sheath, the cable drums to be used when ploughing are quite normally quite large.

9.16 In my opinion, it is unlikely that a cable plough machine can carry more than two cable drums simultaneously.

9.17 Additionally there is limited space within the tube through which the cable passes from the top of the plough to the exit in the base is limited and, in my opinion, standard ploughs will not accommodate more than two cables.

Crossing Roads or Water Courses

9.18 Crossing of paved roads, water courses or rail is an additional practical restriction on installation via cable plough techniques. It is not possible to install cable across any of these obstacles with a cable plough.

9.19 When one of these obstacles is encountered, conduit is normally installed across the obstacle, either through directional boring[9] or an attachment to a bridge structure typically with a pit or manhole on either side of the obstacle.

9.20 There are two options are available for the installation of cable within the conduit crossing the obstacle. These are to remove all of the remaining cable from the drum, haul through the installed conduit and then rewind onto the drum to continue ploughing, or to cut the cable, haul back from the far side and recommence ploughing on the other side of the obstacle. The second method introduces an extra joint into the network.

9.21 Either of the methods described in paragraph 9.19 are time-consuming when only one cable is involved and any additional cable adds time to the process. Multiple cables require a significant length of time for the ploughing machine to lay idle while crossing activity is completed.

---

[9] Directional boring is a technique that allows the installation of conduit between two points by the use of specialised equipment which drills a hole below the surface into which a conduit is installed.

Variation in the Alignment of Cable Installed by Ploughing

9.22 The ploughing of cable is normally restricted to areas where the density of utility services is relatively low.

9.23 The nature of plough installation techniques make the final route of the cable less accurate than when the installation is completed by trenching. The final path of the cable is dependent on the movement and positioning of a very large machine and can be impacted by underground obstructions such as rocks etc which impact the horizontal and vertical alignment of the cable/s. The plough can shift in a horizontal or vertical direction as it moves to the path of lower resistance as for example around larger rocks.

9.24 As the exact location of the cable is difficult to predict, and not constant along a route, the installation of another cable/s in close proximity to that cable by cable ploughing technique is generally not considered a viable option. If ploughing of a second cable is proposed in the proximity of an existing ploughed cable there is, in my opinion, a high likelihood of damaging the existing cable which may have varied horizontally from the planned installation alignment.

9.25 Therefore to propose the ploughing of an additional cable on a route requires a significant separation between the cables to avoid the potential of damage to the existing cable. It is likely that, even in rural environments, there will be space restrictions, which include other utility services, roads and often flora, which may not allow sufficient separation on the same side of the roadway.

9.26 The practical solution is to complete a second plough installation on the opposite side of the road to prevent damage to the existing cable.

9.27 This approach would allow for up to four cables to be installed through two separate plough installations.

9.28 It is good engineering practice to, where ever possible, install a cable capable of supplying the known and future demand, , rather than installing multiple small cables.

9.29 I have been asked:

9.30 **In your view, what is the maximum number of copper pairs and the maximum gauges of those copper pairs in a sheath to be ploughed, in any network modelled by the Analysys model? Please set out the reasons for your view.**

9.31 In my opinion, the maximum size cable, which can be installed using that is currently available equipment, is a cable equivalent to 100 pairs of 0.64 mm cable (100/0.64). Cables containing 50 pairs of 0.90mm gauge or 200 pairs of 0.40 mm are an equivalent size to 100/0.64. The maximum cable diameter, is in my opinion, based upon the space available for the cable to pass within the plough and the bend radius within available ploughs.

9.32 As discussed in section 9.8 of this report, cable ploughing apparatus consists of a machine, tracked or wheeled, which pulls a plough through the ground. Within the plough there are tubes through which the cable passes and is inserted directly into the ground.

9.33 The effort required to pull a plough through the ground is dependent on the type of ground, the depth and width of the plough. The wider the plough, or deeper the installation, the more difficult it is to pull the plough through the ground.

9.34 Cable ploughs are designed and manufactured to install certain cable diameters. The width of the plough is the sum of the diameter of the largest tube and the width of the steel on either side. The width of the steel is a factor of the strength required within the structure. The larger the cable to be installed the greater the diameter of the tube, and the wider the plough.

9.35 Current cable ploughs have a tube of sufficient diameter to accommodate a 100 pair cable of 0.64 mm gauge. The typical diameter of this cable with a protective sheath is 32 - 35 mm.

9.36 For different gauges, different numbers of pairs within the cable equate to a similar diameter cable. For example for 0.90 mm conductors a 50 pair cable is an equivalent diameter to the 100 pair, 0.64 mm gauge cable. Similarly a 200 pair 0.40 mm gauge cable is also of a similar diameter.

9.37 The maximum cable size which can be installed by a cable plough is limited by the diameter of the tube and the radius of the bend in the tube as it goes from vertical to horizontal at the base of the plough.

9.38 To install larger diameter cables a plough would have to specially manufactured with a larger tube and a greater radius of bend at the base of the plough. For example a 400 pair 0.40 mm protected sheath cable has a typical diameter of 45mm which is approximately 30% greater. The larger tube diameter would require the plough to be wider and longer than current ploughs. To my knowledge, ploughs capable of the larger cable sizes are not currently available.

9.39 The larger plough will require a greater force to pull it through the ground. The requirement for a greater force, in my opinion, is in many cases likely to increase the size of the machine on which the plough has to be mounted.

9.40 The maximum cable size for which cable ploughs are currently designed is 100 pair 0.64mm. This maximum copper cable size of 100 pair 0.64 mm accommodates all optic fibre cable diameters.

9.41 In my opinion, based on my knowledge of current industry equipment, the maximum size of cable which can be ploughed is a cable of 35 mm. This diameter is equivalent to cables of 200 pair 0.40 mm, 100 pair 0.64 mm or 50 pair 0.90 mm cables with a protective sheath.

10 CABLE SHEATH TYPES

10.1 I have been asked:

10.2 **Whether or not it is reasonable not to allow for protected cable in instances where cable is directly buried in the ground in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please set out the reasons for your view. Please also explain what further inputs are required to allow for protected cable in instances where cable is directly buried in the ground in any network modelled by the Analysys model.**

In addressing this question, you are to assume that the Analysys cost model installs the same standard cable in conduits and as for directly buried routes.

10.3 Due to the potential for damage to the cable sheath when cable is installed without conduit for mechanical protection, in my opinion it is unreasonable not to allow for the use of protected cable where the cable is to be directly buried in the ground. If protected cable is not used it is likely to result in an increase in maintenance activity to replace damaged cable.

10.4 My opinion is based on the potential risk of damage to a cable which is installed directly into the ground without a protective sheath. Whilst a standard cable sheath protects the conductors within a cable from moisture ingress a standard sheath does not protect the cable from puncture by rocks and other in ground material. This will result in future repair or replacement of the cable. The use of cable with a protective sheath can significantly reduce the likelihood of a cable being damaged during installation or by the environment. Telecommunication cables used within land based telecommunication networks are available in two broad categories of sheath.

10.5 Standard telecommunication cable is the most common category which is provided with a sheath, typically polyethylene, which protects the contents within the cable from moisture ingress etc.

10.6 However for those circumstances in which increased mechanical protection is required, telecommunication cable can be manufactured with additional layers that surround the standard sheath. This protected cable may have an additional harder plastic layer (commonly referred to as hard jacket) or additional layers which include steel bands (armoured) to further protect the cable. The provision of protective layers increases the cost of manufacture.

10.7 I have assumed for the discussion within this section that protected cable is typically hard jacketed cable but may include armoured cable.

10.8 As the naming convention suggests, standard cable, which does not include additional protective layers, is not as resilient to damage from physical impact. The effect of any damage to a cable sheath is that water may ingress into the cable and cause the copper pairs or fibre within the cable to fail.

10.9 Hard jacket (protected) cable is typically used when there is an expectation of insect attack or where mechanical protection of the cable from the environment is required.

10.10 Mechanical damage may occur to a telecommunication cable is when the cable is not protected by a conduit.

10.11 Directly buried cable is subject to direct contact with objects in the ground, including rocks, which can be forced against the cable sheath either during installation or through ensuing shifting of the ground. A sharp object forced against a cable is likely to puncture a standard telecommunication cable sheath.

10.12 Protected cable can withstand many of the impacts which would damage a standard sheath.

10.13 Protected cable is used to prevent future damage when telecommunication cable is to be installed directly in the ground either by the provision of a trench or by plough.

10.14 On the other hand, where telecommunication cable is to be installed in conduit standard cable is suitable and is normally the lowest cost option. The cable is protected from mechanical damage by the conduits. The only exception to the use of standard cable within conduit is in areas which are known to be infested with insects which attack and damage a standard cable sheath.

10.15 In my opinion, for the purpose of modelling the cost of constructing a CAN standard cable should be used for installation within conduit and protected cable should be used for direct buried installations.

11 BEND ANGLE

11.1 I have been asked:

11.2 **In your view, what is the maximum angle that a large nest of cables is physically able to turn without a manhole or a pit? Please set out the reasons for your view.**

11.3 In my opinion, the maximum angle that a large nest of cables is physically able to turn without a pit or manhole is approximately 90 degrees. If the nest of cables is to turn more than 90 degrees a pit or manhole will be necessary.

11.4 If there is no manhole or pit, premade "curved conduit sections" would typically be installed to go around the bend. These conduit sections are typically premade because heat and force needs to be applied in order to curve straight 100 mm PVC conduit so that it can curve around a bend. The bending process is typically completed within a factory environment where moulds are available and the heating of the PVC conduit can be controlled.

11.5 The typical bend radius of premade curved conduit sections for this purpose is between 3 and 5 metres.

11.6 There are two engineering issues which are relevant to determining the maximum bend angle: whether or not the cable tension is such that the cable can be hauled (or whether the hauling tension placed on the cable by the bend is too great for it to be hauled) and second, whether or not there is enough space within the footpath (property boundary to kerb) to accommodate the curved conduit.

11.7 In relation to hauling tension, using example 2 in Table 2, for a single 90 degree bend with 500 m of straight conduit the hauling tension is 707 kg. If, however the same example is considered with a 180 degree bend the hauling tension increases to approximately 960 kg.

11.8 In relation to the space needed within the footpath, a typical urban footpath is only 4.5 m wide. This space is sufficient to accommodate the curved conduit for a 90 degree bend (typically at an intersection). However for a 180 degree bend and a minimum premade conduit radius of 3 metres the space within the footpath needed to accommodate the conduit is 6 meters. This exceeds the width of a typical footpath and cannot be installed.

12 DECLARATION

12.1 I have made all the inquiries that I believe are desirable and appropriate and that no matters of that I regard as relevant have, to my knowledge, been withheld from the Commission.

Craig Lordan
Senior Consultant
Gravelroad

13 LIST OF REFERENCES

FLRIC Report for stakeholders-Workshop Version

FLRIC user guide for stakeholders_Workshop Version

Geoanalysis user guide_Workshop Version

Appendix 1 - Craig Lordan Curriculum Vitae

EXPERIENCE SUMMARY

Craig Lordan is an Electrical Engineer who graduated from Central Queensland University in 1988, and now has 20 years of experience in the telecommunications industry and procurement strategy development. Prior to consulting roles, Craig was engaged in a number of roles within Telstra from 1989 through to 2001.

During his career in Telstra, he completed a number of roles which generally specialised in network construction, project management and contract management. His experience extends from hands on responsibility for individual construction projects through to long term strategic planning and budgeting.

Craig also completed international roles with Telstra, including the planning and development of networks within Vietnam. Later roles with Telstra included national responsibility for the development and application of network design and construction practices.

During the past eight years as a consultant, he has provided advice, expert opinion and support in the development and implementation of telecommunication networks to many organisations. Craig has also provided expert support in the development and implementation of procurement strategies. Organisations that have received and implemented advice include existing telecommunication carriers, electricity utilities, and Local and State Government organisations.

Recently he has contributed to the Queensland electricity industries' successful implementation of commercial telecommunication service supply, delivered Expert Witness Statements in relation to specific matters, assumed responsibility for the delivery of telecommunication and other infrastructure projects and the completion of technical feasibility reports for the implementation of very high speed access networks on behalf of State and Local Governments.

QUALIFICATIONS:

B.Eng. (Electrical) Central Queensland University
GCM Southern Cross University

EXPERIENCE HISTORY:

2001 – Present	**Position:**	Senior Consultant
	Role:	Specialist consulting assignments in the Telecommunications and Infrastructure fields including assessment of commercial issues, procurement, bidding strategies, project management and strategic advice.
	Highlights:	Project Cost Estimation and Feasibility Analysis for the construction of a capital city wide very high-speed open access telecommunication network. Project management of procurement of major items (long lead time) for Geothermal Power Station. Published Expert Witness Statements in relation to DSLAM installation and optic fibre cable installation. Development of procurement strategies for major corporate users within Queensland. Project management of major customer telecommunication network installation and commissioning. Advice on the establishment of Telecommunication Networks and Commercial Operation for Queensland Government Owned Corporations. Technology application strategy advice and customer engagement policy formulation for major local government body. Cause Analysis of failed Mobile Network Rollout for legal proceedings. Activity pricing analysis for prominent Telecommunications Constructor during contract negotiation. Facilitation of Post Implementation Review for a major Intelligent Traffic System installation project. Strategic advice to a Queensland Government GOC Utility regarding the commercial opportunity to enter the telecommunications industry.

TELSTRA

2000 – 2001	**Position:**	National Operation Improvement Manager
	Role:	Leadership of the National Operations team responsible for high level analysis and improvement of existing process, contractor relationships, tender submissions, IT System Strategy and performance measurement for Global Connects Contracts
	Highlights:	Introduction of an improved work management and scheduling system, increased linkage between capital investment plan and daily operations. Tender analysis, including ongoing price negotiations and the redevelopment of Business Unit Communication Process.
1999	**Position:**	National Strategy Development Manager
	Role:	The primary responsibility of this position was, with a small team, to develop strategies improving the efficiency of capital expenditure within the Telstra Access Network and manage IT System improvements.
	Highlights:	Development of an innovative, efficient National System to identify substandard network, either due to maintenance or insufficient capacity, to facilitate a $250M capital investment program.
1998 - 1999	**Position:**	National Reporting Manager CAN2001 Project
	Role:	The initial requirement of this position was to contribute to the development of the business case for submission to the Telstra Board for additional funding ($500M) to rehabilitate Telstra's Customer Access Network. After approval of the project, responsibility for the national reporting of progress against the Business Case to Telstra Executive.
	Highlights:	Development of dynamic solutions for capturing contractor performance information.
1997 – 1998	**Position:**	Expert Decision System Development
	Role:	Through analysis of a number of Telstra Customer Access Design centres a high degree of variation in network build solutions was identified as a major issue for the company. A software solution was developed and implemented to provide a universally consistent design decision and outcome.
1994 – 1997	**Position:**	Central Vietnam Plan and West HCMC Business Plan
	Role:	As part of a three person team, a 10 Year Telecommunication Network Development Plan for the Central Vietnam Region was developed and presented to the Vietnam Telecommunication Department (VNPT).
	Highlights:	10 Year Telecommunication Network Development Plan for the Central Vietnam Region. Customer Access Network plan and costing of submission by Telstra to build the network for half of Ho Chi Minh City. Representation of Telstra and International Telecommunication Conferences in Asia.
1989 – 1994	**Position:**	Engineer and Senior Engineer Area Planning and Development (N&ITI)
	Role:	Responsibilities included the planning and project management of the Customer Access and Local Switch Network for Central Queensland. This involved the planning of conduit, copper, optic fibre and both internal and external switch technology.

Appendix 2 – Received Questions

MALLESONS STEPHEN JAQUES

Mr Craig Lordan
Senior Consultant
Gravelroad Consulting
201 Wickham Terrace
SPRING HILL QLD 4004
By email:
Craig.Lordan@gravelroad.com.au

9 September 2009

Dear Mr Lordan

Telstra Corporation Limited

We refer to our letter dated 13 August 2009.

1 Report

We are instructed to request that you express your opinion in relation to the following additional questions in the report that you are preparing for use by Telstra in the Joint Arbitrations:

(a) Whether or not it is reasonable to assume that main network CAN cables can be housed in the same trenches that have been dug to house distribution cables in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please explain:

  (i) why it is necessary to house main CAN cables separately from distribution cables;

  (ii) what inputs would be required, and how could they be determined, to take into account the separate housing of main CAN cables from distribution cables in the network modelled by the Analysys model.

We refer you to the trench sharing coefficient in the Analysys cost model (see CAN.xls, Access, rows 360-374). Please assume that the trench sharing coefficient reduces the amount of distribution trench in the Analysys cost model to account for the fact that two or more distribution cables may share a common route and thus should be placed in the same trench.

(b) Whether or not it is reasonable not to allow for conduits to house IEN cables which are assumed to be placed in CAN trenches in any network modelled by the Analysys model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required, and how they should be determined, to take account of such conduits in the network modelled by the Analysys model.

In addressing this question, please assume that the Analysys cost model places all IEN cable within 4 km of an exchange in a CAN trench. Further, please assume that 1, 2, 4, 6, 8 etc 100mm conduit are used in the CAN as necessary to accommodate the required number of cables provisioned for a particular CAN route.

(c) Whether or not it is reasonable not to allow for fibre joints in the CAN in any network modelled by the Analysys model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required, and how they should be determined, to allow for fibre joints in the network modelled by the Analysys model.

In addressing this question, please assume that the Analysys cost model uses fibre in the CAN.

(d) Whether or not it is reasonable to include the cost of fibre joints in the cost of fibre cable without knowing how many joints are required in any network modelled by the Analysys cost model? If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain how the number of joints should be calculated and what inputs would be required to take account of the cost of those fibre joints in the network modelled by the Analysys model.

(e) whether or not it is reasonable not to include joints to connect one gauge of cable to another, in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please set out the reasons for your view. Please also explain what inputs are required to take account of such joints in the network modelled by the Analysys model.

(f) whether or not it is reasonable not to include a pit or a manhole to house any joints used to connect one gauge of cable to another. If, in your opinion, it is not reasonable to do so, please set out the reasons for your view. Please also explain what further inputs are required, and how they should be determined, to take account of any pit or manhole to house any such joints in the network modelled by the Analysys model.

(g) In your view, what is the maximum number of cables it is reasonable to plough in any network modelled by the Analysys model? Please set out the reasons for your view.

(h) Whether or not it is reasonable not to allow for protected cable in instances where cable is directly buried in the ground in any network modelled by the Analysys model? If, in your view, it is not reasonable to do so, please set out the reasons for your view. Please also explain what further inputs are required to allow for protected cable in instances where cable is directly buried in the ground in any network modelled by the Analysys model.

In addressing this question, please assume that the Analysys cost model installs the same standard cable in conduits and as for directly buried routes.

(i) In your view, what is the maximum angle that a large nest of cables is physically able to turn without a manhole or a pit? Please set out the reasons for your view.

In addressing this question, please assume that in instances where a road turns a corner (for example, where there is an intersection with another road), the Analysys cost model hauls cable around that corner, without passing the cable through a manhole or a pit at that corner.

2 Materials

We note that we have provided you with a CD containing a copy of the most recent version of the Analysys cost model.

3 Confidentiality

This document and all other communications between us and you and our client are confidential.

Yours faithfully

Mallesons Stephen Jaques

MALLESONS STEPHEN JAQUES

Mr Craig Lordan
Senior Consultant
Gravelroad Consulting
201 Wickham Terrace
SPRING HILL QLD 4004
By email:
Craig.Lordan@gravelroad.com.au

6 October 2009

Dear Mr Lordan

Telstra Corporation Limited

We refer to our letter dated 9 September 2009.

1 Report

We are instructed to request that you express your opinion in relation to the following additional questions in the report that you are preparing for use by Telstra in the Joint Arbitrations:

(a) Whether or not it is reasonable not to allow for joints to connect copper main or distribution cables at pillars or large pair gain systems in the CAN in any network modelled by the Analysys model? If, in your opinion, it is not reasonable, please set out the reasons for your view.

(b) In your view, what is the maximum number of copper pairs and the maximum gauges of those copper pairs in a sheath to be ploughed, in any network modelled by the Analysys model? Please set out the reasons for your view.

2 Confidentiality

This document and all other communications between us and you and our client are confidential.

Yours faithfully

Mallesons Stephen Jaques

Level 50 Bourke Place 600 Bourke Street Melbourne VIC 3000 Australia **T +61 3 9643 4000**
DX 101 Melbourne ABN 22 041 424 954 mel@mallesons.com www.mallesons.com **F +61 3 9643 5999**