BEFORE THE BOARD OF INQUIRY

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of applications for resource consent and notices of requirement by Transpower New Zealand Limited for the North Island Grid Upgrade Project

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STATEMENT OF EVIDENCE OF RICHARD EDWARD JOYCE ON BEHALF OF TRANSPOWER NEW ZEALAND LIMITED
(Construction processes and management: cables)

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INTRODUCTION

Qualifications and role

1. **MY** name is Richard Edward Joyce. I have a Bachelor of Science in physical electronics from the University of Warwick, United Kingdom. I am a Chartered Engineer (Member of the United Kingdom Institution of Engineering and Technology), European Engineer and Member of the Institute of Electrical and Electronic Engineers (USA).

2. I am employed by Transpower New Zealand Limited (**Transpower**) in the role of North Island Grid Upgrade Cable Project Manager. I commenced employment in this role on 12 December 2005. Since that time, I have been responsible for ensuring the delivery of the cable sub-project of the North Island Grid Upgrade Project (**Upgrade Project**).

3. I have 17 years experience, working in the field of Extra High Voltage (**EHV**) cables. I have specialised in their installation since 1992. Prior to commencing my employment with Transpower, I held a number of positions in the United Kingdom, Singapore and Hong Kong for Prysmian Cables and its predecessor organisations. Prysmian Cables is one of the world's largest cable companies.

4. **OVER** the period of March 2001 – April 2004 I was employed as a Project Engineer in Hong Kong with overall responsibility for the US$54.5M 1000 MVA 400 kV turnkey cable circuit between Tsenug Kwan O and Taiwan Substations. This cable circuit was approximately 14 km in length, comprising 33 sections (one of which being in excess of 1000 m installed through a road tunnel) laid through the dense urban environment of Kowloon. All members of the installation team reported to me via specialist engineers. My duties also included the maintenance of a constructive relationship with the utility CLP Power Limited, as well as the local authorities. I was also responsible for the provision of information to my employer's cable factories in Europe, and those of our subcontractors in Japan.

5. **PRIOR** to March 2001, I worked in Singapore for eight years and held many positions providing support to the installation of 66, 230 and 400 kV cable circuits. Examples of this work include:

   (a) The overall management of a project undertaking the diversion of four cable circuits as part of an exercise to reinforce the power supply to a large oil refinery, including control of the civil works subcontractor, as well as the jointing and other engineering specialities.

   (b) The direct control of up to three EHV cable jointing teams and ancillary support staff, totalling some 18 people, undertaking 66 kV and latterly 230 kV XLPE and 230 kV oil filled cable jointing.

   (c) Part of a large team responsible for the installation of approximately 60% of the Tuas Power Station – Labrador/Ayer Rajah 400kV Power cable circuits which included the laying, jointing and testing of water pipes in an 800m cable tunnel. These pipes were to be used to provide for the eventual forced cooling for this particular section of the route.

6. **IMMEDIATELY** before accepting my current position, I worked in the United Kingdom as a Project Engineer providing both contract support to the Electrical Supply Industry, including on-demand maintenance of installed cable systems at voltage levels from 33 kV up to and including 400 kV in the North of England. I also had responsibility for a number of projects to reinforce the 132 kV and 33 kV cable systems in the City of Leeds, West Yorkshire and refurbishment a number of 275 kV cable circuits in the City of Sheffield, South Yorkshire, some of which were installed some forty years ago.

7. **I** confirm that I have read and am familiar with the Code of Conduct for Expert Witnesses in the Environment Court Consolidated Practice Note (2006). I have approached the preparation of this evidence in the same way that I would for the Environment Court.

Scope of evidence

8. **THIS** brief of evidence is split into two sections as follows:

   (a) An overview of the proposed cable system and routing.

   (b) An overview of the anticipated cable installation process.

OVERVIEW OF THE CABLE WORKS

9. **TRANSPOWER** is seeking designations for the following two cable routes:

   (a) two 220 kV underground cable circuits of approximately 10.6 km, that will connect Pakuranga Substation to the proposed Brownhill Substation; and

   (b) two 220 kV underground cable circuits of approximately 9.9 km, that will connect the proposed Brownhill Substation and Otahuhu Substation.

10. **BOTH** of these cable routes are located entirely within Manukau City, and traverse areas of existing, or planned, urban development.

11. **THE** greater proportion of both routes are located within road reserve. However, there are sections in other reserve types and privately owned land, which are mostly rural lifestyle blocks.

12. **MR** Wildash has described the cable routes. I do not repeat those descriptions in my evidence.

13. **CURRENT** programming for the Upgrade Project has construction work for the circuits connecting Pakuranga Substation to the proposed Brownhill Substation commencing in the latter stages of 2009. As explained by Mr Coad, the first circuit connecting Brownhill and Otahuhu Substations is not required to be commissioned until 2021, with the second in 2023. Therefore I would envisage installation activities commencing in 2019 for the former, and 2021 for the latter.

14. I will describe later in my evidence that Brownhill Road will be upgraded as part of the works to install the circuits between connecting Pakuranga Substation to Brownhill Substation.

15. IT is Transpower's intention to let a contract for the design, manufacture, installation and commissioning of the proposed underground cable system/route(s). Extra High Voltage (**EHV**) cable systems are not available "off the shelf". Instead, EHV cable systems are provided to the customer's design requirements. The final details of the overall system design would only be known after a contract has been let and the successful contractor has completed the detailed design. The contractor would first need to study the selected route in total and any imposed constraints.

16. I will now briefly discuss the main processes involved with the installation of the underground cable circuits. Mr Wildash, in his evidence, discusses the individual components and design considerations in more detail.

Cable trench

17. **EACH** cable circuit will be buried in a trench approximately 1.5 m width and 2.2 m deep, with the distance between the top cable and ground level of 1.5m and upon completion will generally consist of:

(a) Three separate, single core power cables.

(b) Two small pipe ducts, sometimes referred to as sub-ducts.

(c) One optical fibre cable installed within one of the ducts detailed in (b) above, which will be used to carry essential control and protection data as well as telecommunications, cable alarms and data for other Transpower operational requirements.

(d) One optical fibre cable laid in close proximity to one of the power cables that will form part of a distributed temperature sensing (**DTS**) system for the cable circuit. This system allows the temperature of the cable to be continuously measured along the cable route in order to identify any hot spots and warn of overheating.

(e) Polyethylene pipes to provide for the later application of forced water cooling, will be installed alongside the cables. At this stage, it is proposed to install four such pipes.

(f) Rigid protection covers and warning marker tapes laid on top of the items detailed in (a) – (d) over the full width of the trench extending along the entire route.

(g) Proprietary thermal backfill laid around the power cables beneath the covers described in item (f).

Jointing

18. **JOINTING** refers to the process of connecting together distinct lengths of cables. The power and optical fibre cables are manufactured in discrete drum lengths, which are pulled into position and then jointed in situ.

19. **JOINTS** for all three power cables have to be located in the one position. These areas are commonly referred to as joint bays. The jointing operation is precise and carried out in clean working conditions by personnel specifically trained for the work. I anticipate that the jointing operation would take at least 4 weeks to complete.

20. **THE** optical fibre cable joints, sometimes referred to as "splices" will be located in the same area as the power cable joints. However, because these cable are physically much smaller than their power equivalent, much greater lengths can be easily handled, hence the number of splices required is reduced when compared to the power cable joints.

Terminating

21. **AT** the substations, the power cables are terminated into accessories commonly referred to as "*sealing ends*". The types of sealing ends depend upon the type of switchgear used. However, for the Upgrade Project they can be classified into two categories:

(a) those that are open to the elements and known as outdoor sealing ends; or

(b) those that are installed within enclosed gas filled chambers of Gas Insulated Switchgear (**GIS**), these are commonly called SF_6 Terminations.

22. **SPECIAL** cabinets shall be provided in a separate area of the substation and transition stations into which the optical fibre cables will be terminated.

23. **OUTDOOR** sealing ends are required at the proposed Brownhill Substation, while those needed at the Pakuranga and Otahuhu Substations will be subject to confirmation after the type of switchgear has been confirmed.

Forced cooling

24. **AS** explained by Mr Wildash, the cable circuits will initially be designed to be naturally cooled by dissipation of heat into the surrounding ground and then to the atmosphere.

25. **HOWEVER**, to provide for a high current requirement it is not always possible to design a cable system, where all the heat generated can be dissipated naturally by the surrounding ground. In such circumstances, it is only possible to achieve the required rating by installing cables to operate in parallel by using multiple cables per phase. The major drawback with this approach is the provision of significant capacity that is usually not required until a much later date in the life of the cable circuit, but which increases the initial project costs. Another method to provide for additional capacity, that defers capital expenditure, is by making use of some form of forced cooling, or allowing for its provision at a later stage. Transpower anticipates adopting forced cooling for these cable circuits.

26. **THE** naturally cooled approach will be sufficient until approximately 2034 after which time forced water cooling will be required. To allow for this later application of forced cooling the four polyethelene pipes would be laid alongside the power cables. Cooling stations would be constructed at each end of the cable route with two or possibly three intermediate cooling stations. These would contain the plant to pump the water through the route

pipe work and discharge the heat to the atmosphere. A cooling system design study would be carried out by the successful contractor to establish potential locations for these stations.

Brownhill Road upgrade

27. **THE** upgrade of Brownhill Road is proposed as part of the underground cable component of the Upgrade Project. This upgrade is required due to the transportation of the 250 tonne transformers, and other construction traffic, associated with the proposed Brownhill Substation works. While this substation construction is not likely to commence until about 2032, Transpower has decided to upgrade Brownhill Road as part of the initial cable route works.

28. **BROWNHILL** Road, is located near Whitford in South Auckland, is a narrow rural road about 1.9 km long. It is sealed for the first 1.22 km from the intersection with Whitford Park Road. The remainder is unsealed (gravel). The sealed section of road is approximately 3 to 7 m wide with poorly formed and irregular edges. I consider the existing road carriage way to be generally suitable for the passage of the necessary construction machinery required for installing the underground cables. I also consider that it would not be necessary to resurface Brownhill Road to accommodate the cable circuits, however a short section could require to be widened where it runs closely to the Turanga Creek and encroaches over the western road reserve boundary.

29. **THE** road currently has a total width beneath 7 metres, including tar seal width of 6 metres is too narrow for the transporters. It is too narrow for the transporters and there are a number of corners and humps that would be too restrictive to transporter movement.

30. **A** bridge over Turanga Creek, about 190 metres north of the proposed Brownhill Substation site, is also too narrow and the approaches have curves that are too tight for the transporters. A new crossing would be required. In addition, the existing road extends over the road reserve boundary at a number of locations and it is therefore intended to undertake a modes realignment such that the road is entirely within the legal road reserve.

31. A study was commissioned a study from Maunsell Limited[1] to ascertain what work would be necessary to upgrade the road to achieve the minimum standards required by Manukau City Council (**MCC**). This study also identified the modifications required for passage of the transporters and recorded a number of ground physical parameters that could be used by the cable circuit designers. The study suggested the following design requirements:

(a) Carriageway width 7 metres (6 metre seal width);

(b) Maximum gradient 5%;

(c) Maximum crossfall 3%;

(d) Surfacing 2 coat chip seal;

(e) Minimum clearance from transporter to level road surface 300mm.

(f) Minimum clearance from transporter to crest of curve 100mm.

32. AS discussed earlier, the cable laying would commence in 2009, prior to the transportation of the transformers. The primary reason for completing the upgrade as part of the underground cables component of the Upgrade Project is avoid the possibility of cable disturbance during upgrading works and ensure the correct burial depths are maintained. This approach also means that the cables can be installed within the proposed Turanga stream bridge crossing, and therefore limiting excavation activity in the stream bed. Mr. Burns in his evidence discusses the proposed road upgrade works.

Easement width

33. AS discussed earlier, the majority of the cable routes are to be installed within existing road reserve corridors and other public reserve areas. There are only a limited number of privately owned properties across which it is proposed to install the cable circuits and the intention is to acquire

[1] Maunsell Report Number AGT TPRE004-60019119 dated 12 October 2007.

easements in these instances. Transpower is negotiating the purchase of the necessary property rights with the owners of the land affected by the easement.

34. **IT** is proposed that the designation and easement widths be the same, and generally 20 metres. This width is considered adequate to accommodate two cable trenches, and any intermediate joint bays, provide for access to construct, operate, maintain as well as provide a level of protection of the circuits over their anticipated lifetime. The 20 metres width requirement can be broken down into the following components:

(a) Two 6 m wide strips on the extremities of the easement measured from the edge of the cable trench to the boundary of the easement. This figure is commonly used by other utilities in New Zealand (eg Vector Gas) and elsewhere in the world.

I also consider this width to be adequate to prevent the penetration of the roots of trees planted immediately outside of the easement into the cable trenches. These roots are a concern due to their extraction of moisture from the ground potentially affecting the performance of the circuits.

In addition, should repairs be required that calls for the excavation, the spoil can be stockpiled at a safe distance away from the trench thus minimising the risk of trench collapse.

(b) Two 1.5 m wide cable trenches.

(c) A 5 m wide corridor between the two trenches. This corridor provides the ability to accommodate a suitable haul/access road.

35. **THERE** are two exceptions where a wider easement and designated area is sought. These exceptions are as follows:

(a) The area immediately in front of the entrance to the existing Transpower tunnel entrance. An area of approximately 250 m^2 is provided for. This additional area is to provide the successful contractor with the ability to optimise access to the tunnel.

(b) On the Otahuhu route, the circuits traverse privately owned land between the end of Jeffs Road, which is a paper road at this point, and the intersection with Ormiston Road. The presence of a steep bank leading from Ormiston Road onto the private property has necessitated the designation and easement width being increased to 25 metres, to provide the successful contractor with the flexibility to optimise the eventual routing by splitting the circuits.

PROCESS FOR CONSTRUCTING THE CABLE CIRCUITS

36. **IN** this section of my evidence, I discuss the general construction stages, and the methodology that is expected to be performed during the construction process.

37. **A** contract for design, manufacture, installation and commissioning of the proposed underground cable system/route will be let. The successful contractor is expected to engage various subcontractors to undertake particular aspects of the operations; examples may include, but not be limited to, earth works, cable transportation, and heavy lifting.

Construction stages

38. **CABLE** laying and jointing comprises a series of interconnected activities, as follows:

(a) initial investigations;

(b) site preparation;

(c) excavation;

(d) joint bay construction;

(e) cable laying;

(f) backfilling;

(g) reinstatement and rehabilitation; and

(h) jointing.

39. I discuss these stages in more detail below.

Initial investigations

40. **CONTRACTS**, work procedures and designs would be prepared and implemented prior to the implementation of any site works.

41. **THE** cable would be laid in excavated trenches in discrete sections of about 600 to 800 m between the termination and/or intermediate joint locations, referred to as joint bays. The designated line of the cable route would be surveyed by the contractor with a view to locating the positions of the joint bays. In principal, it is normal to use as long a length of cable between joint bays as possible, (ie to have the minimum number of joints practicable). In practice, the maximum section length (distance between consecutive joint bays) can be limited by any number of different constraints. These constraints include:

(a) local restrictions on the length of continuous trench that can be opened;

(b) maximum cable manufacturing length;

(c) transportable length on one drum;

(d) handling limitations at the site of installation; and

(e) physical constraints positioning joint bays.

42. **THE** joint bays would by necessity be required to be generally open for extended periods of approximately 6 – 8 weeks. This is the time required to excavate two cable sections, install and joint the cables, as well as the ground reinstatement process. As a result, efforts will be made to locate joint bays in areas where the overall impact to the public will be minimised.

43. **DURING** this investigative process, the location of existing buried services along the route would be researched by reference to available records, or by the making of direct contact with other utility operators. Where deemed necessary trial holes and/or trial trenches would be dug, usually by hand, to locate subsurface obstructions. The trial holes assist in determining the exact location for installing the cables within the designated area and the positioning of the joint bays.

44. **THE** extent of the trial holing would be determined by experience and moderated in accordance with the accuracy of the available information and known obstructions. The final line of the trench would be selected to have as few changes of line and direction as possible, all corners and vertical profile changes would be taken at a radius at, or greater than, the minimum installation radius of the cable. This figure is specified by the cable manufacturer. This overall process enables the most efficient cable laying operation to be adopted, because cables of the size and weight envisaged require careful handling.

Site preparation

45. **DURING** this phase of construction, the perimeter and/or centre line of the trench would be suitably marked on the ground. Spray paint would be used for rigid surfaces, and suitable marker posts would be utilised for other locations, such as parkland. The assumed location of all existing services crossing, and in the immediate vicinity of the trench would be indicated on the ground by a suitable means and personnel briefed appropriately. Before excavation commences, road paving and any other rigid surfaces are cut along both sides of the proposed trench/joint bay using a diamond-bladed saw.

46. **FOR** parkland and rural sections of the route, the relevant land management agency/owners would be consulted regarding topsoil management. A construction corridor/strip of a width suitable to accommodate the cable trenches, a haul road, and room for spoil storage would be cleared. The normal process would be to strip topsoil from the land to be trenched and stockpile it on site for later use in rehabilitation. Suitable mitigation measures would be implemented to maintain any pile, such as covering with tarpaulin to prevent runoff. If the area is heavily

weeded, it may be agreed with the land management agency that the topsoil is best removed from the site together with other excavated material.

47. **IN** these rural areas, natural surface rocks in the path of the cable route, large and small, would be collected as far a practicable and stockpiled on site for later use in rehabilitation.

Excavation

48. **THIS** phase of construction involves excavation of the discrete section trenches between the termination and/or intermediate joint bays and preparing these for cable installation. Typical periods to complete one section are anticipated to be one – two weeks in the rural areas, increasing to three – four in the urban fringe.

49. **RIGID** road surfaces would be broken using either an excavator mounted breaker or pneumatic hammer.

50. **FOR** the most part, a mechanical excavator would be used to remove material down to the base of the trench. A number of methods could be adopted for this work two of which are described below:

(a) Where space allows, the excavator would stand directly over the cable route and load excavated material into dump trucks standing immediately to the excavator's side. Within roadways this operation would effectively occupy two lanes. The obstruction in the second lane would be limited to about 20-40 m in length. The major advantage to this approach is that none of the operations would extend out of the installation area.

(b) If it is not possible, for whatever reason, to close the lane adjacent to the excavator the trucks reverse into the work area to the rear of the excavator. This may require the excavator to turn through 180° to load the excavated material into the truck. During these turning processes the arm of the excavator may extend outside of the installation area and suitable risk assessments would have to be undertaken at each location to implement suitable procedures which remedy any safety issues. Such procedures could include physically limiting the extent of the arm of the excavator, such that it always remains in the barricaded works area, utilising a conveyor belt system, or using watchmen to coordinate all pedestrian or traffic movement during the excavator turning operations.

51. **TRAFFIC** management measures would be developed in conjunction with Manukau City Council and implemented (and if mutually agreed modified) during excavation as appropriate. Mr Prince discusses traffic management in his evidence.

52. **WHERE** rock is encountered which is unable to be removed by the excavator, the contractor may elect to loosen the material with a rock breaker, jackhammer, or other specialist measures, as appropriate.

53. **TO** minimise the risk of damage to buried services, the contractor may use hand methods to expose other buried services for the guidance of the excavator operator. Every reasonably practical effort would be made to avoid damage to existing services. However, should accidental damage occur, the contractor would be required to expedite repairs in consultation with the owner of the service. In particular, should a service to an individual premises be accidentally damaged, the contractor would ensure that service is restored as a priority on the same day or provide temporary arrangements until such time as the supply's restoration.

54. **MATERIAL** excavated from the trench would be completely removed from the site. Apart from topsoil, and surface rock, as described above, excavated material will not be reused on the Upgrade Project.

55. **THE** roadway or ground adjoining the trench would be cleaned of any spillage as the excavation progresses. At the end of each working day all paved surfaces comprising the worksite would be left in a swept state.

56. **AS** the trench is excavated, an assessment would be made of the stability of the sides. Where necessary, support in the form of shoring to the trench walls would be installed as a precaution against slump or collapse, particularly where deeper sections of trench are required. However, all joint bay walls would be supported. The contractor would also be expected to

institute a system of regular inspections of all open excavations and implement measures to ensure remedial action is taken if any instability is noted. Such measures could include reinforcing the trench shoring at particular locations.

57. **AS** soon as the excavator completes a section of trench and moves along the road, the contractor would place barricades on both sides of the trench as a visual and physical barrier for the safety of motorists and pedestrians. Flashing lights would be affixed to the barricades for night time warning. The same level of barricading would be used in grassed parkland areas used by the public. In the rural areas where access by the public is difficult, the extent of barricading or stock proof fencing would be discussed with the land management agency/owners. The contractor would be required to monitor and maintain the barricades and lights daily, with increased intensity during and following weather incidents, to ensure adequate protection is provided for the public.

58. **WHERE** the trench traverses a road or property access way, steel plates would be placed over the trench as soon as excavation has passed the crossing or access point. These plates would be of an adequate thickness to carry the weight of heavy vehicles and would be anchored to the road if necessary to avoid movement.

59. **IN** order to meet the overall construction program it would be necessary for the contractor to work in a number of locations simultaneously along the length of the route.

Joint bay construction

60. **AS** discussed earlier, joint bays are the areas where two sections of cables are jointed. This stage of construction involves a widening of the cable trench with a concrete base and walls. Typically these take five – ten days to complete. The jointing works, after the cables have been installed, is discussed later in my evidence.

61. **VARIOUS** cable contractors have slightly differing designs for joint bays. Generally, joint bays would be from 10—15 m long x 2 m wide x 2 m deep, excavated in the line with the cable trench. The joint bays are generally

deeper than the trenches, and this difference is dependant upon the actual finished diameter of a particular joint and practices. The reason for this increased depth is because the top of the finished cable must be as deep as the cable at the standard laying depth. It also provides adequate clearance under the cable to allow jointing operations to be carried out. In addition, the width of the spacing between the cables in the joint bays may need to be increased to enable the jointing staff to move between the cables with their equipment.

62. **THE** transition between the trench and joint bay must not take place too sharply after leaving the joints because a length of straight cable is required during jointing for 'passing back' the joint sleeve. In addition, the cable bending radii must not be compromised as this could lead to the internal components in the cable joint becoming misaligned. Hence, the need for the indicated joint bay length.

63. **CONCRETE** sides of the joint bay would ensure stability of the excavation throughout the jointing period. They would also assist in maintaining clean conditions which are essential during the jointing process. Long term, the concrete sides provide ongoing mechanical protection for the cable joints.

64. I expect that the contractor will construct joint bays in advance of cable trench excavation so that cable installation can commence as soon as a section of trench is complete.

65. **AFTER** jointing, joint bays are normally backfilled in a similar manner to the cable trench.

Cable laying

66. **THIS** stage of construction involves the positioning of the cable drums at one end of an excavated section and pulling them into their final position in the trench.

67. **THE** open trench is prepared for cable laying, by placing a bedding material of sand/cement mixed in the proportion of 14:1 (or similar material) to provide a smooth base. The bedding material is delivered to the site in concrete mixers and dropped directly in the trench for manual spreading

and mechanical compaction. When the bedding is in place for the full drum length of cable, rollers are placed on the floor of the trench at specified intervals (typical being 1 – 2 metres). Modified vertical rollers and/or skid plates are positioned at bends to assist with the guiding of the cable.

68. **CABLE** drums would be held in a separate remote storage area until needed. They would be delivered to site by low loader and unloaded by crane. This operation could take place at night to avoid disrupting daytime traffic along the route. Cable drums would be temporarily stored on the roadside, securely chocked to ensure they can not roll and barricaded. Each drum would be lifted in turn onto the axle stand for cable laying. Thereafter, each of the three power cables and water pipes are sequentially pulled into the trench and bedded into their final position. In a difficult section, it could take a full day to pull each cable into position.

69. **TWO** principal methods of cable pulling, either singularly or combined are anticipated to be utilised. These methods are referred to as nose and bond pulling respectively. The exact choice of method used will be made by the contactor.

70. **IN** a nose pull situation, a winch is positioned at the opposite end of the trench from the cable drum. A suitable rope, commonly referred to as a "bond" is paid out of the winch through the trench and connected to the cable end, which will have been fitted with a pulling eye in the factory. A schematic of this method is shown in **Figure 1** below. However, I consider that there is a number of limitations to this technique. The main limitations being:

(a) the maximum tensile load (force) that can be safely applied to the cable or to the pulling eye; and

(b) the maximum side wall thrust developed on the cable as it traverses directional changes, such as a curve, along the cable trench. This thrust is produced by the pulling force attempting to compress the cable against the vertical rollers and/or skid plates positioned to guide the cable around the bend described previously in my evidence.

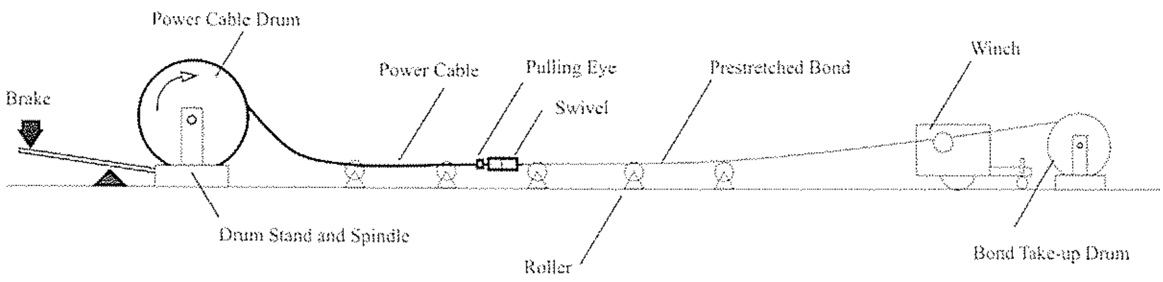

Figure 1: Principles of Nose Pulling Technique

71. **THESE** limitations are directly proportional to the complexity of the cable pull and the physical cable parameters. It is therefore necessary to calculate the anticipated loads before installing the cable by the nose pulling method and introduce systems to ensure these are not breached. However, because the cables would both be heavy with long lengths between joints, the pulling tension and/or side thrust would reach an unacceptable level and possibly lead to damage of the cable during installation. To address this situation, the bond pulling technique is used, which distributes the pulling force more evenly through out the cable length.

72. **THE** pulling technique involves attaching the cable to a separate wire which is then used to carry the cable into the trench. A wire "bond" of more than twice the length of the cable route would be coiled on a drum mounted on a suitable stand in the immediate vicinity of the cable drum. The bond would be run out through the whole length of trench and attached to the pulling winch usually positioned at the remote joint bay. At each change in the route, the bond would be taken through a pulley, generally referred to as snatch blocks anchored to the side of the trench. These snatch blocks take the full side force of the bond from the change in direction. **Figure 2** shows an example of the bond pulling process.

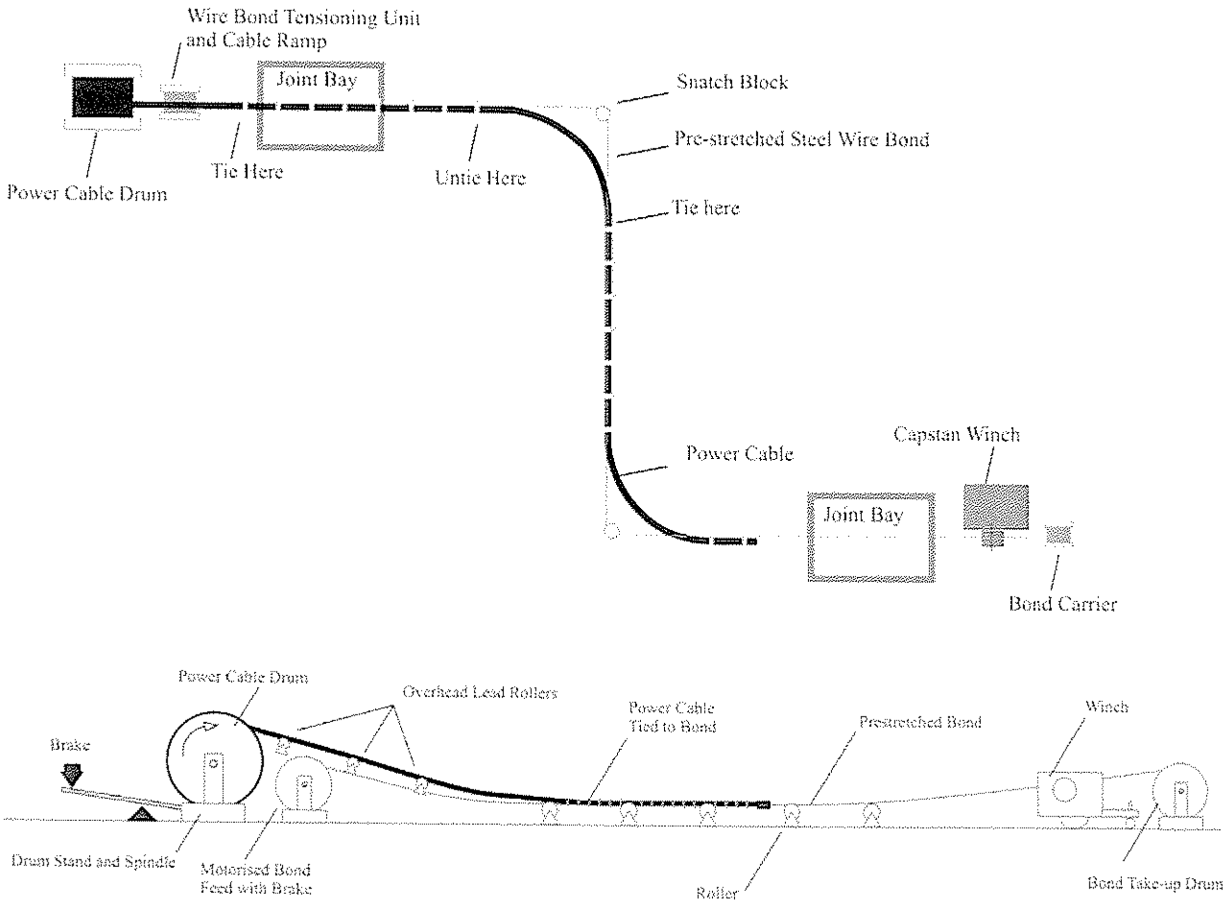

Figure 2: Principles and Arrangement of Bond Pulling Technique

73. **INITIALLY**, a short length of cable would be pulled off the drum by hand, thereafter the bond would be attached to the cable using ties with a spacing of approximately 250 mm. Once the winch starts, the cable would then be tied to the bond at intervals of approximately 1 – 2 m as it is drawn from the drum. Prior to each change in position at snatch block positions, the ties are removed while the cable is taken round the bend and the ties are then reattached to the bond immediately after the directional change.

74. I note that other specialist techniques are available for cable laying. These techniques involve driven rollers, or caterpillar type machines, that turn and thereby apply a motive force to the sides of the cable that moves it along. However, I do not anticipate that these techniques would be used as standard methods because the equipment is costly and introduces additional levels of complexity.

75. **EMPTY** cable drums would be removed from site as soon as possible after the cable has been dispensed. Because the drums could be 4 m wide , it may prove economic to cut the drum into smaller sections on site before transporting them away. The resulting pieces would then be sold to companies that are registered to receive, as well as dispose, of such materials.

Backfilling

76. **BACKFILLING** involves the filling in of the trench after the cables have been positioned.

77. A further layer of the same material used for bedding mix would be placed around, and over, the power cables, to a pre-determined level. The bedding material cures to a firm barrier. This barrier resists scouring by groundwater, and ensures good contact with the cable surface for heat conduction.

78. **CONCRETE** cable covers would then be placed over the bedding mix for mechanical protection against accidental excavation. The exact type of cover has not yet been determined. Concrete slabs and fibre board tiles are utilised elsewhere in the world. Whatever material is used would be inscribed with a warning that high voltage electricity cables lie below. The two subducts/pipes for the communication optical fibre cable, and the spare for future uses, would be installed at the top of the bedding material just beneath the cable covers.

79. **THE** balance of the trench would be backfilled with an aggregate mix depending on whether the trench was located in a road or soil in park land areas as detailed earlier in my evidence. The backfill material would be compacted as it is placed into position to encourage rapid consolidation of the mix.

80. **BACKFILLING** is usually carried out as quickly as possible, to minimise the possibility of damage to cables, enable the surface to be restored, and to minimise the effects of subsequent rain. Backfilling work may be underway at several locations along the same drum section of cable route.

Reinstatement and rehabilitation

81. **REINSTATEMENT** refers to placing the final surface over the cable trench and restoration of any other areas disturbed during the construction process to match the existing surface type. Such areas may include sections of nature strip, footpath or kerb and gutter, or parkland areas damaged by vehicle movement.

82. **WHERE** the cable is laid in a roadway, the provisions of the Code of Practice for Working in the Road (**COPWIR**), as developed by the Road Controlling Authorities within the Auckland Region and the Auckland Utility Operators Group would apply. The COPWIR details a number of variations dependant on the carriageway surface however I would expect the contractor to place a temporary reinstatement of bitumen over the backfilled trench. This bitumen would remain in place for up to several weeks while the backfill material consolidates under the weight of traffic. During this period the contractor would monitor and maintain the surface to an acceptable standard (which would be determined in consultation with Manukau City Council).

83. **PERMANENT** reinstatement would be carried out after the backfill material has consolidated. Where deemed appropriate, reinstatement methods and standards would be discussed with all stakeholders, such as Manukau City Council or private land owners, along the route prior to this part of the work commencing. Special arrangements would be made where rigid concrete pavement is to be reinstated or other particular circumstances exist. In the case of concrete pavement, replacement of full concrete panels may be the most suitable solution to ensure long term serviceability.

84. **IN** locations where the cable is laid in parkland, rural areas or other non-sealed locations, the backfilled trench would be restored to a condition similar to, or better than, that existing prior to cable installation. All surfaces would be finished to minimise the potential for erosion in a manner agreed with the responsible land management agency/owner. Previously stripped and stockpiled topsoil would be spread over the backfilled trench to an agreed depth. In grassland, the disturbed area would be reinstated in such a way to match the adjoining grass as closely as practicable. In natural

areas, the soil could then be seeded with local vegetation or stabilised with rocks, logs and other forest debris to allow natural revegetation to occur.

85. **THE** contractor would monitor restored areas and attend to any locations where deterioration of restoration work is evident. Such deterioration could result from trench sinking as the material used for the backfilling consolidates, the effect of rain on restored areas, the failure of regrowth, or weed infestation. Monitoring would continue until it is agreed with the relevant road authority or land management agency/owner that disturbed areas have reached a satisfactory level of restoration.

86. **IN** relation to the roads a maintenance period of one year is specified in the COPWIR for roads in the Auckland area, which includes Manukau City.

87. **IN** my experience periods of 6 – 12 months are seen for planted areas as this allows the vegetation to regenerate satisfactorily.

88. **AT** the time of temporary reinstatement in roadways, or permanent reinstatement in parkland or rural areas, the contractor would ensure that all construction equipment, materials and debris are completely removed from the site.

Jointing

89. **JOINTING** is a separate operation to the cable laying. It is carried out by a specialist team of staff in the joint bays. At 220 kV, the jointing operations would extend over many days, typically 14 – 21 days. It would be essential to provide some form of weather/security protection in the form of an enclosure over the joint bay.

90. **IN** addition, the jointing procedures demand a clean environment, and depending on the circumstances, humidity control may also be required. In these circumstances, specially air-conditioned enclosures would be constructed within the external enclosure. A low voltage electricity supply to power the equipment used is needed, and would be provided by a silenced three phase generator positioned adjacent to the joint bay.

91. **IN** addition, joint bays require portable amenities for six or more staff, parking and materials storage. A security fence would be erected around the overall joint bay perimeter and may have a security guard present at night. Because of these requirements the "footprint" required during the process can be significant.

92. **WHEN** all joints are complete, the joint bay would be filled using the same or similar mix, cable covers and backfill material as used in the cable trench. The backfill material would be placed and compacted by hand in layers of 150 mm. No mechanical compaction methods should be used on the joint bays until after the marker covers/slabs over the joint bay are installed.

CABLE LOCATIONS WITH SPECIFIC DESIGN REQUIREMENTS

Brownhill Road to Pakuranga cable route

93. **BROWNHILL** Road and the sealed parts of Caldwells Road have carriageways less than 6 m wide. These roads would be widened and upgraded as necessary to have a 6 m carriageway width before the cables are installed.

94. **THE** method of crossing of the Mangemangeroa Stream on the paper road section of Caldwells Road would depend on whether the section of paper road from the stream to its junction with Griggs Road is ever likely to be made into a proper road. At present, this development seems unlikely as there is a rise in elevation of approximately 110 m at an average slope of 1 in 4 from the stream to the junction of Caldwells Road with Griggs Road. If a road is not required, then the stream could be crossed by a cable bridge or the cables installed in the stream. If a road is required, then the stream could run through a culvert under the road with sufficient cover to include the cables, say 2 m, between culvert and road surface.

95. **SPECIAL** construction techniques may be required to excavate trenches down steep slopes and then to pull in the cables. Sections where these may be required are on Caldwells Road from the Mangemangeroa Stream to the junction with Griggs Road, and from Point View Drive down across

private land, to an unnamed ephemeral stream in boggy ground. The latter involves an elevation change of about 55 m at an average slope of 1 in 6.

96. **THE** section in boggy ground alongside the ephemeral stream should not present undue construction difficulties, if the work is carried out at a dry time of the year. The stream would be crossed either by a cable bridge, embedment in the stream bed, or by extending the existing culvert up stream a short distance so the cables can be installed over the top.

97. **A** cable tunnel exists from Dunvegan Rise to the stormwater reserve adjacent to the existing Pakuranga Substation. This tunnel is approximately 2.3 km in length, with an internal diameter of 1.8 m. It has three intermediate jointing chambers with dimensions of 8.3 m (l) x 3.8 m (w) x 2.0 m (h), which are not spaced equidistantly.

98. **THE** tunnel is currently occupied by one ARI-PAK A 110 kV circuit, which consists of three cables. There is one joint chamber utilised, (ie there are two cable section lengths).

99. **I** commissioned an independent report[2] to investigate the possibility of installing two 220 kV cable circuits in the existing tunnel. This report was commissioned because the 220 kV cables would be significantly larger than the existing 110 kV cables. In addition, I was advised that Transpower's maintenance staff had commented that presently the tunnel is a difficult environment to work within.

100. **THE** report found that:

(a) It is feasible to install two 220 kV, 2,500 mm^2 copper conductor, cross-linked polyethelene (XLPE) insulated circuits in the tunnel.

(b) The installation of the two 220 kV circuits would be a major engineering challenge. The report strongly recommended that a full detailed design study should be performed before a final decision is taken.

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[2] Cable Consulting International Report Number ER248 Arapuni – Pakuranga Cable Tunnel, dated 24 September 2006.

(c) Safety of personnel in the tunnel during the construction, operation and maintenance phases is paramount and the report recommended a "safety by design" approach.

101. **HOWEVER**, a number of issues and concerns were identified by the report, which are summarised in **Appendix 1** to my evidence.

102. **GIVEN** that the ARI-PAK A tunnel was not designed to accommodate two circuits of the size proposed for the Upgrade Project, the significant Health and Safety concerns for the installation staff, and that it will not be possible to segregate both circuits, makes it extremely difficult to effect maintenance and/or repair work on one circuit while the other is live (the 400 kV transmission link from Whakamaru to Auckland being designed as a high reliability link with a high availability meaning for system security reasons it would be undesirable initially to switch off both cables circuits and impossible as demand increases over the years). Transpower therefore concluded that only one circuit should be installed in the tunnel, with the other laid directly in the road adjacent to and generally along the same line of the tunnel.

103. **THE** existing 110 kV cables would be removed from the ARI-PAK A tunnel before installation of the 220 kV cables. The arrangement of the cables and fastenings required would be for the cable contractor to determine. It is considered likely that the spaced trefoil layout suggested for the trenched sections would not be adopted because the restricted space would present difficulties in positioning cable rollers and the like to achieve this. Presently I would anticipate an horizontal arrangement. There are at present three jointing chambers in the tunnel and it would be for the cable contractor to determine whether modifications would be required to the chambers and/or additional ones constructed along the tunnel route.

104. **THE** cable route crosses Watercare's East Tamaki to Howick 700 mm diameter water main in open ground between Guys Road and Te Koha Road. The depth to invert the water main is only 1500 mm and so it should be possible for the direct buried 220 kV cables to pass underneath.

105. **THE** route crosses Watercare's Botany Branch 600 mm diameter sewer close to its junction with manhole 34 of the Tamaki East Interceptor 1000 mm diameter sewer. There is also a 375 mm diameter local sewer that discharges into the manhole that would also have to be crossed. The depth to invert at the manhole is 2775 mm and so it should be possible for the direct buried cables to pass over the top of these pipes.

Brownhill Road to Otahuhu cable route

106. **THE** section of the route from the proposed Brownhill Road Substation rises across undeveloped land to Redoubt Road on the crest of a ridge. The cable route follows a spur ridge that is relatively narrow in places and flanked by instability with a moderate to steep section near the crest. The elevation change is 105 m at an average slope of 1 in 7 over 700 m. Significant cuts and fill with retaining walls would be required together with special construction techniques to pull in the cables.

107. **THE** proposed route crosses a 10 m high, steep road cut at 542 Ormiston Road where it leaves the road to enter private land. It is expected that excavating a cable trench up or across the slope would be impracticable and it would be better to install pipes for the cables from behind the top of the bank through to the banks base on Ormiston Road. The cables are effectively being installed in air for this short section.

108. **THE** proposed route crosses Murphy's Road at its intersection with Jeff and Stancombe Roads. Installed in Murphy's Road is Vector's Oaonui to Auckland 350 mm diameter gas pipeline laid with a minimum depth of cover of 1200 mm. Vector also have a designation for a second 350 mm pipeline to be laid parallel to the existing pipeline with an offset of 2000 mm and with a minimum depth of cover of 2000 mm. In addition, Watercare's East Tamaki No 2 700 mm diameter watermain is laid with a depth to invert of 2120 mm on the opposite side of the road to the gas pipe. The 220 kV cables would have to cross under these pipes at a sufficient depth to be clear of excavation work for the proposed additional gas main ie depth of cover to the top cable of 3000 mm instead of 1500 mm. This would require the cables to be spaced further apart to counteract the adverse thermal effect of the greater depth on the cable rating. The spacing and any other

measures required would depend on the local ground conditions and would be for the cable contractor to determine.

109. **THE** proposed route crosses Watercare's Chapel Branch 525 mm diameter sewer pipe between manholes 13 and 14. The depth to invert between these manholes varies between 3420 mm to 2790 mm so it should be possible for the cables to pass over the top of this pipe.

110. **THE** proposed route crosses a storm water reserve between Chapel Road and Ti Irirangi Drive and traverses the sloping edge of a storm water pond. This would require sheet piling to retain the slope during excavation of the cable trenches. Also, the work would have to be carried out at a dry time of year.

111. **THE** proposed route crosses the Hunua No 2 1070 mm diameter watermain at the junction of East Tamaki and Springs Road. The depth to the watermain's invert is 5000 mm at this point so it should be possible for the cables to pass over the top of the water main.

112. **THE** proposed route crosses Otara Creek.

113. **THE** following four options in respect of installing the cable across Otara Creek were investigated and assessed by Transpower:

(a) the use of the existing pedestrian bridge;

(b) a purpose built cable bridge;

(c) a new pedestrian/cable bridge; and

(d) embedment of the cable in the bed of the creek.

114. **A** report was commissioned[3] to investigate these options. This report recommended that the cable crossing of Otara creek be facilitated by embedment. All four options are discussed below:

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[3] Beca Carter Hollings & Ferner Ltd Report North island 400kV Project – Otara Creek Crossing dated 21st March 2006.

Existing pedestrian bridge

115. **A** pedestrian bridge crosses Otara Creek from Franklyne Road to Johnstone Road. The option of attaching the cables in a similar way to the existing single service duct underneath the bridge was investigated. This is supported along the centre of the underside of the bridge, by hangers fixed into the longitudinal concrete deck joints. This passes through cast in voids in the concrete abutments and diaphragms over the piers.

116. **THE** advantages of attaching the cable to the existing pedestrian bridge are that it would involve no vegetation or tree removal, and there would be minimal visual impact. However, any route across the bridge would leave the cables or their ducting exposed and would be accessible to the public, thereby posing risks associated with vandalism and damage to the cables. There is also a possibility of public exposure to electric and magnetic fields (**EMF**) given the exposed nature of the cable placement.

117. **A** number of options for affixing the cables to the bridge were considered, but all would have required the strengthening to piers, abutments and the deck.

Purpose built cable bridge

118. **A** stand alone purpose built cable bridge across Otara Creek was considered, with a likely location being to the south of the existing footbridge. The installation of a cable bridge would require extensive clearance of trees and vegetation from the riverbanks, together with possible land purchase for the new bridge foundations. The proposed circuit spacing of 3.5 m also posed a variety of logistical and technical problems. Due to the exposed nature of the cable/ducts it was considered there would be a high risk of vandalism.

Combined pedestrian and cable bridge

119. **THIS** option involved a new footbridge being constructed alongside the existing footbridge to accommodate pedestrian traffic and the cable and services currently carried by the existing bridge. This option would require demolition of the existing footbridge. As with the other two bridge options,

this option would require extensive vegetation clearance and involve risks of vandalism and the possibility of public exposure to EMF fields.

Creek bed embedment

120. **TWO** alternative methods for placing the cables beneath the creek (rather than above) were explored by Transpower. One option was directional drilling and installation of a 600 mm diameter pipe for each cable circuit below the Creek from one bank, with the pipes maintained at a depth of over of 1.5 m. The second installation option was that of laying the cables in an open trench excavated within the Creek bed. The pipes laid in the open trench would be sealed and continuous to prevent ingress of water.

121. **ALTHOUGH** some tree and vegetation removal would be likely, the main advantages of embedding the cable in the Creek bed would be the high level of security given that the cable would be below ground at all times, any visual impacts would be minimal, and the proposed circuit spacing and cable configuration could be appropriately achieved.

122. **THE** investigations recommended that burying the cables within the creek bed would provide the most beneficial solution in terms of cable operation, and security and construction; in particular the maintenance of cable spacing and depths. It is intended that the eventual decision on the method to be adopted would be made by the contractor after performing detailed investigations and consideration of any imposed conditions, but both schemes are considered feasible. It is recognised that any change in the method adopted by the contractor for crossing Otara Creek will in any event be subject to assessment through resource consent applications.

123. **IF** the cable is to be buried in the creek bed by trenching, the anticipated procedure would be to lay two large diameter pipes in separate trenches, excavated within the creek bed about 5 m apart. Each pipe would contain the cables and polyethelene pipes for one circuit. The method to be adopted for installing the pipes would be dependent on the ground conditions on the approaches to, and beneath, the creek. A detailed ground investigation would therefore be required in order to determine a suitable cable route and depth. The route would also be determined by the

location of trees on the banks of the creek. Where it is not possible to avoid the tree roots, the removal of trees may be required.

124. I anticipate that the cable crossing would be installed during periods of lower flow a few hours either side of low tide. I estimate that it would take about 10 – 12 weeks to finish the crossing. The creek bed and banks would be excavated, to a depth of between 1 and 2 m. However, as indicated above, this depth would be dependent on the ground conditions, which will be determined through geotechnical testing. Prior to commencement of trenching activities, a temporary silt fence would be installed across the stream, down stream of the works.

125. **AN** access/working platform, called a "cofferdam", would be constructed using hard fill to provide the working platform for the excavation activities. The cofferdam would be built out from the edge of the creek following the route of the trench. This work would be undertaken in two stages, first from one bank to mid channel and then from the other bank to mid channel. The trenches would be suitably shored to prevent collapse, to minimise the width of the excavation and to enable construction in dry conditions using similar techniques to those employed elsewhere on the Upgrade Project.

126. **THESE** cofferdams would be used to divert water flow around the works area so that trench excavation and positioning of the cable duct could be undertaken in the dry.

127. **THE** pipes would be laid in a bedding material to provide adequate support and be suitably protected (ie encasement in concrete or covered with sand cement filled bags). The trench would be filled to just below existing levels, so that it would then fill in naturally over time with the accumulation of sediments in the estuary.

128. **THE** cofferdam and trench shoring would be removed once the pipes are laid. A new cofferdam would then be constructed from the other side of the creek to lay the second section of pipes from the creek midpoint to the opposite bank.

129. **SOIL** stabilisation measures or other methods as may be determined during the detailed design would be immediately applied to the banks after the

work is completed. This stabilisation could include protective blankets of biodegradable organic material, seeding, turfing, planting or other measures as appropriate. The sediment barrier would be retained in the creek bed downstream of the worksite for as long as practicable after completion of the work.

130. **BURYING** by trenching the cables in the bed of the creek method of laying the pipes could also be achieved using a barge to excavate the trench or a trestle. If a barge or trestle was used as a working platform to dig the trench and lay the pipeline, there would be no need to construct a cofferdam, reducing the environmental effects of this method. It would, however, be difficult to send excavated materials (sediments and mud) from the trench to landfill using a barge system.

131. **IN** my view, burying by trenching the cables in the bed of the creek is the preferred option, as it represents the most cost effective method of installation. Adverse effects of this method are mainly associated with the potential mobilisation of sediment during the trench excavation and pipe laying operation. To mitigate the risk presented by the trench excavation and subsequent activities, shoring inside the trenches and construction of cofferdams around the works area before excavation begins would prevent large quantities of sand and mud moving through the estuary.

CONSTRUCTION MANAGEMENT / RELATIONSHIP WITH THE CONTRACTOR(S)

Type of contract

132. **AS** stated earlier in my evidence, Transpower will let a contract for the design, manufacture, installation and commissioning of the proposed underground cable circuits. This is commonly referred to as a 'Design & Build' contract. A general breakdown of the anticipated scope of works is given in **Appendix 2**.

Contractors / workforce involved

133. **THE** contractor and subcontractors will determine the optimum workforce for different sections of the Upgrade Project. A number of activities may be

underway simultaneously at different parts of the cable route with varying numbers of personnel involved, depending on the changing requirements at that site. I consider that typical workforce numbers for various parts of the work are as follows:

Work	Likely Workforce Number
Trenching team	4 – 6
Backfilling team	8 – 12
Cable pulling	20 – 40
Cable jointing	4 – 6
Special constructions/operations	8 - 10

134. **BASED** on my experience, I anticipate that two trenching gangs will be utilised.

135. **ADDITIONAL** personnel on site at times could include delivery drivers, Transpower supervision staff, and inspection personnel from other authorities.

Contractor facilities

136. **THE** contractor would require facilities for a site office, staff amenities, and secure storage for equipment. Subcontractors will have similar requirements, but on a lesser scale. It is anticipated that these would be fall into two categories as follows:

(a) small scale facilities, in close proximity to the areas where installation activities are ongoing; and

(b) site office-type facilities, with a larger storage area, at a remote location.

137. **DEPENDING** on available space, smaller scale facilities, such as chemical toilets and a demountable office may be stationed at one or two positions along the route. I anticipate that the contractor would opt for transportable roadside facilities for individual work-gangs, as commonly occurs when

other utility operator road works are being carried out. Such facilities would include a chemical toilet, caravan style office and lunch room.

138. **THESE** facilities would normally be positioned within the designated area, or in a low traffic side street, or other secluded area, and be relocated as often as required. Such facilities would be needed at every joint bay. At any one time, there could be several locations where contractors' transportable facilities are in use. Where verges are utilised, the contractor would make good any damage to grass cover as part of the overall restoration works.

139. **THE** contractor may also elect to establish a site office on other premises at a central location. It would be the contactor's responsibility to obtain all necessary approval for establishing and utilising that site.

140. **TRANSPOWER** would instruct the cable installation contractor to minimise materials storage along the route of the direct burial section by delivering needed items on a "just in time" basis. Such materials could include traffic barricades, heavy steel plates, shoring material cable rollers, cable drums, concrete covers, form work, steel reinforcing, link pits, jointing equipment and the like. As soon as work has progressed from a particular street or park, with the cable trench or joint bay backfilled and the surface reinstated, the contractor will be required to remove any remnant construction materials from that location.

Hours of construction

141. **WHEREVER** works are being undertaken at, or near, the surface of the ground in the vicinity of residential areas, normal construction working times are proposed, subject to the exceptions I discuss below, as follows:

Monday to Friday: 7am to 6pm
Saturday: 8am to 1pm
Sundays and public holidays: No work

142. **HOWEVER**, I note that exceptions could occur as follows:

(a) Special circumstances such as where work is planned to be carried out at low traffic times, for example trenching across busy roads. At such locations weekend work and night work may be necessary, or indeed stipulated by Manukau City Council.

(b) Delivery of large cable drums.

(c) Emergencies or contingencies that may require attention at any time. Some remedial work may be anticipated during or following heavy rain.

(d) Locations where the nature of the work is low impact and there are no nearby residences to be disturbed. An example might be cable jointing.

Once the power cables have been cut and prepared for jointing, it is necessary to work continuously and be completed because the cables are vulnerable, particularly to moisture ingress until they are sealed.

143. **AT** any particular location, if the contractor can demonstrate that it is not practical to restrict work to the above hours, application may be made to the appropriate authorities to extend the hours of working contingent upon the undertaking of a consultation process.

Services

144. **VARIOUS** services may be required to the site operations and may include electricity, water, sewer and telephones, waste collection, chemical toilets and fuel delivery. The contractor would be responsible for arranging all necessary construction services with the relevant service providers.

Refuelling

145. **THE** contractor would arrange on-site refuelling, where this is required for mobile plant and static machinery, such as tracked excavators, pumps, backhoes, rollers, vibrators silenced generators and the like. Often it would not be practicable for an item of mobile plant to be taken to a service station for refuelling, in which case refuelling will occur on site. Refuelling would be carried out by mobile tanker, dispensing directly into the items of plant

being refuelled. On-site refuelling would minimise the amount of volatile liquid stockpiled along the route at any one time.

Duration of construction

146. **AS** detailed earlier in my evidence, Transpower will let a contract for the design, manufacture, installation and commissioning of the proposed underground cable system/route(s), as well as the upgrading of Brownhill Road.

147. **CURRENT** programming has a completion date for all works in the third or fourth quarter of 2011 (ie generally a three-year implementation period).

148. **IT** is anticipated that the design phase could take up to one year to complete.

149. **I** have maintained contact with representatives of the cable manufacturers, who all advise that regardless of the design period they are currently experiencing high levels of demand which is extending delivery periods. Transpower has therefore made a conservative assumption that procurement, manufacture and delivery of all cables and joints, would take 106 weeks. This period comprises a 48 week lead time, a 52 week manufacturing time, and 6 week delivery time for the final materials produced. This extended period would also allow the provision of the specialist installation staff to be managed by the successful contractor.

150. **THE** first excavations for the cable circuits are anticipated to commence such that trenches are available for installation when the first cables are delivered. I anticipate excavation to commence in the second or third quarter of 2010.

151. **WORKS** would then continue for an 18 month period, concluding with a period of commissioning tests.

Installation programme overview Brownhill Road – Pakuranga cable route

152. **THE** overall manufacture and installation process is anticipated to take 145 weeks (approximately 2 ¾ years) and is broken down into the following two major phases, that overlap:

(a) the Design and Procurement phase: 106 weeks; and

(b) enabling and cable installation: 136 weeks.

153. **IT** is difficult to provide a similar overall assessment for the manufacture and installation process for the Brownhill – Otahuhu circuits because such issues as manufacturing lead time for the cables will be dependant upon demand at the time contracts are placed.

CONSTRUCTION MANAGEMENT PLAN

154. **MITIGATION** of construction impacts will be achieved through a construction management plan. The construction management plan will be submitted to Auckland Regional Council and to the Manukau City Council prior to the commencement of any physical works.

155. **THE** design/build construction contract will include contractual requirements for the contractor to manage construction impacts.

156. **CONSTRUCTION** management plans will be required to be implemented by the contractor. It is anticipated that the construction management plan will address the following matters:

(a) Storage and reuse of top soil: Requiring the reuse of quality soil, where appropriate and to provide suitable stockpiling areas.

(b) On and off site disposal of spoil: Ensuring surplus spoil is disposed of at appropriate and approved facilities.

(c) Silt and dust control during site levelling and earthwork stages: Requiring the minimisation of dust on site to ensure there is no dust nuisance off-site as a result of the works. Such minimisation could include dampening down of bare areas in dry windy conditions.

(d) Stormwater/sediment-laden runoff: Ensuring that clean stormwater is directed away from bare or earthworked areas and that sediment laden runoff is properly controlled and managed to minimise any discharge of sediments into watercourses.

(e) Traffic management and property access management: Requiring notification to the Councils in writing at least two weeks before commencing works (including a separate notification for works commencing in Turanga Creek and Mangemangeroa Stream), and notifying the Councils that works have completed within two weeks of completion of the works.

(f) Access management: Requiring Transpower to provide 'as built' plans within one month after the completion of the underground cable works.

(g) Contaminated land management procedures: Ensuring that the Construction Management Plan includes acceptable measures for testing and removing any contaminated land along the route.

(h) Hours of operation: Restricting the hours of operation to:

(i) Monday to Friday: 7am to 6pm

(ii) Saturday: 8am to 1pm

(iii) Sundays and public holidays: No Work

Except in defined situations where after hours work is necessary or will have no impacts. The following are anticipated:

(i) Special circumstances, such as where work is planned to be carried out at low traffic times, for example, installation across busy roads. In these circumstances weekend work and night work may be necessary.

(ii) Delivery of the large cable drums.

(iii) Emergencies or contingencies that may require attention at any time. Some remedial work might be anticipated during or following heavy rain.

(iv) Locations where the nature of the work is low impact and there are no nearby residences. An example might be cable jointing in a commercial/ industrial environment.

(i) Existing network utilities protocols and guidelines: Ensuring liaison with existing utility providers with underground services within the route to ensure that the integrity of those services is not undermined.

(j) Cultural and archaeological protocols: Requiring the contractors to have a copy of the agreed discovery protocol on site at all times and that the contractors understand it.

(k) Land stability management: Ensuring that adequate measures are implemented so as to avoid land slope failure.

(l) Vegetation disturbance/removal: Requiring the removal of the minimum amount of vegetation necessary. Requiring tidy up of the area within one week of completing works in the area where vegetation was removed. Requiring the re-grassing of areas as soon as practicable after the completion of works through previously grassed areas.

(m) Management of construction activities: Ensuring that a copy of the consent conditions are to be kept on site at all times and that the contractors understand the consent conditions.

(n) Health and Safety: Ensuring that Health and Safety issues are addressed within the Construction Management Plan.

(o) Land stability management and water quality and sediment controls: Ensuring that clean stormwater is directed away from bare or earthworked areas and that sediment laden runoff is properly controlled and managed to as to minimise any discharge of sediments into watercourses.

(p) Construction noise: Compliance with New Zealand Standard 6803:1999 Acoustics – Construction Work.

(q) Community information and liaison: Requiring notification of works commencing and updating to parties adjacent to the route prior to commencement.

(r) Temporary activities and equipment storage in specified areas: Ensuring that temporary activities such as equipment storage are in suitably located areas (ie not within 20 metres of a watercourse).

(s) Contractor car parking in specified areas: Ensuring that contractor car parking is suitably located, so as to not prevent property access etc.

(t) Security and lighting during construction: Ensuring the site is secure and illuminated to restrict access as appropriate.

157. I consider that adoption of these measures will ensure that all adverse environmental effects associated with construction works will be appropriately addressed, and mitigated to an adequate standard. I anticipate that many of these requirements form the basis of conditions on the resource consents and designations (if confirmed), with the detail to be specified through the construction management plan. The contractor will be required to comply with all resource consent conditions relevant to the scope of work.

MAINTENANCE

158. **THE** following section sets out Transpower's maintenance, monitoring and emergency response regime that will be set in place once the cable is installed and in operation.

Patrols

159. **THE** cable route would be routinely patrolled at a frequency determined by Transpower. Initially patrols could be once a month or even more frequently if permanent reinstatement of road surfaces over the cable route is being carried out. The frequency could then be reduced to twice a year if it is known that no other utilities are planning works along the cable route. Cable patrols would look for evidence of construction work being undertaken in the vicinity of the cable, check for any deterioration of the ground surface over or near the cable trench, and replace any missing or worn cable route markers. Patrol personnel would record any construction projects likely to affect the cable and make sure that the person in charge is aware of the location of the electricity cable.

160. I have also been told that the designation, if confirmed by the Board, would require any other person to obtain Transpower's approval before it did any work in the designated area that would prevent or hinder the designated works. Patrol personnel would also make sure that the person in charge was aware of this requirement.

Standby

161. **WHERE** Transpower receives advice that an excavation is to take place in the vicinity of the proposed cable, a qualified person may be assigned to stand by while the excavation takes place. The standby person would have authority to issue directions to the excavator where this direction is necessary to ensure safety and the security of the cable.

Routine maintenance

162. **ROUTINE** maintenance along the cable route would be limited to ensuring accessibility of pits associated with link boxes and communication cables.

Every few years a maintenance team would ensure that pits can be found in the road, footpath, or park, that lids can be removed and resealed as intended, and that the pit is not full of water or tree roots. Future accessibility is one of the factors considered when siting joint bays in off-road areas.

163. **MAINTENANCE** crews would carry appropriate traffic warning devices when undertaking work at the roadside and set up barricades to restrict approaches by the public whenever link boxes are opened.

Routine testing

164. **THE** cable would undergo routine testing from time to time to give advance notice of any deterioration. The cable would be taken out of service periodically so that technicians could test the cable sheath bonding system. Failure of these tests gives advance warning that the outer serving of the cable has been breached and is an indicator that the cable may have been struck by others or otherwise deteriorated, which if left unrepaired could lead to a cable fault.

Emergency action

165. **EMERGENCY** action may be precipitated by a cable alarm, a poor result from a testing procedure, or an electrical fault. Such conditions could arise in the following ways:

(a) physical damage to the cable from an excavation, boring machine, or failure of another nearby service in the ground;

(b) ground movement around the cable, such as in poor soil conditions impacted by traffic or water;

(c) deterioration because of corrosive agents in the ground; or

(d) internal failure from manufacturing defect, deterioration of the cable or damage sustained by prolonged operation outside its normal temperature range.

166. **THE** response to an emergency condition would depend on the incident. Initially, further testing would be undertaken to determine the nature and location of the unusual condition. Where such testing reveals a fault, such as low sheath insulation resistance, the cable would have to be excavated at the nominated point and repairs carried out. If a section of cable has been damaged beyond repair, the damaged section would have to be cut out and a new section inserted. Consequently, repairs may require two new joint bays with work continuing for several weeks. In responding to an emergency situation, it is common for crews to work 24 hours per day.

ISSUES RAISED IN SUBMISSIONS

167. **A** number of submissions raise issues in relation to construction processes and management of cables. I discuss a representative selection of submissions below.

Issues raised by Camperdown Holdings Limited (Camperdown) (Submission No. 0842)

168. **CAMPERDOWN** raises issues in relation to cables and its subdivision development. Its submission relates to the NOR for the Underground cable from Pakuranga to Brownhill, and all ARC resource consent applications. Camperdown submits that it is unsure when it will undertake subdivision, and it is also doubtful that Transpower will be able to perform to the programme indicated given the overall scope of the project.

169. **TRANSPOWER** is currently in discussions with Camperdown's Property Agent, and is considering issues raised in relation to its proposed subdivision activity and the ability to accommodate those.

170. **CAMPERDOWN** also raises concerns about difficulties that may arise during cable construction (including silt generation, ground instability, and detrimental visual and farm operational issues) particularly when combined with the timing issues. I have addressed issues in relation to construction. I consider that Camperdown's concerns would be addressed through the Construction Management Plan.

Issues raised by R and J Carpenter (Submission No. 0717)

171. **THE** Carpenters raise issues in relation to their property. Their submission relates to the Manukau City Council NOR and the Auckland Regional Council land use consent (34711) and discharge consent (34712). The Carpenters seek that construction is limited to 8.00am to 6.00pm Monday to Friday only.

172. **AS** stated earlier in my evidence, wherever works are being undertaken at, or near, the surface of the ground in the vicinity of residential areas, normal construction working times are proposed to be as follows:[4]

Monday to Friday: 7am to 6pm
Saturday: 8am to 1pm
Sundays and public holidays: No work

173. **I** consider that these hours provide a reasonable compromise between the need to provide residents and/or commercial operations immediately adjacent to the construction works with a quiet enjoyment, while allowing the works to proceed efficiently and productively. I note that any condition that limits time available for construction could as a consequence extend the overall time to implement the project, as it may not be possible (because of site physical restrictions) to increase construction resources.

Issues raised by Housing New Zealand Corporation (HNZC) (Submission No. 1047)

174. **HNZC** raises issues in relation to construction processes. Its submission relates to all NORs and resource consent applications. HNZC submits that the environmental effects associated with the construction of the Upgrade Project will be the most significant effect on HNZC properties and tenants.

175. **HNZC** seeks that the actual and potential effects associated with construction be clarified and confirmed with specific reference to HNZC properties and tenants.

[4] Note that earlier in my evidence I discussed exceptions to these hours in limited circumstances.

176. I can confirm that all properties that front onto the streets where it is proposed to install the cable circuits have been provided with regular updates on project progress over the course of the last few years.

177. **FURTHER**, I understand that no part of either the Pakuranga – Brownhill or Brownhill – Otahuhu cable circuits cross any property owned by HZNC. Should any HNZC properties become so directly affected by the proposed cable works, which is considered unlikely, Transpower would contact and consult with HNZC.

178. I have outlined elsewhere in my evidence that a Construction Management Plan will be implemented that mitigate the effects that HNZC raises concerns about.

Issues raised by Manukau City Council (Submission No. 0861)

179. **MANUKAU** City Council raises issues in relation to construction processes and management of cables. Its submission relates to all NORs and resource consent applications.

180. I met with representatives of Manukau City Council, Chris Freke, Jade Wikaira and Steve Wren on 3 December 2007 to discuss their concerns relating to the cable circuits. The general principal they annunciated was to seek conditions/reliefs similar to those imposed and/or agreed by other utility operators who have previously sought designations. The National Gas Corporation (now Vector) was specifically mentioned by the Council Officers.

181. I consider that approach is generally fair and reasonable. However, the actual conditions proposed by MCC would need to be considered and assessed in relation to their relevance to the Upgrade Project and whether they were in fact reasonable or practicable.

182. **AT** paragraph (h), MCC seeks conditions to preserve its existing designations and proposed road improvements. I can confirm the general principal being adopted by Transpower is that, where plans have been provided for future upgrades, this information will be one criterion used for the detailed design of the cable circuits. However, should it transpire that in

the future known plans are modified or new ones developed that traverse the cable routes then we would expect Manukau City Council to similarly ensure that the presence of the cables is considered. Should MCC seek diversion of the Transpower cables, then I consider that it is fair and reasonable that the full cost for this work should not be borne by Transpower.

183. **AT** paragraph (i), MCC seeks assurances that the cable route along Whitford Park Road does not compromise a current designation for its future widening. I can confirm that the intention is to install the cables in the currently metalled road, (i.e. to leave the verges available for the widening works).

184. **AT** paragraph (j), MCC raises concerns about the impact of the works on the community, and impacts of construction traffic on roads. Mr Prince has responded to this submission. However, in addition, I consider that the request to provide detailed assessments on the impacts of construction traffic and to strengthen roads prior to construction and maintained during and after construction ceases for an unspecified period to be unreasonable.

185. **AT** paragraph (k), MCC expresses concern that the presence of the cables and designation does not adversely impact upon its powers as a road controlling authority, or unduly impact on the ability to provide utility services within the city. Given that the intention is to have 1.5 m of cover, measured from the top of the uppermost cable to the road service, I consider that once completed, the undertaking of the normal road management functions described will not be compromised. The only potential issue would be if any manhole covers are required to be installed within the carriageway. These manholes are, however, no different in scale to those already present in the road. I also note that one reason for locating the cable circuits within the road, both existing and planned, is to ensure space is available in the verge for services.

186. **AT** paragraph (o), MCC requests that the cable installation works do not interfere with the retaining wall ground anchor at Sandstone Road. I appreciate the concern, and have therefore separately requested as-built details of the retaining wall. These details have now been received. I have visited the site and consider that there is adequate road width available to

be able to ensure that the wall is not compromised by the cable installation activity. The as-built information provided by MCC will be incorporated in the overall tender documents, such that its presence can be considered during the design process.

187. **AT** paragraph (q), MCC raises concerns about the impact of the Pakuranga - Brownhill cable circuits and the future connections from Griggs Road where Caldwells Road joins it. I do not understand the comments because the cable circuits are not planned to be laid in Griggs Road. During discussions and after review of route plan for this vicinity the Council commented that their concern did not appear to be relevant.

188. I now address the specific relief requested by MCC:

(a) Relief paragraph 9: MCC seeks reasonable conditions or modifications to ensure that the proposed cable route does not compromise further proposed roading. I can confirm that Transpower does not object to this position in principle as long as the suggested conditions are similar to those imposed on other Utility Operators. However, as stated previously in my evidence there is one specific section of the currently unformed paper road that is very steep in places and I therefore consider it questionable that this would ever be formed because of the significant work required. This was discussed with Manukau City Council who acknowledged that the slope is severe. It was suggested that separate discussions be arranged to further investigate this issue. MCC further commented that in the event it was decided that a road was not be required the Council would probably wish to reserve the right to be able to construct some form of pedestrian type access track. Transpower believe that this would be a sensible compromise.

(b) Relief paragraph 13, bullet point 3: MCC is seeking a condition that Transpower will meet additional costs in respect of various process and maintenance, where these are specifically caused by the presence of the cables in roads. I consider that this request is unreasonable, due to being open ended, and in excess of that outlined in the Auckland Utility Group Code of Practice for Working in the Road. MCC is a member of this group. This code requires a 12 month maintenance period for the section of road where the cables are installed. Transpower will comply with this requirement by ensuring suitable contractual clauses are incorporated in the 'Design & Build' contract.

(c) Relief paragraph 13, bullet point 4: MCC is seeking an undertaking that Transpower will not use the terms of any designation granted to oppose any lane rental regime that may be imposed generally in the Manukau District. In the absence of any further details of the scheme envisaged. I cannot provide such an undertaking. I therefore consider this condition to be unacceptable. I also consider that the correct forum for coordinating discussions of this issue is the Auckland Utility Operators Group.

(d) Relief paragraph 13, bullet point 6: MCC requests clarification around the conditions to ensure that the designation does not unduly impact on their ability to undertake roading activity functions. I am unsure of what concerns they have in this regard. The presence of the cables is no different to other services presently buried within the roads of Manukau City.

(e) Relief paragraph 13, bullet point 8: MCC is seeking an assurance that liaison with all relevant utility operators will be undertaken during the detailed design and subsequent construction. In addition, MCC seeks that measures are taken to locate and protect existing utility services in, or adjacent to, the designated area. I consider that the conditions requested are reasonable.

Issues raised by Marie Morgan Trust Incorporated (Submission No. 0987)

189. **MARIE** Morgan Trust Incorporated raises issues in relation to construction processes. Its submission relates to the Underground Cable – Otahuhu to Brownhill NOR. It raises concerns about:

(a) the disruptive impact construction will have on residents; and

(b) the length of time residents will experience access difficulties.

190. I have checked our records and I can confirm that Transpower has corresponded with Marie Geraldine Morgan on 25 August 2005 (announcement of the Underground route) and 24 November 2005 informing her of the Final Underground Cable route. The letters were sent to 183 Jeffs Road, East Tamaki, Manukau (as her contact address) concerning property located at 189 Jeffs Road, Manukau City.

191. **THERE** will be an impact upon all residences fronting the cable route when work is undertaken. I would estimate that the residents in this area will suffer inconvenience for 6 – 8 weeks. However, earlier in my evidence I discussed potential mitigation measures to address such issues.

Issues raised by Telecom New Zealand Limited (Telecom) (Submission No. 1157)

192. **TELECOM** raises technical issues in relation to cables. Its submission relates to all NORs and resource consent applications. It raises concerns about the impacts on its infrastructure, customers and personnel.

193. I can confirm that Transpower engineers are aware of Telecom's concerns and will ensure the work is carried out in such a way that the risks referred to are minimised so far as is reasonably practicable.

194. **TRANSPOWER** and Telecom, as stated in their covering letter, are currently working towards a general Memorandum of Understanding which will resolve these issues and provide a framework within which similar projects and issues can be identified and addressed in the future.

Issues raised by Watercare Services Limited (Watercare) (Submission No. 0800)

195. **WATERCARE** raises issues in relation to construction processes and the management of cables, and the impact on its infrastructure. Its submission relates to four NORs in Manukau City (Pakuranga Substation, Otahuhu Substation, Underground cable from Pakuranga to Brownhill, and Underground cable from Otahuhu to Brownhill) and the ARC resource

consent applications for the Pakuranga to Brownhill Underground Cable (applications 34102, 34370, 34372 and 34373).

196. I can confirm that contact has been made with Watercare and further discussions are planned.

197. I can further confirm that Transpower shares Watercare's concern that the proposed underground cables do not adversely affect the operation and maintenance of their existing physical below ground infrastructure resources.

198. **WATERCARE** requests that Transpower submit to MCC for its approval detailed construction and contingency plans for any crossing of Watercare's infrastructure prior to commencement of those works by the proposed cable circuits. I consider that it is a reasonable for Transpower to liaise with Watercare about its construction and contingency plans.

199. **WATERCARE** wishes that Transpower, as consent holder, enters into an arrangement with Watercare for existing and future pipes. As stated in my evidence earlier contact, has been made with Watercare and it intended to meet next month to discuss the issues raised. However, I would like to state that I do not believe it is reasonable for Transpower to take account of development works that are not known to us.

200. I also would expect that any arrangement would include a condition similar to those Watercare require, such as the requirement for them to seek approval from Transpower before undertaking works within 10 metres or the same streets where our cables are buried.

Issues raised by Vector Limited (Vector) (Submission No. 0863)

201. **VECTOR'S** submission relates to all NORs and applications for resource consents. Vector supports the Upgrade Project as a whole. However, it opposes the NORs for the underground cable routes, and raises concerns about its gas and electricity infrastructure located within the underground cable routes.

202. I can confirm that contact has been made with Vector and further discussions are planned.

203. I can further confirm that Vector and Transpower's interests in the long term protection of their respective assets is very much in alignment; Transpower's objectives in gaining its designation are similar to Vector's in wishing to manage development by others around its planned cable assets.

204. **VECTOR** wishes that conditions be imposed on Transpower, that the planned works do not impact adversely on Vectors existing and future gas pipes and electricity asset. As stated in my evidence earlier, contact has been made with Vector and it intended to meet to discuss the issues raised.

Issues raised by Dr Laura Bennet and Mr Adrian Kinsler (Submission No. 1085 and 1091)

205. **DR** Bennet and Mr Kinsler make separate but identical submissions. Their submissions relate to all NORs and resource consent applications. They submit that Transpower has stated that undergrounding is not only more expensive, but makes it technically challenging to maintain power lines. They submit that:

(a) this technical challenge is clearly not a limiting factor in placing lines underground north of the city and in other areas of the city;

(b) while the standard methodology of placing cables 1 m underground in cut and shut trenches does make it difficult to maintain lines and detect faults, this problem is managed by other power and phone utility companies who are required to underground services to new subdivisions in order to reduce the visual impact of overhead lines; and

(c) consistent with overseas practice, there are alternative strategies to address the issue of undergrounding, for example, larger, more accessible service tunnels which run alongside motorways or in other designated public utility corridors. Such tunnels can be sufficient to add new lines, and to offset costs by renting space to other service providers, such as telecommunication companies.

206. **AS** stated earlier in my evidence, I have personally been involved with the installation of cable circuits that are in excess of those for which designations are currently being sought.

207. **IN** my view, it is not reasonable to compare the 220kV cable circuits with those used to service subdivisions. The power transfer is many magnitudes greater. However, the process and strategies I have described in my opinion do mean that, upon commissioning, the 220kV cable section of the circuits will prove to be extremely reliable.

208. **THE** use of common service tunnel that Dr Bennet and Mr Kinsler described are indeed used by other utility operators elsewhere in the world. However, personally I have no experience of installing cables in shared structures of this sort. Nor are there any such tunnels along the route that could be used.

CONCLUSIONS

209. I would therefore conclude that:

(a) The proposed underground cable installation works whilst being the first project of this size to be undertaken in New Zealand are not unusual when viewed in the international context.

(b) That Transpower will be adopting best international practices, is intending to employ competent global contractors who have extensive experience of installing similar or indeed larger cable circuits elsewhere in the world.

(c) That the comprehensive set of mitigation measures proposed are incorporated in Management Plans to ensure that through sound construction practices disturbance is minimised to road users, local residents and businesses.

(d) Whilst some limited sections of the proposed underground cables component of the Upgrade Project are located in undeveloped land the greater majority is predominately lies within public roadways and other reserve land, which minimises the disruption to private property. Work of this nature, being similar to that undertaken by other utility operators on a regular basis can be considered by no means out of character within the urban environment.

Richard Edward Joyce
1 February 2008

Appendix 1: Cable Consulting International Report Number ER248 Arapuni – Pakuranga Cable Tunnel, 24 September 2006

This report identified the following issues and concerns:

(a) Suitability of jointing chambers: The current jointing chambers are considered too small to accommodate six joints, and it was therefore recommend that the length of each chamber should be at least doubled. This will require significant excavation and may be difficult to achieve at two of the current locations.

(b) Cable repairs: In the event that a fault did occur there is insufficient room in the main tunnel bore for a repair joint (or more likely two repair joints between a piece-in length of cable) to be inserted:

(i) Cable jointing is a long and highly skilled process and it is essential that the jointer is given the right conditions in which to work. Allowing for the need for a clean enclosed area, humidity control and temperature control during jointing, the jointer would almost certainly have to work hunched over and would not be able to stand upright.

(ii) If the adjacent circuit is live whilst a repair is being made, complex induced voltage working procedures will need to be followed.

(iii) A repair joint and the steelwork necessary to support it would protrude out into the central walkway and partially block it.

Transpower would therefore have to accept that, in the event of a cable failure, the complete length of damaged cable would have to be removed and a replacement length installed.

Regardless, it is believed that magnetic fields will be in excess of 500 μT, this being the present occupational exposure limit, within the tunnel. Hence, the second circuit would have to be turned off before any work on the adjacent could be performed.

(c) Personnel Safety: A set of detailed tunnel safety procedures for cable system installation will have to be written and some of the key issues are given below:

(i) Personnel access and egress: Installation will be labour intensive with limited scope for mechanical assistance. A particular concern being the difficulties of installing the second circuit when the available space has been reduced because of the presence of the first.

(ii) Safety training must be provided to all personnel.

(iii) Control and logging of personnel entering and leaving the tunnel is essential.

(iv) An emergency evacuation procedure must be established, again the presence of the first circuit could severely impair movement of staff during an urgent situation.

(v) Additional tunnel personnel protective equipment (**PPE**), such as gas detectors and 10-minute emergency breathing apparatus must be supplied and used on top of the usual standard PPE requirements.

(vi) Assessments of all substances to be used in the tunnel must be performed taking due account of the situations in which they are to be used.

(vii) Manual handling: Manual handling procedures that take full account of working in a restricted space, which will be made more difficult after the first circuit has been installed.

(d) Current International Practice: In Europe, major cable tunnels have been constructed in Germany, Spain and the UK. Examples outside of Europe are in Saudi Arabia and Singapore. At voltages above 200kV, most tunnels are designed to accommodate two circuits and typically have internal diameters of 3 metres or more, i.e. considerably larger than is the situation here. Some tunnels are rectangular in cross section rather than circular as this geometry is more accommodating for cable circuits.

Appendix 2: Design & Build Contract Scope of work

The scope of works includes all work, other plant, equipment and materials required to design, manufacture, test, deliver to site, joint and the installation of the cable circuits. This includes but is not limited to the following:

a) Survey of cable route to determine the following:
   - All information required on ground conditions for design of the cable circuits. This shall include but is not limited to moisture content, water table level and soil thermal resistivity tests
   - The exact location of existing buried utilities or infrastructure that could affect the design, construction and installation of the cable circuits.
   - All information required on above ground conditions e.g. road traffic that could effect the design, construction and installation of the cable circuits.
   - Actual required cable lengths.

b) The determination of the size and construction of XLPE cable together with sheath bonding arrangements and laying conditions to meet the specified continuous, cyclic, emergency and fault current ratings.

c) The design of cable installation arrangements and requirements for cable joints and terminations to meet magnetic field, thermal, thermo-mechanical, electro-mechanical force and seismic requirements.

d) The design of earthing arrangements to ensure earth potential rise (EPR) together with step and touch voltages at joint and termination positions are kept to safe levels under fault conditions.

e) The design of arrangements to minimise induced voltages in metal pipes, other cables and metal structures due to cable load and fault currents.

f) Design and installation of the complete cable system to meet the specified reliability requirements and to facilitate maintenance and repairs and minimise outage time. This includes all cable supporting structures.

g) The provision of a Design Report for the review and approval of the Engineer covering the above design of the cable system.

h) Provision of full specifications for laying of cables for the review and approval of the Engineer. This includes for direct buried cables, performance requirements for and dimensions of thermally stabilised backfill and the location of cables within it.

i) Supply and delivery to site of the following:
   - Cable, joints, terminations and all other equipment that will form part of the cable circuits. This includes support stands for outdoor sealing ends.
   - Cable temperature monitoring system
   - Set of Transpower specified spares
   - Set of other recommended spares
   - Set of special tools, test equipment and instruments required for installation, and site acceptance tests

j) All civil works required for installation of the cable circuits including foundation pads for outdoor sealing ends.

k) Cable laying and final positioning of cables including installation of cable supports, cable cleats and other fastenings. This includes backfilling of direct buried cables and reinstatement of ground cover.

l) All jointing work required including sheath bonding and connections to link boxes, earthing points and DTS cable.

m) Pre-commissioning and acceptance tests of the installed cables, earthing and bonding system and temperature measurement system.

n) Supply of 'as built' route records

o) Supply of Operation and Maintenance Manuals including factory test reports for cables, accessories, special tools and instruments.
p) Liaison with the Engineer and others carrying out the cable laying work.
q) Technical support and engineering advice as required.
r) Liaison with members of the public and local authorities.