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27 October 2017

Attention: Ray Hardy
Wellington Electricity Lines Limited
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Petone
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Subject: Independent Review of WELL Earthquake Readiness Business Case

Introduction

Wellington Electricity Lines Limited (WELL) is submitting a streamlined customised price path (CPP) proposal to undertake earthquake readiness investments. This will require additional capital expenditure of $30.07m and operating expenditure of $1.17m over the next three years to improve its ability to respond to a major earthquake. The proposed investments relate to the quick wins it can achieve in the short term to help reduce the impact of a major earthquake.

WELL engaged Jacobs NZ Ltd (Jacobs) to undertake an independent engineering review of the earthquake readiness Business Case and supporting material that WELL will be including in its CPP application. The scope included the following:

- Reviewing the engineering options analysis and selection process used by WELL;
- Commenting on the prudency of the preferred options;
- Reviewing the preferred option's costings and cost benefit analysis (CBA); and
- A review of WELL's approach and the costs associated with its seismic reinforcement programme.

The review process has involved significant interaction between Jacobs and WELL, and during the review Jacobs was supplied with the following material in order to undertake its review:

- A draft Business Case document;
- Supporting option costing and CBA spreadsheets;
- Substation earthquake risk assessments;
- Restoration time analyses;
- Supporting evidence of equipment pricing from various suppliers;
- An overview of the actions WELL undertook to address Jacobs' feedback; and
- An updated Business Case that incorporated Jacobs' recommendations.

Where there was uncertainty Jacobs has sought additional information from WELL to justify key assumptions around costings, ability to transport equipment into the area post-earthquake and to clarify inconsistencies in the document and supporting information. Jacobs found a number of non-material errors in WELL's documents that resulted in changes to some of the original costings and cost benefit analyses. An issues list was maintained to track key Jacobs feedback and recommendations so that WELL could make corrections and where necessary provide further clarification or justification in its final Business Case.

The contents of this letter outlines Jacobs' review of the options that WELL is proposing in order to mitigate five key risk areas associated with a major earthquake.

Summary Findings/Recommendations

The table below outlines Jacobs key findings in relation to the Business Case developed by WELL. Additional details of Jacobs review are in the attached Appendix.

Risk Area	Preferred Options	Proposed Expenditure	Key Findings and Recommendations
33kV Cable Damage	Temporary overhead line spares (19km) Spare 33kV cable joints	$4.66m capex $0.67m opex	· The options chosen by WELL build off the learnings from Orion's temporary overhead lines built after the Christchurch earthquake. · The cost estimates are well supported by preliminary designs and supplier quotes. · However, the pole/line foundation costs are a significant component of the overall cost and subject to final pricing. · The CBA approach has correctly excluded the cost / benefits of lines that are included in the substation options below. · Jacobs found some errors in the initial CBA which WELL has resolved. The changes did not change WELL's preferred options. · The preferred options chosen would provide a significant economic and social benefit by reducing the length of outages from 33kV cable faults by several weeks compared to the status quo (do nothing) option.
Zone substation Damage	Mobile 10MVA substations in: - Hutt Valley - CBD	$4.73m capex $0 opex in first 3 years (~$50k post year 3)	· The cost estimates are supported by supplier quotes or from publicly available information. · The CBAs were robust; however, the net benefits were not as significant as the line options above. · The CBAs may improve if the line/pole foundation costs are reduced (as noted above). · The capex can potentially be reduced by $136k by using the same design for both mobile substations. · The flexible use of mobile substations for "*business as usual*" strengthens the economics associated with mobile substations. However, their movement should be carefully considered (i.e. to low seismic risk locations).
11kV Cable and Distribution Equipment Damage	1018 spare 11kV cable joints and 11kV cable Spare 11kV transformers / RMUs	$4.94m capex $0 opex	· Jacobs agree with the concept of storing spare 11kV cable joints to reduce joint supply delays. · Jacobs questioned whether it would possible to transport (relatively small / light) joints via helicopter or boat to the Hutt within 5-6 weeks thus reducing the spares by 40-50% ($1-1.3m). WELL indicated that there is doubt that this would be possible and is having ongoing discussions with Wellington Lifelines. · Overall the cost estimates associated with the option are robust and the CBA is likely to be conservative.
Buildings	Seismic strengthening	$10.4m capex	· The approach taken by WELL is a pragmatic estimate of the risks and consequences of potential earthquake damage to substation buildings. · Jacobs recommended reviewing Transpower's seismic policy and design standard for relevance. · Jacobs recommended including a provisional sum for strengthening foundations to mitigate ground failure risks under new regulations. WELL increased its capex estimates to include Detailed Seismic Assessments

Risk Area	Preferred Options	Proposed Expenditure	Key Findings and Recommendations
			(DSA) of its buildings – however did not add funding for additional strengthening. · In Jacobs view, Transpower's policy addresses geotechnical hazards including liquefaction and provides specific performance criteria. If WELL intend to adopt Transpower's policies and/or achieve the appropriate Importance Level standards and Building Consent for the strengthening works, there is a risk there will be insufficient funding to meet the full strengthening aspirations in the Business Case. · Jacobs are not in a position to judge the criticality of the structures chosen for seismic strengthening. · While no CBA has been undertaken, the ratio of avoided repair costs by upfront strengthening of buildings based on Orion's experience is in the order of 5 to 8 times · Additionally, this will ensure that workers can safely access equipment to expedite the restoration of power, resulting in reduced restoration times.
Communication Links	3 Separate Data / Control Centres Upgraded Radio system New phone exchanges	$5.26m capex $0.50m opex (in 3 years)	· Jacobs questioned WELL on the necessity of having three standalone control room / data centres. · Jacobs understands that the magnitude 7.5 earthquake scenario would likely result in the physical isolation of three key areas of WELL's network and the loss of communication between them. · Therefore, in order to maximise its ability to safely restore load in all three areas, Jacobs is satisfied that three centres would reduce restoration times. · A review of WELL's initial costs found potential savings of around $500k capex and phasing of costs has reduced total opex by $550k. · Jacobs is comfortable that the cost breakdown for each of the communication components is robust but is not in a position to comment on whether all the equipment is required. However, we note that the specifications have been determined by independent specialist providers. · While no CBA has been undertaken Jacobs agree that a functional communications and network information control/data centre is a key enabler that is necessary to achieve the benefits of the restoration options discussed above.

General Findings/Recommendations
· WELL's risk assessment is based on a magnitude 7.5 event on the Wellington Fault. Given the existence of numerous other fault lines this approach has some limitations, but Jacobs is of the view that the methodology used is pragmatic · WELL has used, in its analysis, a 300 year return period for a magnitude 7.5 event. The return period is based on the cumulative probability of occurrence of the five regional fault lines. Jacobs is of the view that the assumption is reasonable and we note that that WELL has also used sensitivity analyses to test the viability of the options against different return periods. · Given the timeframes associated with design and procurement of some of its preferred options (i.e. mobile substations, data centres etc.), and based on discussions with Jacobs, WELL updated its Business Case to phase capital expenditure over FY18 to FY21. This change also impacted on the operating expenditure of the Business Case.

Confirmation of Independence and Qualifications

I, as a chartered professional engineer (as defined in Section 6 of the Chartered Professional Engineers Act 2002), can confirm that:

1) Jacobs has acted independently with respect to WELL and its subsidiaries and affiliates;

2) The scope of Jacobs' services is outlined in WELL Short Form Agreement for Consultant Engagement dated 26th September 2017;

3) Jacobs has significant experience in New Zealand, Australia and the United Kingdom in relation to the design, planning, management and valuation of electricity networks. Jacobs' review and preparation of the report has been undertaken by Dr Richard Fairbairn, Mr Peter Apperley, Mr Jose Lopez-Roldan, Mr Arno Percival and Mr Jerry Spinks. Dr Fairbairn is a professional qualified engineer and a Chartered Professional Engineer in NZ (CPEng). Messrs Apperley, Percival, Spinks and Lopez-Rolden are professionally qualified and experienced in the type of work concerned and are familiar with the WELL distribution network;

SIGNED on behalf of Jacobs New Zealand Ltd by:

Designated Engineer	**Principal Engineer**
R. Fairbairn, MIPENZ, CPEng	**P. Apperley, MIET**

Appendix – Detailed Review

1. Supporting Assumptions

1.1 Value of Lost Load

WELL has utilised the Electricity Authority's definition of the value of any expected unserved energy of $20,000 from the 2010 Electricity Industry Participation Code (originally set in 2004). This has been escalated to 2017 dollars by WELL utilising the average Consumer Price Index (CPI) of 2.7% per annum to establish a figure of $28,278/MWh for the value of unserved energy.

> The value of unserved energy used by WELL is reasonable, especially given the criticality of electricity supply for health, safety and personal security following a major disaster.

1.2 Risk Assessment

WELL's estimate that a total load of ≈90MW is potentially at risk (i.e. 20% of WELL's 2017 disclosed peak load of 523MW). The methodology used considers the following factors:

- Those substations that have high or medium risk of damage (due to their associated seismic risk). Low risk substations are excluded.
- The average electrical load supplied by individual substations.
- The extent of the 11kV back-feed that is available to substations.
- Both 33kV and 11kV equipment failures.

> Jacobs is of the view that the risk assessment methodology employed by WELL and the final total value of load at risk is reasonable. This is substantiated by Orion's experience during the Christchurch earthquakes that resulted in damage to 50% of its 66kV underground cables. WELL's sub-transmission supply network is mostly via underground 33kV cable Jacobs expect these cables to experience significant damage.

WELL has estimated consumer restoration times based on the following:

- Its view of typical equipment repair times.
- Overhead line construction times.
- Significant delays transporting equipment to site, which are based on documents published by Wellington Lifelines that indicate equipment transport delays of up to four months could be possible. WELL has applied a range of transport delays and applied >3 weeks of transport delay to six zone substations (≈20% of 27 substations).

> Jacobs is of the view that the equipment repair times, overhead construction times and delay assumptions utilised by WELL in its analysis are reasonable. The analysis is substantiated by the Christchurch earthquake during which it took Orion ≈10 days to restore power to ≈90% of consumers. Jacobs expects the restoration of WELL's network will be significantly more challenging given the rugged terrain coupled with the expected islanding of the different regions.

1.3 Cost Benefit Analyses

All Cost Benefit Analyses (CBA) have been based on a 1 in 300-year event (i.e. a 0.33% chance of occurrence in any year) so any reduction in unserved load (in MWh) is multiplied by the VOLL x 0.0033 and modelled in each of the 20 years in the CBA models.

WELL has utilised a weighted average cost of capital of 7.19% and a life of 20 years in its economic models.

Jacobs is of the view that WELL has used an appropriate probability-weighted methodology to value the potential benefits in its cost benefit analysis (CBA) model. Jacobs agree that the WACC and term of 20 years is appropriate.

2. Options Assessment

2.1 33kV Cable Failure

WELL has identified that its fluid filled (oil and gas) 33kV cables are at significant risk from a major earthquake that would impact up to 29,000 customers and it could take considerable time to locate and repair underground faults. WELL note that after the 2011 Christchurch earthquake, Orion built two emergency overhead sub-transmission lines to supply the most seriously affected areas of their network.

2.1.1 Potential Options

WELL has provided four options in their Business Case:

1. Option 1 - Current State (do nothing).
2. Option 2 – Carry overhead line spares for vulnerable routes (total of 19.3 km).
3. Option 3 – Replace all fluid filled 33kV cable with XLPE cable in the near term (instead of the current asset management plan of replacing these cables over decades).
4. Option 4 - Carry 33 kV XLPE cable spares including jointing kits for Wilton-Moore St 33kV cables.

2.1.2 Equipment Costings

For Option 2, WELL has developed bottom up estimates of the equipment quantities based on determining a preliminary overhead route length between the effected zone substations. These preliminary line routes and emergency pole structure designs were developed by Linetech Consulting, an experienced overhead line designer. The temporary pole structures are supported by a number of heavy or light base foundations which are held down by concrete support blocks. The quantities of these are dependent on the number of dead-end and strain poles vs standard poles on each route.

Jacobs has reviewed the preliminary emergency line route plan and a detailed construction schedule for the Evans Bay – Ira St route against the cost estimate and have confirmed that the quantities and assumptions in the cost spreadsheet are consistent with the plan and schedule.

The cost of each option is supported by an internal schedule of the costs of each component of the required elements to build the emergency overhead circuits. The cost of the poles has been based on a supplier quote for the various pole sizes and fitting and this has been correctly transcribed into the cost build up. The costs for the remaining pole hardware and overhead conductor is based on an external contractor quote.

In addition to this WELL has received high level cost estimate ranges from a supplier for large and small portable pole foundations. While the manufacturer has indicated that there would be benefits in buying these in bulk batches, WELL has conservatively utilised the top end of these cost estimate ranges. Jacobs considers this as a reasonable assumption as the manufacturer indicated that field trials of these foundations were still to be undertaken, which could result in further changes in the design and cost. Jacobs understands that the field trials have now been undertaken, but revised cost estimates have yet to be obtained from the supplier.

A total capital cost of $160k has been included in the breakdown for two 10 x 15m storage units for the Evans Bay/Ira Street and Plimmerton/Mana line equipment in addition to the opex costs discussed below. WELL provided a supporting internal memo from 2014 outlining a range of storage options that WELL was considering at the time. This included the options for small and large storage units which has served as the source of the $80k per storage unit cost estimate.

Opex costs for the equipment discussed above are based on annual leases for various storage locations around the Wellington region, ranging from ~$30k for containerised storage to $110k for a sublease / management of a storage unit in Taita.

Option 2A is based on the cost of 2 x oil and 2 x gas stop joints, and a 600m 33kV cable drum. These are relatively expensive items compared to XLPE cable and joints, as they are no longer used in modern 33kV cable installations.

Option 3 has been based on WELL's asset management plan assumptions of 106km of fluid filled cable to be replaced at an estimated rate of $1.5m per circuit per km. This figure is very high level and could be +/- 50%. However, further accuracy on this is not warranted due to its ranking in WELLs CBA that is discussed below.

Option 4 is based on supplier pricing for 33kV XLPE cable joints and cable.

WELL has used "bottom up" preliminary line designs to arrive at its cost estimates for the Emergency 33kV Hardware and Jacobs is of the view the costs are reasonable. However, Jacobs note that the cost estimate for the pole foundations is a significant component of the overall cost and is subject to a final quote, which may change the capex required for this option.

2.1.3 Cost Benefit Analysis (CBA)

In undertaking the CBA, WELL note that the benefits associated with the spares for three of the emergency lines (Gracefield-Korokoro, Central Park-Evans Bay and Evans Bay-Ira St) are interlinked with substation options so the costs for these are included in the CBA for these substations and the restoration benefits for these combined options are based on the longest restoration time of the two.

Jacobs found that the way Option 1 was originally calculated was inconsistent with the other analyses and could create confusion for the reader. WELL had calculated the NPV cost of total unserved load due to the longer repair times expected to get equipment from outside of Wellington into the various areas of damage. The NPV of the total estimated unserved load based on a 1 in 300-year event in this scenario is $ 36.1 million. This NPV cost analysis has now been removed from the Business Case and the subsequent options have been presented in Table 11 of WELL's Business Case (based on the value of avoided unserved load resulting from a reduction in restoration time), and should be interpreted as NPV improvements on the Current State option.

Note no costs for replacement equipment and labour for repair were modelled in this analysis as this will be common for all scenarios. Options 2 to 4 are for the most part temporary fixes which enable load to be restored faster until the replacement cable equipment can be brought into the region and the damaged cabling replaced.

Option 2 provides a restoration improvement of 1 to 12 weeks depending on the line route and provides a net benefit of $18.47m. An Option 2A variant looks at an alternative of carrying 33kV fluid filled cable spares and jointing kits for the Brown Owl-Maidstone cables rather than overhead line spares for this route. This option would be ~$1m less expensive, however only results in a 7-week restoration improvement for these customers and a corresponding $12.76m net benefit.

In reviewing the above, Jacobs initially found an error in the total costs for Option 2A that had been utilised in the CBA for this option. However, even with the error corrected, the resulting net benefit did not change the option's precedence against Option 2.

Option 3 results in the highest reduction in unserved load, but is the least economic at -$258.4m given the high upfront costs and the risk weighting from the 1 in 300 year return period reducing the net present value of the benefits.

Option 4 is a standalone option (i.e. not mutually exclusive to Option 2) and provides a net benefit of $1.56m for a relatively modest outlay of $80k.

In the second draft of the Business Case supplied to Jacobs, WELL included a sensitivity analyses of the options for shorter and longer return periods (150 and 400 years respectively) and value of unserved load ($15,000 and $45,000/MWh respectively). Under all sensitivities the order of options remained the same, and Options 2, 2a and 4 continued to have a positive net benefit.

Jacobs found some errors in WELL's initial cost benefit analysis (CBA) calculations. However, they did not materially affect WELL's Business Case. Jacobs considers the base case CBA and the sensitivity analyses undertaken to be robust and we note that WELL has been careful not to double-count the benefits associated with the different options.

2.1.4 Preferred Options

The preferred options to address the risk of 33 kV cable damage are:

- Option 2 - carry sufficient spares to construct around 19 km of emergency overhead line and
- Option 4 - carry sufficient XLPE cable spares to repair damaged cable in the CBD

The total Capex of both options combined is $4.74 m and the total net benefit is $20.03m relative to the Current State option.

Jacobs agree that it would be prudent to purchase the additional overhead line and underground cable spares to accelerate the restoration of load lost from 33kV cable damage in the event of a major earthquake.

2.2 Zone Substation Damage

2.2.1 Key Risks

WELL has identified 5 substations that are at the highest risk of being damaged in a major earthquake resulting in the possible loss of transformers and switchgear. This could result in the loss of supply to over 8,000 customers for between 4 and 16 weeks.

In the Hutt Valley the key assumption is that the transformers and 11kV switchboard at Korokoro will be lost as well as the 11kV switchboard at Petone. Options 2 to 4 below provide alternative options to restore the loads at these two substations and are mutually exclusive. It is also expected that the transformers at Seaview would be lost. However, WELL's emergency plan would be to move an existing transformer from Waterloo to re-establish supply. This could be done in 8 weeks and requires no further upfront investment.

In the Porirua area, the key assumption is that the transformers at Mana would be lost. The emergency plan for this involves a temporary 33kV overhead line and operating it at 11kV should this occur. This option is covered in Section 2.1 above.

In the CBD, the key assumption is that the transformers and 11kV switchboard at Evans Bay will be lost, and there would be flow on supply loss to Ira Street due to Evans Bay damage. Options 5 and 6 below have been identified to provide alternative supply restoration options at these two substations and are also mutually exclusive.

2.2.2 Potential Options

There were six options analysed in the WELL Business Case:

1. Option 1 - Current state - Do nothing
2. Option 2 - 1 new spare 20MVA 33/11kV zone transformer and two mobile 11kV switchboards in Lower Hutt (and requires 33kV overhead line from Gracefield to Korokoro)
3. Option 3 - Mobile substation and one portable 11kV switchboard in Lower Hutt (and requires 33kV overhead line from Gracefield to Korokoro)
4. Option 4 - Refurbish & relocate the 20MVA Petone spare transformer, two portable 11kV switchboards in Lower Hutt (and requires 33kV overhead line from Gracefield to Korokoro)
5. Option 5 - New spare 20MVA 33/11kV zone transformer and portable 11kV switchboard in CBD (and requires 33kV overhead lines between Central Park to Evans Bay to Ira St)
6. Option 6 - Mobile substation located in Palm Grove (and requires 33kV overhead lines between Central Park to Evans Bay to Ira St)

Jacobs questioned the discrepancy between the 20MVA transformer sizing of Options 1, 4 and 5 relative to the 10MVA mobile substation Options for 3 and 6. WELL revised the report to note that the transformer options would ultimately become the permanent transformer in the substation location where they were moved to post-earthquake and would need to be of sufficient size for the future peak loads at that site. Whereas the portable substation transformer needs to be sized to be mobile and is providing a temporary solution until a permanent transformer can be sourced and installed. Jacobs agree that this is a sensible and cost effective approach.

2.2.3 Equipment Costings

The cost of each option has been determined by WELL as follows:

- Option 2 - The transformer cost estimate is based on a recent quote for 33kV/11kV, 20 MVA, OLTC transformer from Australia, allowing for the exchange rate.

- Options 3 and 6 - The mobile substation costing has been based on the $1.5m cost of a South Island Electricity Distribution Business' (EDB) 10 MVA mobile substation that was purchased in 2013/14. This has been increased to $1.7m accounting for inflation. For Option 6 an additional capex allowance of $150k has been made for a storage site in the CBD for the mobile substation.
- Options 3, 4 and 5 - The mobile 11kV switchboard has been based on recent quotes for a containerised switchboard and a side-loader trailer.
- Connecting 33kV and 11kV cabling, joints and terminations have been determined for each option by WELL and equipment costs taken from supplier quotes.
- Option 4 - Refurbishment of the spare Petone transformer, transportation and reinstallation at temporary location has been estimated at $416k. Jacobs challenged the associated civil and installation costs until subsequent discussion with WELL confirmed that the transformer would be located at a low risk site where it could be livened (rather than being stored / mothballed). This is a prudent approach as it would ensure that the transformer is operational when called on to be moved to a damaged zone substation site.

Operating costs for each of the options are based on annual testing of the equipment, and ~$30k p.a. has been allowed for storage of a spare transformer / mobile switchboard in the CBD (Option 5). Following the initial Business Case draft and feedback from Jacobs, WELL phased the capital costs over FY18-FY21, which also resulted in a delay of some of the operating costs in the forecast outside of the three-year window.

Jacobs found some discrepancies relating to the civil and installation costs of options considered (i.e. Options 2 and 4), but on balance concluded that the cost estimates are well supported and reasonable.

2.2.4 Cost Benefit Analysis

In undertaking the CBA, the costs and benefits associated with 3 of the emergency lines spares (Gracefield-Korokoro, Central Park-Evans Bay and Evans Bay-Ira St) have been included in the related substation options above.

As per that in Section 2.1, the Current State is the base line option estimated to have a net present value cost of unserved energy of $34.86 million, and again, to avoid confusion, WELL has removed this from its NPV comparisons (i.e. Table 13 of the Business Case).

Options 2 – 4 all relate to restoring load at Korokoro substation so are mutually exclusive options. All are dependent on a temporary 33kV overhead line between Gracefield and Korokoro to obtain the maximum improvement in restoration time of 12 weeks. WELL has determined that the load at Korokoro can be restored 12 weeks faster under Option 3, vs 10 weeks for Options 2 and 4 due to the additional time it takes to move and connect a transformer for these two options.

Of these three options, only Option 3 has a marginally positive NPV at $0.4m, whereas Options 2 and 4 have marginally negative NPVs at -$0.48m and -$0.03m respectively. Under the sensitivity analysis on return periods and value of unserved energy, the priority order of the options remains the same – however under a longer return period (1-in-400 years) or low value of unserved load ($15,000/MWh), all three options are uneconomic.

Options 5 and 6 relate to restoring load to Evans Bay and Ira Street substations in the CBD and are also mutually exclusive. Both are dependent on the temporary CBD 33kV overhead line options to achieve an overall 4 to 6-week improvement in restoration time. The NPVs for these options are both positive at $2.39m and $2.31m respectively, with the spare transformer (Option 5) providing the highest net benefit. In the sensitivity analyses, the priority orders stay the same (but still only within $70k difference). However, only under the low value of unserved energy scenario are the NPVs negative.

Jacobs noted that WELL has not included any potential economic benefits associated with using the mobile substations in the day to day operation of its network. These benefits would bolster the mobile substation business cases.

The net benefits for the mitigation of Zone Substation Damage in the Hutt Valley do not appear to be as clear cut as that for the 33kV Cable Failure (i.e. temporary 33kV line options). However, on balance, Jacobs considers the base case CBA and sensitivity analyses undertaken on the options to be robust and WELL has been careful to ensure that benefits were not double-counted.

As noted in Section 2.1.2, WELL's cost estimates for pole foundations are conservative and could improve with a supplier quote, which would also marginally improve the net benefit of all the substation options above.

2.2.5 Preferred Options

WELL's preferred option is a combination of Option 3 (mobile substation and mobile 11kV switchboard to be located in Lower Hutt) and Option 6 (mobile substation located in the CBD). In the case of Option 6 this was not the highest net benefit option – however the NPV difference between Option 5 and 6 was in the order of $70k. Once the benefits of potential BAU usage of the mobile substation is taken into account, it is expected that this would be the economically preferable option.

This would result in a total capital expenditure of $4.73 million over three years and annual operating costs of ~$50k per annum which would be incurred after the three-year period.

Jacobs agree that it would be prudent for WELL to have access to mobile substations in order to accelerate the restoration of load lost due to Zone Substation Damage in the event of a major earthquake.

Jacobs expect that there will be "economies of scale" in the event that WELL purchases two mobile substations. Particularly with respect to the design costs, which could reduce the mobile substation costs by as much as $136k.

Using the mobile substations and switchboard during "business as usual" should provide WELL with additional economic benefits (i.e. temporary restoration of load following major equipment faults). However, WELL would need to be careful to monitor this activity and ensure that the equipment is not temporarily located in a high earthquake risk zone.

2.3 11kV Cable and Distribution Equipment Damage

Based on Orion's experience from the Christchurch earthquake and its own experience following the 2016 Kaikoura earthquake, WELL expects that a main cause of outages within its network after a major earthquake will be cable faults in the 11 kV distribution network. WELL estimate that damage to 11kV cables will be extensive especially in potential areas of high liquefaction such as the reclaimed land in the Wellington CBD.

WELL has estimated up to 19,000 customer connections could be affected by loss of power due to damage to the 11kV network and have calculated estimates of how long it would take to restore the lost load based on:

- 3 cable faults per km (as per Orion's experience) requiring 2 cable joints to fix and 5m of cable per fault
- Some back-feed capability from adjacent zone substations
- 2 cable joints per cable jointer installed per day

The above results in an estimate of lost load per 11kV cable joint of between 8 kW and 117kW for the 11kV cables off each of the zone substations. WELL has used the minimum figure of 8kW per joint in its estimates of the value of restored load.

Jacobs considers the 11kV Cable and Distribution Equipment Damage assumptions to be reasonable (based on Orion's experience) and the quantum of avoided unserved load to be conservative (given the average load per joint is 20kW).

2.3.1 Potential Options

In this case only two options have been considered:

1. Option 1 - Do nothing
2. Option 2 - 11 kV cable, cable joints and emergency distribution spares.

In this case the cost for Option 1 (do nothing) is difficult to estimate given the restoration efforts will progressively restore load. However, an outage of 2 weeks could result in unserved energy of 16,030 MWh and a 12-week delay could result in unserved energy of 96,180 MWh.

2.3.2 Cost Estimates

WELL has determined that it would require 2,385 cable joint kits, 6km of 11kV cable in order to repair the estimated damage above. For Option 2, WELL has determined that in addition to existing stocks they would require 1,018 11kV joint kits, 4km of 11kV cable, thirty 11kV ring main units, twelve 11kV/400V distribution transformers and 3 sets of fault location equipment.

The cost of the above distribution equipment has been based on pricing from WELL suppliers and contractors. The fault location equipment consists of LV and MV cable fault location equipment, insulation resistance testers, cable locators, VLF testers and budgetary prices of $193k per set have been provided by a supplier.

Jacobs has challenged the requirement for 1,018 cable joint kits given the total upfront cost of these would be $2.64m and they would represent 10 weeks of supply based on the number of cable jointers that would be available and their expected work rate. Orion's reported experience was that "*only a few joint kits were on hand but additional kits were quickly obtained with the cooperation of the Auckland supplier and the German parts manufacturer*" [1].

[1] Resilience Lessons: Orion's 2010 and 2011 Earthquake Experience, Independent Report, Kestrel Group September 2011 http://www.eqrecoverylearning.org/.

While Jacobs agree that the Hutt Valley could be cut off at both ends from road access for a significant period of time, it has questioned whether it would be possible to bring some cable joints (~8kg per pack) by helicopter or barge / boat in less than 10 weeks. WELL's response has been that the Civil Defence would have control of all airspace following an earthquake and may not deem this a priority relative to other emergency flights in the area. Likewise, WELL has discussed possible barge landings with Wellington Lifeline Group and this is still subject to ongoing discussions.

The total cost of the 11kV spares and fault locators is $4.94m and overall, the cost estimation is well supported and reasonable. However, Jacobs remain to be convinced that it would not be possible to reduce the amount of 11kV cable joints held in the Hutt Valley and bring them in within 5-6 weeks via alternative transport options.

2.3.3 Cost Benefit Analysis

The Current State option is dependent on the number of 11kV cables damaged and the length of time taken to get 11kV cable spares and other equipment in the region. The net present value of lost load could be between $16 m for two weeks' delay and would rise to $96 million for a 12-week outage.

For Option 2, WELL has assumed 4 jointers would be located in the CBD and 6 jointers in the Hutt Valley. Based on 2 cable joints installed per day per jointer, WELL has estimated an overall reduction in outage time of 10 days in the CBD and 64 days in the Hutt (due to the greater isolation of the Hutt following an earthquake), per cable joint repaired using local spares. This results in an estimated avoided unserved energy benefit of 9,607 MWh and a net benefit of $9.45m. Overall this option has a net benefit of $4.84m against the Current State option.

WELL has used the minimum value of lost 11kV load per joint rather than the average across all substations. This results in a fairly conservative net benefit for WELL's proposal to purchase additional distribution spares.

2.3.4 Preferred Option

WELL's preferred option is Option 2, purchasing additional 11kV cable spares and distribution equipment.

Notwithstanding the uncertainty around the quantum of 11kV cable joints that need to be stored, Jacobs agree that the purchase and storage of a critical spares would be prudent to accelerate the restoration of load lost from 11kV cable damage in the event of a major earthquake. Without a reasonable level of 11kV spares being held in the Hutt Valley, WELL could be hampered in its ability to restore loads at the 11kV level should its supplies run out before road access is restored.

2.4 Buildings

WELL has assessed the risk to its substations by overlaying its network with Regional Council and GNS seismic hazard maps and rating the potential damage as high (total loss of electricity), medium (equipment damage but power remains on) or low (service continues as normal).

Jacobs note that the draft Business Case report has been developed in part from Orion's experiences following the 2010/2011 Canterbury earthquake events (the report references a 'Resilience Lessons' report, prepared for Orion by Kestrel Group in September 2011). The report has also documented the observed damage following the 2016 Kaikoura event, all of which helps to qualify the overall strategy, the risk assessment process, and the cost estimates.

2.4.1 Geotechnical Hazard Assessment (GHA)

The GHA comprises a desktop exercise that has been undertaken qualitatively by WELL, drawing on Opus' 2013 Lifelines Report. Table 2 of the Business Case presents a risk assessment for each individual site. We would suggest that table is only useful to show trends and overall quantum of the risk. Site specific hazard assessments will be undertaken by a geotechnical engineer when the work is instigated, and should be expected to change for some of the sites, as a result of this assessment.

The link between the geotechnical risk rating and quantum/cost of damage is not clear. For example, liquefaction induced settlements, lateral spreading or slope movement alone may not result in significant damage to the building.

2.4.2 Selection of the Seismic Event

The basis for the risk assessment and cost estimate is a M7.5 event on the Wellington Fault. WELL accept in their report that this is partly short sighted, given that the Ohariu Fault has the potential to generate significant damage within the north-western region. We also note that the active Wairarapa Fault, the Hikurangi Subduction Zone, and numerous other minor active faults in the wider Wellington Region, have the potential to generate damage due to slope instability and liquefaction.

2.4.3 Basis for the 300 Year Return Period

WELL has used a 300 year return period earthquake event in its analysis. This is based on the cumulative probability of occurrence of the five regional fault lines. The value chosen is considered, by Jacobs, to be reasonable based on publicly available information, for example, the following extract from a GNS publication:

"The last time the Wellington Fault ruptured through the Wellington region, causing a major earthquake, was around 300 - 500 years ago. Geoscientists estimate the Wellington Fault will cause a major earthquake every 500-1000 years. However other faults around the Wellington region are also active and capable of generating major earthquakes, for example the Ohariu Fault, and the Wairarapa Fault which last ruptured in 1855 causing a great earthquake that severely affected Wellington. The frequency of large earthquakes affecting the Wellington Region is therefore much higher, with an average return time of about 150 years for a very strong or extreme ground shaking quake."

2.4.4 Building Code Importance levels

There does not appear to be any discussions re structure importance levels. This is important because the IL value has a direct and at times significant effect on the value of the strengthening scheme. Jacobs understands that IL4 has been adopted for all structures, this could be re-evaluated by WELL, thinking more strategically around the relative criticality of each building or distribution line. For example, Transpower's Seismic Policy recommends IL2 for 'substation non-essential buildings'.

Jacobs recommended that WELL undertake a review of Transpower's seismic policy and design standard (TP.GG 61.02 and TP.DS 61.03) and consider their relevance to the wider exercise.

WELL has subsequently indicated that it has undertaken this review and that it uses the Importance Level (IL) to determine criteria for strengthening, whereas Transpower refer to essential and non-essential buildings. However, their definitions and application of those definitions is much in line with WELL's Importance Levels. Both Transpower and WELL use a similar form of assessment (IEP/ DSA) to evaluate buildings.

Transpower strengthen their buildings to 75% whereas WELL go to 34%. They also try to take their essential buildings to 100% where reasonable. Neither Transpower or WELL make any allocation for remedial works to address liquefaction risk.

2.4.5 Buildings

Section 4.5 of WELL's Business Case has been based on the experiences of Orion in the Christchurch events of 2010 and 2011. As a result of the review of the report produced by Kestrel Group in September 2011, in the document WELL has set an objective to upgrade its building infrastructure to 67% of IL4. This figure has been chosen as a realistic goal given that there are substation structures that have been assessed at below 34% NBS in the past.

This is a reasonable approach given the limited data that is available for the performance of this type of building infrastructure in New Zealand in a major seismic event. It should be noted however that the seismic strengthening target is less than the target adopted by Orion. This is partly due to the adoption of the 1 in 300 year return period as opposed to Orion's 1 in 500 year return period.

It is important to understand the rating system represented by the %NBS commonly used for the recognition of seismically prone buildings. This rating system has limited applicability in considerations of damage and rebuild time for structures. This is because the only factor considered in the %NBS rating system is life safety. It is advisable going forward that buildings be rated using other criteria including considerations of potential damage and capacity for recovery of the structural system. It is not possible to consider this important factor in this report but is something for consideration going forward.

A significant factor which may affect the seismic strengthening costs which we are not aware has been considered are the potential costs of strengthening foundations to mitigate ground failure risks. Consideration of potential seismic geotechnical risks is now a prerequisite for all seismic strengthening projects as a result of the recent regulations that came into force in July 2017 [2].

Based on Jacobs' advice WELL has adjusted its building costs to allow for a further $5k for post-1976 buildings to accommodate for the increased cost of Detailed Seismic Assessments (DSAs) due to this regulation. This is because all pre-1976 buildings have already had DSAs conducted and the post-1976 buildings have already had an allocation of $5,000 put against them to allow for DSAs. This has resulted in an increase of $360k to WELL's cost estimates.

However, WELL noted that their seismic policy does not cater for addressing liquefaction which, in WELL's opinion, is aligned with Transpower's policy. In light of this, WELL has not allocated additional funding to address the liquefaction risk.

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2 The Seismic Assessment of Existing Buildings – Technical Guidelines for Engineering Assessments, July 2017, http://www.eq-assess.org.nz/

It is difficult (at this stage) to assess the impact that the recent regulatory changes in relation strengthening foundations[2] (to mitigate ground failure risks) will have on WELL's building strengthening budgets. Given this fact Jacobs recommended that WELL marginally increase its building seismic reinforcement budgets.

In Jacobs view, Transpower's policy (TP.DS 61.03 SA1) does address geotechnical hazards including liquefaction and provides specific performance criteria. If WELL are intending to adopt Transpower's policies and/or achieve the appropriate Importance Level standards, there is a risk that there will be insufficient funding to meet the full strengthening aspirations in the Business Case and it may not be able to achieve Building Consent approvals.

2.4.6 Seismic Strengthening Costs

Because WELL has been strengthening many substations over some time we would expect that costs derived from their experience should be reasonably accurate. WELL is also currently doing strengthening work at multiple sites and therefore Jacobs would expect their cost estimates to be current.

The Business Case indicates that cost estimates are based on the strengthening of 91 high priority buildings over the next three years at a budget of $10.4 million which represents an average cost of $110,000 per building.

Jacobs note that there are some limitations in the risk assessment approach and are not in a position to judge the criticality of the structures chosen for seismic strengthening. However, the approach taken by WELL is a pragmatic estimate of the risks and consequences of potential earthquake damage to substation buildings.

2.4.7 Cost Benefit Analysis

No cost benefit analysis has been undertaken for seismic strengthening by WELL. However WELL note that the ratio of avoided asset replacement costs by upfront strengthening of buildings based on Orion experience is in the order of 5 to 8 times (i.e. the $10.4m proposed expenditure for strengthening could avoid $50-80m of repair costs after an earthquake). Additionally, the benefits of strengthening the 91 substation buildings now, will ensure that workers can safely access equipment post-earthquake to expedite the restoration of power, which will result in reduced restoration times.

2.5 Communication Links

WELL is currently reliant on a communications link to Melbourne for its critical business systems which include:

- Geospatial Information System (GIS) – containing spatial information for network asset data.
- Stationware – protection settings database.
- DIgSILENT Powerfactory – network power flow and fault level analysis tool.
- ProjectWise – drawings server.

WELL note that without timely access to the information located in these critical systems, its ability to plan load transfers, manage switching and restore loads following an earthquake will be compromised, creating safety issues and further delays.

WELL currently has its main control centre at its Petone office and a backup control room at Haywards. It has a single physical communication link between its Disaster Recovery control centres in Petone and Haywards, which creates a vulnerability, should it be damaged during an earthquake. The Petone head office is vulnerable to the effects of an earthquake given its location on the foreshore, which means that the Haywards control room would be the likely location of control and planning activities for the Hutt region. Given the potential islanding effect following a 7.5 magnitude earthquake, WELL notes that it would be beneficial to have localised data and control centres in the CBD and Porirua region, to enable local staff in these areas to manage the restoration of power independently, should all data communication links be lost.

WELL is also reliant on cell phones utilising the public mobile network for the majority of their communications between the control room and field workers. WELL note that following an earthquake, cellular network coverage would be unreliable due to overloading and loss of power to cell towers.

To alleviate the above risks WELL proposes the following:

- Two new containerised data and back up control centres located in Newtown (Wellington CBD) and Porirua (Porirua City), and an upgrade of the existing backup control room in Haywards (Hutt Valley)
- Strengthening and diversifying its communication infrastructure by building a communications connection between its Petone Head Office and the primary Disaster Recovery control centre at Haywards and also between the two other data centres
- Establishing phone exchanges at Petone and Haywards to remove reliance on the public mobile network
- Upgrading the network controller’s phone system with additional capability and functionality, and
- Replacing its existing voice radio system with a better “fit for purpose” radio system

While Jacobs understands the overall logic of WELL’s proposal it did question the need for three standalone control room / data centres. On subsequent discussion and clarification from WELL Jacobs understands that the magnitude 7.5 earthquake scenario would result in physical isolation of three key areas of WELL’s network and loss of communication between them. Therefore, in order to maximise its ability to safely restore load in all three areas, Jacobs is satisfied that three centres would provide significant benefit to the restoration process. We note that three centres would significantly reduce travel times/distances for staff manning the recovery centres during a period when there will be significant road blockages.

2.5.1 Equipment Costings

Each of the three data centres have been costed based on quotes from equipment suppliers for a range of network equipment, servers, software licences, and tape backup systems totalling around $900k per data centre. The data centres at Newtown and Porirua are to be established in prefabricated containers with fire detection / suppression systems, server racks and power / UPS systems, costing around $635k each.

The cost of a new phone exchange system between Petone, Haywards and the Newtown data centre has been estimated at $0.86m by an independent engineering firm, PSC, and quotes have been obtained from a radio vendor for an upgraded radio system at $0.436m. Fibre connection costs have been estimated at $70k capex based on a supplier quote and PSC estimates. The total capex estimate is $5.26m.

Annual operating costs for the phone, fibre and radio systems have been determined from supplier quotes and total $350k per annum from year 3 ($150k in year 2).

The costs above were refined by WELL following initial queries from Jacobs in relation to the source of the radio system upgrade costs and potential double counting of UPS systems between the prefabricated building costings and the internal equipment. WELL has also spread the capex over FY18 – 21, which has resulted in a reduction of opex in the first 3 years.

Jacobs also questions whether WELL had considered portable standby generators for each of the data centres. WELL noted that they have four already and two would be deployed at the data centres.

Overall Jacobs is comfortable with the robustness of the cost estimate breakdown for the Communication Links equipment, but it is not in a position to comment on whether all the equipment is required (e.g. the number of servers, user licences, radios, etc. in each location). However, Jacobs notes these equipment specifications have been determined by specialist providers independent from WELL.

2.5.2 Cost Benefit Analysis

Jacobs note that no cost benefit analysis has been undertaken for this option by WELL as it is difficult to determine how much quicker power could be restored across the network from timely access to critical data and the ability to communicate between data centres and field staff. However, as WELL note, without these critical systems it would not be able to assess how much load it could safely transfer between operational sites, re-determine protection settings and coordinate with its field workers.

Without the distributed control/data centres, there are likely to be significant delays post-earthquake while WELL wait for telecommunication network supplier to re-establish communication links and it would be difficult and time consuming for WELL to manually determine safe operating levels of its equipment without access to the data stored in its information and decision support systems.