SCIRT Rebuilding Infrastructure LEARNING LEGACY

Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

Evaluation of Whole of Life Costs for Rebuild Option Evaluation (Design Guideline 27)

Story: Evaluation of Alternative Rebuild Options

Theme: Governance and Decision Making

A design guideline which provides guidance to designers on how to carry out a whole of life evaluation of rebuild options.

This document has been provided as an example of a tool that might be useful for other organisations undertaking complex disaster recovery or infrastructure rebuild programmes.

For more information about this document, visit www.scirtlearninglegacy.org.nz

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SCIRT
Rebuilding Infrastructure

DESIGNERS GUIDELINE

Stronger Christchurch Infrastructure Rebuild Team

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X Wastewater
□ Structures
□ Stormwater
□ Roading
□ Geotechnical
□ Water Reticulation

Subject: **Evaluation of Whole of Life Costs for Rebuild Option Evaluation**

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Updated by: David Heiler (15/7/13). Updated for:
- Revised Scope and Standards table format

Keywords: Wastewater, whole of life cost, NPV

1. Purpose of guideline

To provide guidance to designers on how to undertake a whole of life evaluation of rebuild options.

2. Background

The IDS and IRTS&G require new infrastructure to be designed to minimize life cycle costs over the life of the asset. In considering multiple options for rebuild to council infrastructure, designers should evaluate options on a whole of life basis. A NPV analysis is being used to estimate the whole of life cost of different options to assist in the evaluation of rebuild options.

What is it?
NPV is a financial calculation that provides the whole of life cost for projects in today's dollars.

Why is it needed?
NPV is a fundamental calculation required to assess project options by providing whole of life costing analysis that enables SCIRT to make reliable decisions about which options provide the best value.

When it is completed?
It should be completed during Concept Design where multiple options are being considered and a table of comparative results must be included in the Concept Design Report and Scope and Standard papers.

Who should complete the calculation?
The design engineer completing the design report should complete the calculation for all options. Designers can consult with Asset Engineers, the Data Assessment Team (David Heiler), Maintainers, Manufacturers, and the Commercial Team to obtain information and check logic within the calculation.

3. Completing Whole of Life Calculation

SCIRT have developed a standard calculation method that will enable consistency and accuracy. The calculation is completed in an Excel spreadsheet, which includes a cost library of applicable costs.

Three earthquake risk scenarios are generally considered for each design option during Concept Design. These are presented below and explained further in Section 4.4. The 2 earthquake scenario needs to be presented in the costing table of the Scope and Standards paper.

Figure 2.1 - Typical whole of life costs for a project/asset (No future earthquake scenario)

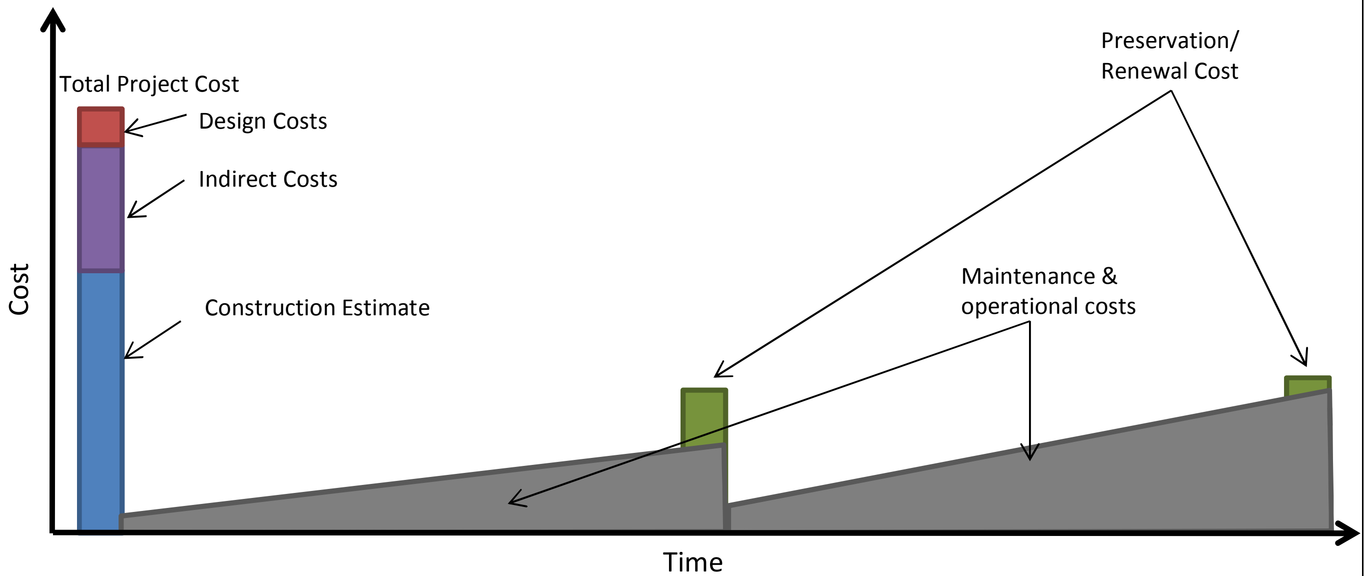


Figure 2.2 - Following one significant aftershock at Year 5 (1 earthquake scenario – in accordance with 4.6.1 of the IRTSG)

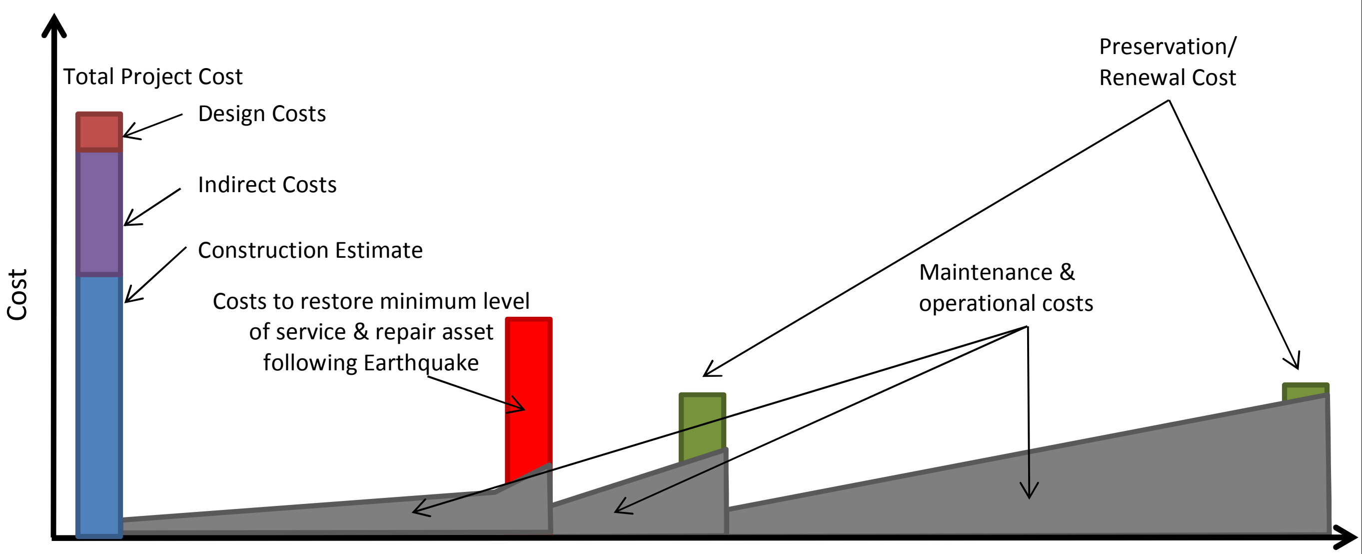
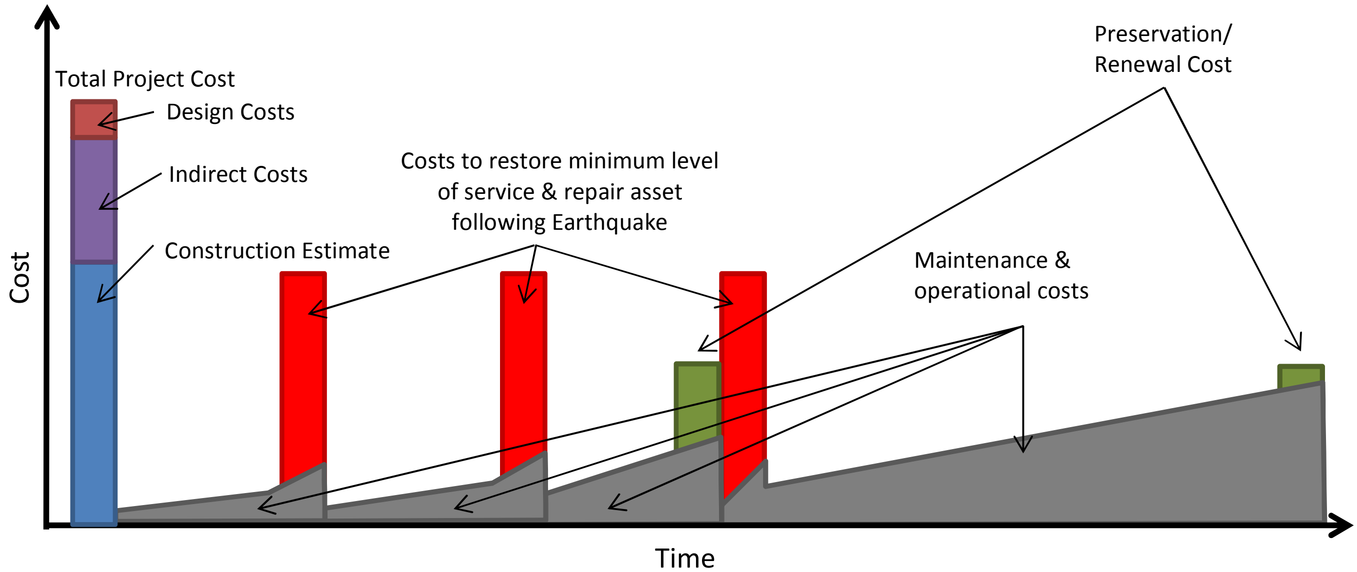


Figure 2.3 - Following three significant aftershocks at 5, 10, and 15 years (3 earthquake scenario)



3.1 Explanation of Cost Items

The Total Project Cost includes the Construction Estimate (estimate of the physical works costs and onsite overheads), Design Costs, and Indirect Costs.

Preservation/renewal costs are the costs associated with the partial or full replacement of parts associated with an asset at agreed time periods (e.g. renewal of certain components every 15 years).

Operational and Maintenance costs are the annual costs associated with maintaining the asset to provide normal levels of service. These should be in a saw tooth pattern as more maintenance is normally needed as the asset gets older. The asset may also become less efficient as it gets older so operational expenditure may also increase (e.g. pumps expected to draw more power as mechanical components wear).

Earthquake costs are capital and operational expenditure associated with an earthquake event sufficient to cause liquefaction and damage to in-ground infrastructure. GNS has provided guidance on the probably of such an earthquake occurring and the earthquake risk is presented in section 4.6 of the IRTSG. Some rebuild options are more resilient than others, and hence, following a future earthquake, need different amounts of effort to:

1. Restore and maintain a minimum level of service, and
2. Rebuild infrastructure damaged in a future event.

4. Populating the SCIRT NPV Spreadsheets

There are four worksheets that need to be populated in the Excel Model:

1. Total Project Cost
2. Preservation & Renewal Costs
3. Maintenance & Operational Costs
4. Earthquake Costs

A generic spreadsheet can be used for most whole of life cost comparisons. A specific spreadsheet has been developed for evaluating wastewater network rebuild options given the number of options being considered and the sensitivity of the selection to a whole of life evaluation. This spreadsheet is stored along with this guideline in Project Centre (Designer Guideline 027).

4.1 Total Project Cost

The Total Project Cost is the cost to investigate damage, scope, design, construct and handover the rebuild project to CCC. It includes the Construction Estimate (estimate of the physical works costs), Design Costs, and Indirect Costs.

The TOC Team has provided unit rates and descriptors to Designers to prepare a Construction Estimate for each option. These cells should not be changed without consulting with the TOC team.

Designers insert quantities into the shaded cells to complete their concept design estimates. Costs will self-calculate using inserted quantities and the unit rates. The spreadsheet will self-calculate Construction allowances for TMP, P&G and Contingency. The TMP allowance is only made against physical works items that require TMP (ie works on the road).

Allowances are made for the following design and indirect costs (in accordance with the requirements of the Standards and Scoping Committee):

- Design costs have been estimated at 6% (for network rebuild and roading projects) or 15% (for pump stations and civil structures) of the Construction Estimate. The Designer shall enter the design cost percentage.
- Indirect Costs (that include for asset assessment costs, SCIRT overheads, Delivery team overheads, Limb 2 profit) have been estimated at 45% of the (Construction Estimate + Design Cost).

Where specific options require a significant amount of additional onsite investigation, consultation or approvals to allow them to proceed, the costs of these tasks should be included in the Construction Estimate. An example of this could be additional CCTV inspection to identify whether damaged pipes can be lined rather than re-laid.

For the purposes of estimating the Earthquake Costs, the Construction Estimate is automatically broken down into different components so that the relative resilience of each can be estimated and compared. Construction Estimate allowances (TMP, P&S, Contingency), and Indirect and Design estimates are allocated back to these. These figures then linked through to the Earthquake Costs tab.

If Designers add additional rows to the Construction Estimate, they may need to adjust the TMP allowance and the Construction Estimate item split to incorporate the added items. They can check that they have done this correctly by checking that the highlighted summation checks equal zero.

4.2 Preservation and Renewal Costs

Preservation/renewal costs are the costs associated with partial or full replacement of parts associated with an asset at agreed time periods (e.g. renewal of certain components every 25 years).

The spreadsheet provides a library of standard rates collected from CCC and equipment suppliers. Designers insert quantities into the shaded cells to estimate capital renewals associated with the different options being evaluated. These then automatically populate a timeline of renewal costs. Renewal frequencies are taken from CCC Activity Management Plans.

Designers can insert new items if the library of renewals doesn’t cover their requirements. Please provide information on these costs and any comments back to David Heiler so that the library of renewals can be updated.

4.3 Operation and Maintenance Costs

Operational and Maintenance (O&M) costs are the annual costs associated with maintaining the asset to provide normal levels of service.

The spreadsheet provides a library of standard O&M costs collected from CCC and equipment suppliers. Designers insert quantities into the shaded cells to estimate O&M associated with the different options being evaluated. These costs then automatically populate a timeline of O&M costs.

It is anticipated that the performance of components will reduce over time due to wear, resulting in a gradual increase in O&M costs. This has been reflected by a Performance Reduction Factor which is used to incrementally increase the O&M costs from construction through to renewal (eg pump renewal assumed at year 25).

Designers can insert new items if the library of O&M rates doesn't cover their requirements. Please provide information on these costs and any comments back to David Heiler so that the library of O&M rates can be updated.

4.4 Earthquake Costs

Earthquake costs are an estimate of the costs associated with responding to a future earthquake event. This includes:

1. First response costs to restore a minimum level of service through sewer jetting and sucking, temporary over pumping, the construction of temporary wastewater systems, the completion of emergency repairs to restore service, repair works to other affected assets, etc, and
2. Network rebuild costs to repair earthquake damage.

Although the spreadsheet has been formatted to provide an automatic calculation of these costs, there is a need for Designers to undertake a sensibility check of the calculated values, drawing on their site specific knowledge of network damage in the local area. The values estimated for first response and network rebuild need to be realistic estimates of what costs could reasonably be expected as a result of a future earthquake event.

Estimated first response and network rebuild costs are summed together and included in a timeline of costs to simulate the effect of future earthquake events. For simplicity earthquake costs have been lumped into a single year to coincide with the future earthquake.

Section 4.6.1 of the Infrastructure Recovery Technical Standards and Guidelines (IRTSG) provides guidance on the probability of future earthquake events. Based on this, earthquake costs should be applied at the following points on the timeline:

- No Earthquake Costs (assumes no future earthquakes of sufficient magnitude to cause liquefaction and widespread infrastructure damage).
- Year 5 (to assess the impact of one earthquake within the next 20 years – this is the most likely EQ scenario based on GNS advice). The results of this scenario should be presented in the Costs table in the Scope and Standards Paper.
- Year 5, Year 10 and Year 15 (to assess the impact of three earthquakes over the next 20 years – most extreme EQ scenario).

In addition, the NPV calculation also produces a whole of life cost for an earthquake at Year 1 (1 year after reconstruction).

4.4.1 First Response Estimate

The first response estimate uses actual first response costs from EQ1,2,3 for different areas of the city to predict the cost to restore and maintain service after a future earthquake.

Actual first response costs have been derived from City Care's 3-Waters network maintenance contract and City Care/Fulton Hogan road maintenance contracts for EQ 1, 2 and 3 (figures for the 20 month period Sept 2010 to May 2012), which have been provided by CCC. The costs are to restore and maintain service to all assets due to the interrelationship between asset types. Works on the wastewater network dominate these figures, making up around 70% of the costs. This period has been selected as is expected that repairs will be well underway 15 months after a future significant earthquake.

Costs are presented below for the 11 sewer parent catchment zones as $/HEU ($/household equivalent unit). CERA Red Zone area costs are excluded from the figures.

Parent Catchment	1	2	3	4	5	6	7	8	9	10	11
$/HEU	7,653	2,530	1,787	4,556	3,388	3,287	870	1,331	639	2,188	732

Designers need to fill in the number of household equivalent units serviced by the different types of systems that make up their proposed system. The spreadsheet will automatically estimate the first response costs using default network scaling factors. Default scaling factors (selected through discussion with various designers at SCIRT) are:

- Repaired/Retained/Replaced gravity 100-50% - dependent on whether grade and material have been improved
- Relined Gravity 80%
- Vacuum 35%
- Pressure 20%

Using a scaling factor of 100% implies that the rebuilt network will behave in the same way as the original network in a future earthquake event. This means that it will require the same amount of effort (in the form of sewer jetting and sucking, temporary over pumping, temporary wastewater systems, completion of emergency repairs, works to other affected assets) to restore and maintain service until it is repaired again.

Adopting a lower scaling factor (eg 20% for pressure sewer) is to reflect our expectation that the rebuilt network will be more resilient to a reduction in service following a future earthquake and so will cost less to restore and maintain service until it is repaired.

4.4.2 Network Rebuild Estimate

The network rebuild estimate is the estimated cost to rebuild the wastewater network following a future earthquake.

The calculation requires the Designer to consider what damage has occurred to the existing gravity network and what damage could be expected to a rebuilt network. Network rebuild is typically falling into one of two categories:

a. Complete rebuild/replacement of the existing network with a new gravity or alternative system.
b. Part rebuild/repair of the existing network resulting in some saved (unmodified) infrastructure.

a. Complete rebuild/replacement of the existing network

Where the rebuild option involves the wholesale replacement of assets, the estimate of future network rebuild costs makes use of the current rebuild Total Project Cost (CAPEX). The current rebuild CAPEX cannot be used directly for estimating future rebuild/repairs costs as the rebuild CAPEX is based on rebuilding the current network, which can consist of various pipe materials (eg EW, CONC, AC, RC).

Networks are being rebuilt using (mostly) PVC and (sometimes) RC pipes, which have been found to perform much better and so the estimate of future rebuild costs needs to consider the Actual Damage experienced by PVC or RC in similar country to the rebuild area. The spreadsheet provides default Actual Damage percentages for PVC and RC pipe based on LRI Zone. Where the Designer has better information on the performance of PVC and RC in the project area, they can over-write the default values.

New enhanced gravity systems and alternative systems (pressure, vacuum) are expected to offer greater resilience than existing PVC and so a ‘Relative Performance Scaling Factor’ is applied to reflect the rebuild greater option’s resilience to future damage. Default Relative Performance Scaling Factors (selected through discussion with various designers at SCIRT) are:

- Repaired gravity 90-100+%
- Relined Gravity 80+%
- Re-laid (enhanced) gravity 50%
- Vacuum 35-45% depending on reserve hydraulic lift below 4m
- Pressure 20%

For a complete rebuild/replacement of the existing network, the future network rebuild cost is estimated by multiplying the current rebuild CAPEX by the Actual Damage experienced by the rebuild pipe material, by the ‘Relative Performance Scaling Factor’.

For specific new items such as pump/vacuum stations and pressure/vacuum pits, the rebuild estimate is a product of the CAPEX and the estimated % damage.

b. Part rebuild/repair of the existing network (resulting in some saved infrastructure)

Where the rebuild option involves only undertaking repairs to part of the network, the estimate of future damage should not be limited to a scaling of the rebuild CAPEX. This is because of the risk that a future earthquake could result in saved/repaired/relined pipes passing a damage threshold that results in more widespread renewal.

An alternative method for estimating the cost to repair saved/repaired/relined pipes after a future earthquake event is:

Estimated rebuild costs = ‘cost to repair length (length x average rate to repair/reline/relay)’ x ‘estimated % damage’

The designer shall adjust the % damage to reflect the expected damage. Consideration should be given to the damaged experienced to date and the how close saved/repaired/relined pipes are to passing the damage threshold that will require them to be re-laid.

The designer shall use the method that produces the best estimate of what costs could reasonably be expected as a result of a future earthquake event.

4.5 Checking the Timeline of Costs

The time of costs presents Capital Expenditure, Operational Expenditure and Earthquake costs on a timeline and calculates and NPV of future costs based on a 30 year period and 8% discount rate.

The Capital Expenditure is the CAPEX at Year 0 and future Preservation and Renewal costs to replace specific components of the system (eg pumps – assumed replacement at Year 15). Operational Expenditure is annual Operational and Maintenance costs such as power and maintenance labour.

The Designer should check that the links are working correctly if they make changes to any of the sheets.

The timeline looks at a variety of earthquake scenarios. The default Earthquake scenario to be included in the Scope and Standards papers is one earthquake over the next 20 years (occurring at Year 5). Other scenarios such as an earthquake at Year 1 and 3 earthquakes are analysed to check the sensitivity of the selection to earthquake risk.

4.6 Completing the Cost table for Scope and Standards Papers

The spreadsheet contains a Scope and Standards cost table in the same format as it appears in Scope and Standards papers.

5. Filling out the Standards and Scoping Table

The table to be presented in Standards and Scoping papers is as follows. The scope and Standards paper template can be found on Project Centre. A fictional example has been included to show how the table is filled out. This matches the example presented in the template spreadsheet.

Project:				
Do minimum/replacement option: *(Outline what a 'do minimum' or replacement/repair option would look like, Insert approximate costs)*				
Recommended option:				
Discount Rate & Period		8%, 30 years	8%, 30 years	8%, 30 years
		Option 1 – Gravity	**Option 2 – Pressure**	**Option 3 – Vacuum**
NPV with no future EQs factored in				
	Year 0 Costs			
A	Construction Cost	$12.62M	$13.65M	$12.90M
B	Design Cost @ *6%*	$0.76M	$0.82M	$0.77M
C	Indirect Cost @ 45%	$6.02M	$6.51M	$6.15M
D	**Total Year 0 Capital Cost** (A+B+C)	**$19.40M**	**$20.98M**	**$19.83M**
	Capital Renewals	Rebuild gravity network	Convert network to pressure	Convert network to vacuum
E	NPV Capital Renewals	$0.03M	$0.37M	$0.04M
F	**NPV Capital Expenditure (D+E)**	**$19.44M**	**$21.35M**	**$19.87M**
G	NPV Capital Cost for Like for Like Option	$19.44M	$19.44M	$19.44M
H	Difference (F-G)	$0	$1.92M	$0.43M
I	Net Resilience Capital Cost	N/A	$1.92M	$0.43M
J	Betterment	N/A	$0	$0
K	Betterment description	N/A	-	-
L	**NPV Operational Expenditure**	**$0.59M**	**$0.78M**	**$0.82M**
M	Indicative OPEX Cost	$46K	$62k	$65k
N	**NPV Total Project Cost (F+L)**	**$20.02M**	**$22.13M**	**$20.70M**

NPV with EQ at Year 5 (1 earthquake scenario) factored in				
	Estimate of Future EQ Costs			
O	Estimated EQ Rebuild Cost	$4.63M	$1.20M	$2.57M
P	Description of EQ rebuild works	Repairs to gravity pipelines and PS	Repairs to pressure pipework and pits	Repairs to vacuum pipework, pits and vacuum station
Q	Estimated EQ Temporary Service Restoration Cost	$1.71M	$0.62M	$1.09M
R	Description of EQ temporary service restoration activities	Based on EQ1,2,3 first response costs (55% of EQ1,2,3 costs)	Based on EQ1,2,3 first response costs (20% of EQ1,2,3 costs)	Based on EQ1,2,3 first response costs (35% of EQ1,2,3 costs)
S	Total Estimated EQ Cost (occurring at Year 5)(P+R)	$6.35M	$1.83M	$3.66M
T	**NPV EQ Cost (NPV of S)**	**$4.32M**	**$1.24M**	**$2.49M**
U	NPV Total Capital Expenditure (copy from F)	$19.44M	$21.35M	$19.87M
V	NPV Operational Expenditure (copy from L)	$0.59M	$0.78M	$0.82M
W	**NPV Whole of Life Cost (T+U+V)**	**$24.35M**	**$23.37M**	**$23.18M**
	Design Life	Lined 50yrs, Relaid – 100yrs	100yrs	100yrs
	Delivery Risk	M	H	M

	Operational Risk	L	M	M

Table Notes

[1] Includes P&G, TMP, Contingency
[2] Design % - 6% for reticulation & roading, 15% for pumping stations, bridges & retaining walls
[3] Indirect Cost = Asset Assessment cost + SCIRT overhead + Delivery team overhead + Limb 2 (45% applied to (A + B))
[4] The Difference is broken into Net Resilience Capital Cost and Betterment
[5] Net Resilience Capital Cost should provide an estimate of additional capital cost for the specific purpose of providing resilience in the option(s) indicated (does not include incremental resilience provided by the use of modern materials)
[6] Betterment (improvements) should provide an estimate of additional incremental cost for the specific purpose of increasing the level of service (does not include incremental increased level of service by the use of modern materials)
[7] OPEX cost at Year 1
[8] Includes Capex (Year 0 and Renewals) and Opex
[9] Estimate the costs required to rebuild assets damaged in a future EQ
[10] Describe the works required to rebuild assets damaged in a future EQ
[11] Estimate the costs of O&M activities required to restore a temporary service immediately following a future EQ
[12] Describe the expected activities required to restore a temporary service immediately following a future EQ
[13] Sum of the EQ rebuild and temporary service restoration costs
[14] Includes Capex (Year 0 and Renewals), Opex & EQ rebuild and temporary service restoration

Rows A to D provide a breakdown of SCIRT project costs at Year 0.

Rows E to N provide a breakdown of whole of life costs with no future earthquake risk factored in.

Rows O to W provide a breakdown of whole of life costs for the 1 earthquake scenario.

All whole of life costs are calculated on the Timeline of Costs for the different options being considered.

Rows G to J are a breakdown of the Capital Expenditure to allow a direct comparison between the different options and a Like-for-Like option. For the Like-for-like option (Option 1 on the Table), F = G. G is the same for all options. The difference between F (for the different options) and G is seen as being either additional Resilience (I) or Betterment (J).

Row M is the O&M costs at year 1. This value is escalated by the Performance Reduction Factor, which is used to incrementally increase the O&M costs from construction through to renewal to reflect reduction in performance.