Kaitoke Water Main Diversion Assessment
Executive Summary

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Note:

Construction costs in table 1 do not include the stockpile of materials, bridge strengthening contribution and raising pipe on the bridge. The diversion construction cost has been significantly revised and reduced to allow for an agreed Transit New Zealand contribution and pipeline already laid.

Executive Summary

The Wellington area is prone to potentially damaging earthquakes. The Lifelines in Earthquakes, Wellington Case Study, 1991 identified a number of potentially vulnerable parts of the bulk water supply pipeline including the Hutt River crossing at Silverstream and the adjacent Wellington fault crossing. The object of this study is to undertake a comparison between this segment of the existing bulk water supply pipeline and the proposed diversion for this segment. The proposed diversion will replace the existing elevated river crossing where the pipe is attached to the side of the Silverstream Bridge and adjacent in-ground pipelines with an underground crossing approximately 1 km downstream. The existing pipeline alignment and proposed diversion are shown in Appendix B.

This study concluded that while the proposed pipeline diversion reduces risk of damage to the pipeline in the event of a significant earthquake it does not eliminate this risk and that damage can be expected and repairs will be required. The study further concluded that the time required for repairs varies only by a day or two between the two options.

A quantitative probabilistic assessment was completed using a total risk approach to compare present value replacement costs (5% rate of return assumed) of the existing pipeline segment with the proposed diversion. These analyses concluded:

Table 1

Present Value of Replacement Cost Comparison

Pipeline Option	Total Annualised Replacement Cost	Construction Cost	Present Value of Replacement Cost
Existing Pipeline Segment	$2,000	-	$40,000
Proposed Diversion	$1,400	$3,110,000	$3,140,000

The above costs assume that the materials for the emergency bridge crossing are not stockpiled. If these materials are stockpiled, as recommended then the annualised cost will reduce and the construction or up-front cost will increase.

Table 2

Time of Repair Comparison

Pipeline Option	Estimated Time to Complete Repair
Existing Pipeline Segment	5- 7 days
Proposed Diversion	3-5 days assuming no breaks at the underground river crossing 5-7 days if the river crossing requires repair

The proposed diversion cannot be easily justified on the basis of earthquake risk. This is often found to be the case when the effects of high impact but low probability events are being assessed.

The bulk water supply network and the Wellington region generally is exposed to earthquake hazard from a number of different fault sources.

The major fault sources are the Wellington and Wairarapa faults. Records from the Wellington fault indicate a characteristic pattern of abrupt displacements of 3.2 – 4.7 m with an average recurrence interval of about 600 years. The location of the Wellington fault at the Silverstream bridge area is not conclusively defined. All available information however points to the fault being located close to the western side of the Hutt River, passing somewhere through the Manor Park Golf Course and then running on the western side of the Silverstream Bridge close to the western abutments.

The Wairarapa fault was the source of New Zealand's largest historical earthquake the M8+ event of 1855. Other faults in the area include the Ohariu fault and Shepherds Gully/Pukerua fault.

The earthquake hazard estimate for the Wellington / Hutt Valley taking into account all the various known earthquake sources is listed in the following table.

Table 3

Earthquake Hazard Estimate for Kaitoke Main at Silver-stream Bridge.

Modified Mercalli Intensity (MM) level	Return Period (years)	Probability over the next 50 years	Probability over the next 100 years
VI	8	0.999	1.000
\WII	100	0.395 0.796	0.958 0.634
IX	370	0.127	0.237
X	1309	0.037	0.074
XI	4634	0.011	0.021

The Kaitoke Main pipeline is a steel pipeline with welded lap joints. Correlation of observed pipeline damage from around the world shows that steel pipelines with welded lap joints are moderately ductile i.e. less ductile than arc – welded butt jointed steel pipes but more ductile than cast iron pipe, asbestos cement or concrete pipes.

In-ground Pipe Performance

Records and observations from previous earthquakes around the world show that the performance of underground pipelines during an earthquake is strongly correlated to whether the pipe is subjected to permanent ground deformations and to a lesser extent to ground shaking. No sources of significant permanent ground deformation, for example, landsliding, lateral spreading or liquefaction under earthquake loads were identified in this study for the existing Silverstream Bridge pipeline segment or for the proposed diversion. Based on the known characteristics of the pipeline and the ground conditions this study assessed the pipeline to be moderately ductile, located in stable ground, subject to ground shaking but not permanent ground deformation. A quantitative probabilistic vulnerability assessment of pipeline damage expressed in terms of breaks per km compared with Modified Mercalli Intensity Scale was developed to describe this risk.

Pipe on Bridge Performance

Performance of a pipeline attached to a bridge is significantly linked to the performance of the bridge itself and of the attachments of the pipe to the bridge. This study concluded that the existing pipeline is vulnerable to significant damage likely to necessitate a replacement river crossing in the event of a Wellington fault characteristic earthquake. A quantitative probabilistic vulnerability assessment was developed to describe the risk.

Pipe at Fault Crossing Performance

Performance of a pipeline crossing a fault is linked to the extent of any fault movement at that location and to the angle of the pipeline crossing the fault. This study concluded, based on the known characteristics of the pipeline, the assessed fault location and the expected fault movement, that the existing pipeline will fail in compression buckling for a length of approximately 200m in a Wellington fault event necessitating replacement of much or all of the pipeline for this length. This study also concluded that the proposed diversion where the pipeline will cross the fault at 90° would perform significantly better than the existing pipeline. Nevertheless the characteristic fault movement expected along the Wellington fault is so great that damage to the pipeline at the proposed new fault crossing can be expected requiring replacement of approximately 75 m of pipeline.

An assessment (based on engineering judgement) of the likely impacts of a Wellington fault event on the existing pipeline paints the following scenario:

- 5 breaks per km on average in the in-ground pipeline which require repair.
- The pipeline at the bridge crossing has buckled and has fallen into the river although damage to the bridge itself may range from light damage through to partial collapse to full collapse. The pipeline section crossing the river requires replacement.
- The pipeline at the fault crossing on the western side of the Hutt River is significantly damaged and requires replacement for 200m.
- Potentially major changes to the Hutt River including rapid bed accretions and channel realignment.

This compares with an assessment of the likely impacts of a Wellington fault event on the proposed diversion:

- 5 breaks per km on average in the in-ground pipeline which require repair including the segment of pipeline crossing under the river.
- The pipeline at the fault crossing on the western side of the Hutt River is significantly damaged and requires replacement for 75 m.
- Potentially major changes to the Hutt River including rapid bed accretions and channel realignment.

We assess repairs will be required for both options following a Wellington fault event.

Recommendations

Based on our investigations and the assessment of relative risk expressed both in terms of present value replacement cost and the relative time to repair both options to restore water supply we believe that the proposed diversion cannot be easily justified solely on a financial basis. We, therefore recommend that the WRC follow an alternative approach of preparing now for the likely repairs required following a significant earthquake by:

- Preparing an emergency repair plan now for repairing this segment of the bulk water supply network
- Stockpiling materials in an easily accessible adjacent location for use in the repairs including material for a temporary river crossing and other repairs. Some work will be required to determine appropriate quantities of materials to stockpile.
- Entering into agreements now with appropriately skilled contractors with appropriate equipment to undertake the repairs immediately following an earthquake.
- Entering into agreements now with other local authorities with a similarly skilled workforce for mutual aid agreement for sharing skilled manpower and equipment in the event of an earthquake.
- Preparing now a methodology to review and reassess and update the emergency plans on a regular basis.

If the diversion is to be built, we believe WRC should consider the benefits of maintaining a dual pipeline in this critical segment. If the existing pipeline is supplemented with the proposed diversion and is left operable, there is a significant increase in the redundancy in the pipeline network at this location with a corresponding reduction in the risk of loss of supply due to fault movement.

We further recommend that the WRC consider undertaking the same types of preparations for emergency repairs to restore water supply service for the rest of the bulk water supply network given that a simple quantitative analysis of the Te Marua to Karori water supply main using the same probabilistic total risk approach expressed in present value terms (assuming a 5% rate of return) gives an estimated present value cost of $440,000.

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