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Ross River Suspension Bridge
Ross River, Yukon

Life Cycle Cost Analysis

Prepared for

Yukon Government Community Services Department
Community Infrastructure
C-9 Second Floor 2071 Second Avenue
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Figure 1. SW Sway Cable Anchor destroyed by flooding of Pelly River in early 2013

1.0 TERMS OF REFERENCE

1.1 Background

David Nairne & Associates Ltd. (DNA) was initially retained by Yukon Territory Government Community Services (YTG-CS) in February 2010 to prepare contract documents for the repair of the Ross River suspension bridge. The repairs were to be based on a scope of repairs identified in a Field Inspection Report of the Ross River Suspension Bridge prepared by AECOM Canada Ltd dated September 9, 2009. However, in our pre-design inspection of the bridge in April 2010, we found further structural damage and deterioration that warranted further investigation and repairs. As result of these findings, YTG-CS requested that DNA to prepare a Repair Options report (October 16, 2012) that identified the scope of work and construction costs for a short-term, mid-term and long-term repair option. YTG-CS closed the bridge to pedestrian traffic in 2012 until repairs could be carried out.

In 2013, YTG-CS retained DNA to prepare contract documents for the repair of the Ross River suspension bridge based on Option 1 described in our Oct 16, 2012 Repair Options report. In a pre-design inspection of the bridge in October 2013, the steel cross beam located on top of the north tower of bridge was discovered to be severely damaged and laterally unstable. Given this finding and the age and overall poor condition of the bridge, DNA concluded in a memorandum to YTG-CS dated September 30, 2013 that it was no longer practical from a structural and construction safety perspective to repair and salvage the bridge. Furthermore, we recommended that the bridge be demolished as soon as possible for safety reasons.

1.2 Life Cycle Cost Analysis

In November 2013, YTG-CS requested that DNA to prepare a Life Cycle Cost Analysis to identify options and cost estimates to provide year round pedestrian access across the Pelly River by means of a pedestrian bridge.

2.0 REFERENCE DOCUMENTS

This report is based on the following reference documents:

Table 1 - Reference Documents

Date	Source	Description
2013 Sept 30	DNA	Memorandum - Inspection of Bridge Towers
2013 August 6	DNA	Pre-design Inspection Report Option 1
2012 October 16	DNA	Repair Options
2011 July 13, 2011	DNA	Memorandum - Interim Bridge Inspection Report
2011	EBA	Foundation Stabilization Recommendations
2010	EBA	Geotechnical Evaluation Ross River Pedestrian Bridge Foundation
2009 September 9	AECOM	Ross River Suspension Bridge Field Inspection Report
2007	YTG	Pelly River Pedestrian Bridge Repairs
2005	YTG	Pelly River Pedestrian Bridge Camber Reinstatement & Repairs
1984	Public Works Canada	Pelly River Suspension Bridge at Ross River Inspection and Evaluation Report
1979	Nielson & Thomas	A Condition Report on the Pelly River Foot Bridge at Ross River

3.0 PROJECT DESCRIPTION

3.1 Canol Oil Pipe Line Project

The Ross River suspension bridge was constructed in 1944 as part of the Canadian Oil Pipe Line (Canol) project to carry a 100mm diameter steel oil pipeline across the Pelly River. The Canol project was abandoned shortly after the end of WW II and the bridge was converted to serve as a pedestrian bridge.

3.2 General Description

The Ross River suspension bridge consists of a timber bridge deck suspended from two sets of steel suspension cables that span 213 m between two 30 m high steel towers. The suspension cables are anchored into buried concrete footings located approximately 55 m beyond the centre of each tower. The bridge deck is 1.30 m wide and 192 m long with a camber of 1.50 m at mid-span. The bridge deck is restrained laterally by a steel sway cable that runs along each side of the bridge deck. Each sway cable curves in plan away from the mid-span of the bridge and is anchored to buried concrete footings located on each side of the steel towers.

The bridge has provided year round pedestrian access across the Pelly River for the Ross River community located at the south end of the bridge for almost 70 years. During the summer (approximately 5 months), vehicle access across the Pelly River is provided by a cable ferry located adjacent to and downstream from the bridge. In the winter (approximately 4 months), vehicle access is provided by an ice bridge on the Pelly River located parallel to and under the bridge.

All dimensions quoted in this report are approximate.

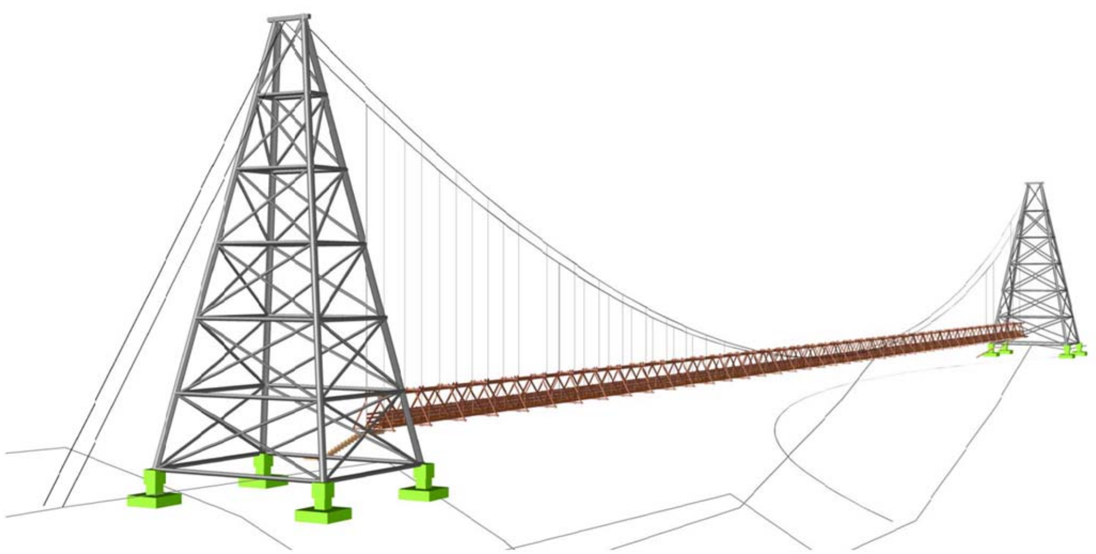


Figure 2. Ross River Suspension Bridge Isometric View

3.3 Inspection and Repair History

DNA has records of engineering inspections and assessments being carried out to the Ross River Suspension bridge since 1979 to address specific concerns and deficiencies occurring with the bridge structure. Over the past 34 years, previous repair work has included replacing the original timber approach ramps and at each end of the bridge with timber stairs, replacing the bridge decking, repairing the deck truss chords, repairing the concrete tower pedestals and reinstating the camber and level of the bridge deck. We note that the attempt to re-level the bridge deck was unsuccessful.

3.4 Structural Evaluations

The pedestrian load capacity of the bridge was assessed in two structural evaluations as noted below.

1984 Public Works Canada Structural Inspection and Evaluation

A detailed structural inspection and evaluation of the bridge was carried out in 1984 by Public Works Canada (PWC) based on the 1978 edition of the CAN3-S6 Canadian Highway Bridge Code. It concluded that:

"the bridge is structurally unsafe to carry the code specified loading as an unrestricted pedestrian facility" and recommended that "the bridge be load posted with a limit of maximum 100 persons on the bridge at any given time as a short-term as well as long-term measure".

2012 DNA Repair Options Report

In 2012, DNA carried out a structural analysis of the bridge based on the current 2006 edition of the CAN3-S6 Canadian Highway Bridge Design Code as part of our Repair Options Report (October 16, 2012). Our analysis generally confirmed the findings of the 1984 PWC evaluation and found that the bridge deck is severely overstressed and did not meet the bridge code requirements for live loads due pedestrian traffic or for snow accumulation and recommended that be designated as a restricted access pedestrian bridge with a posted load limit of six (6) persons on the bridge.

Figure 3. South Elevation of South Tower and Suspension Cable Members

4.0 BRIDGE DESIGN LIFE

4.1 Bridge Design Life

The period of time in which a bridge is intended to remain in service is defined as the design life of the bridge. The design life for a new bridge is specified in the Canadian Highway Bridge Code or by the Owner of the bridge. In 2000, the Canadian Highway Bridge Code increased the specified design life for new bridges from 50 years to 75 years to increase the durability and lifespan of bridges.

4.2 Original Bridge Design

The Ross River suspension bridge was originally designed and constructed in 1944 for war time service in order to carry an oil pipe across the Pelly River. As drawings and specifications of the bridge are unavailable, we are unable to determine key details concerning the design and construction of the bridge;

- The design code and bridge loading used
- The intended design life of the bridge
- the size of the buried steel suspension cable anchors
- the size of the buried concrete suspension cable foundations
- the material specifications for the structural steel, suspension cables, concrete used in the construction of the bridge

However, based on our inspections and engineering analysis of the bridge to date, we do not believe that the bridge was designed to support pedestrian loading with a design life of 50 years. The bridge has in fact remained in service for almost 70 years and has experienced significant deterioration and structural failure in recent years.

4.3 Current Condition

The bridge is in a critical structural condition and in danger of collapse. Given the critical condition of the steel cross beam, the age of the bridge and its poor condition, DNA concluded (see DNA Memorandum to YTG-CS dated September 30, 2013) that it was no longer practical from a structural and construction safety perspective to repair and salvage the bridge. Furthermore, we recommended that the bridge be demolished as soon as possible for safety reasons.

Figure 4. Damaged Steel Head Beam located on top of North Tower

5.0 LIFE CYCLE COST ANALYSIS

5.1 Objectives and Study Period

The objective of this life cycle cost analysis is to identify options and lifecycle costs to provide year round pedestrian access across the Pelly River by means of a pedestrian bridge. We selected a life cycle cost study period of 75 years to coincide with the design life specified by the current highway bridge code for the design of a new bridge. The options presented in this life cycle analysis are based on the three options described in our Repair Options Report for the Ross River Suspension Bridge dated October 16, 2012.

5.3 Bridge Demolition

DNA is currently preparing contract specifications for a public tender to demolish the bridge with an option to leaving both the steel towers in place for cultural reasons. We note that the severe condition of the steel cross beam on top of the north tower of the bridge presents a significant challenge and safety risk for the demolition contractor. We expect that the most cost effective and safest approach is to carry out the demolition of the bridge during the winter freeze up of the Pelly River. At this time, our preliminary cost estimates for the demolition of the bridge during the winter freeze up of the Pelly River is in the order of $ 350,000. We note that the demolition costs are dependent on the method of demolition proposed by the contractor.

5.4 Option 1: Replace Bridge in 5 years

Option 1 is intended to defer the demolition and replacement of the existing bridge by up to five years by carrying out urgent repairs necessary to maintain restricted access pedestrian across the Pelly River in the short term. This option is challenging from an engineering and construction safety perspective due to the number of serious structural deficiencies that need to be addressed on a short term basis. We note that the damaged head beam located on top of the north tower will first need to be safety removed and replaced before any repairs can be carried out to the bridge.

There are important limitations with this option. The short term repairs to the bridge will not increase the restricted pedestrian load capacity of the bridge of six persons, the bridge deck will not be re-levelled and there is a high risk that further deterioration of the un-repaired members and/or further movements in the tower foundations may occur. Furthermore, the use of the existing bridge is conditional and subject to an annual bridge safety inspection and regular maintenance.

5.5 Option 2: Replace Bridge in 25 years

Option 2 is intended to defer the demolition and replacement of the existing bridge by up to 25 years by carrying out major repairs necessary to provide restricted access pedestrian across the Pelly River in the mid-term. The repairs will require; underpinning the tower foundations with piles, re-levelling the towers, replacing and re-anchoring the suspension cables, sway cables, and deck hanger cables, re-constructing a level timber bridge deck and structure, re-constructing the timber approach stairs and repairing and reinforcing the steel towers. We note that the damaged cross beam located on top of the north tower will first need to be safety removed and replaced before any repairs can be carried out.

5.6 Option 3: Replace Bridge Now

Option 3 is intended to replace the existing bridge with a new bridge to provide appropriate pedestrian access across the Pelly River for the next 75 years. To provide a direct cost comparison, the new bridge will be an "in kind" replacement of the existing bridge that matches the design, construction and location of the existing bridge. The new bridge will be designed in accordance with the current Canadian Highway Bridge Code with a pedestrian design loading that will be appropriate for a small remote community. The scope of work for Option 3 does not include the re-location of the bridge to a new site, shore line erosion protection work, roadwork at each end of the bridge approaches or implementing flood control measures.

Table 2 - Life Cycle Options Scope of Work

Item	Option 1 Replace in 5 yrs	Option 2 Replace in 25 yrs	Option 3 Replace Now
Pedestrian design load capacity	6 persons	20 persons	To be determined
Extend service life of existing bridge	5 years	25 years	0 years
Repair timber deck	●	●	○
New timber deck	○	●	●
New timber guard railing	●	●	●
New timber deck stringers	○	●	●
Repair deck truss and sway frames	●	●	○
New timber deck truss & sway frames	○	●	●
Rust coat suspension cables	○	●	●
Re-tighten deck hanger cables	●	●	●
New timber deck hanger cables	○	●	●
Re-tighten sway cables	●	○	○
New suspension and sway cables	○	●	●
New suspension and sway cable anchors	○	●	●
New timber approach stairs	●	●	●
Replace tower cross beams	●	●	○
Repair towers	●	●	○
Underpin towers with piles & re-level	○	●	○
New steel towers with piled foundations	○	○	●
Design & construction period	10 months	14 months	25 months

●	Applicable
○	Not Applicable

5.7 Life Cycle Cost Estimates

The life cycle cost estimates are based on the scope of work identified in Table 2 and conceptual designs we have identified and developed for each option, our past experience with similar projects and discussions with contractors and material suppliers. We believe the Class D level of cost estimate used for this life cycle cost analysis is appropriate and that the additional engineering costs to prepare design for each option in order to prepare more detailed costs estimates is not warranted at this time. We note there are several factors that increase the construction cost of each option:

a) bridge construction requires specialized skills and equipment
b) Ross River is considered a remote community where the cost of labour, materials and equipment high, and
c) some of the construction is expected to occur during the winter.

Table 3 - 75 Year Life Cycle Cost Analysis

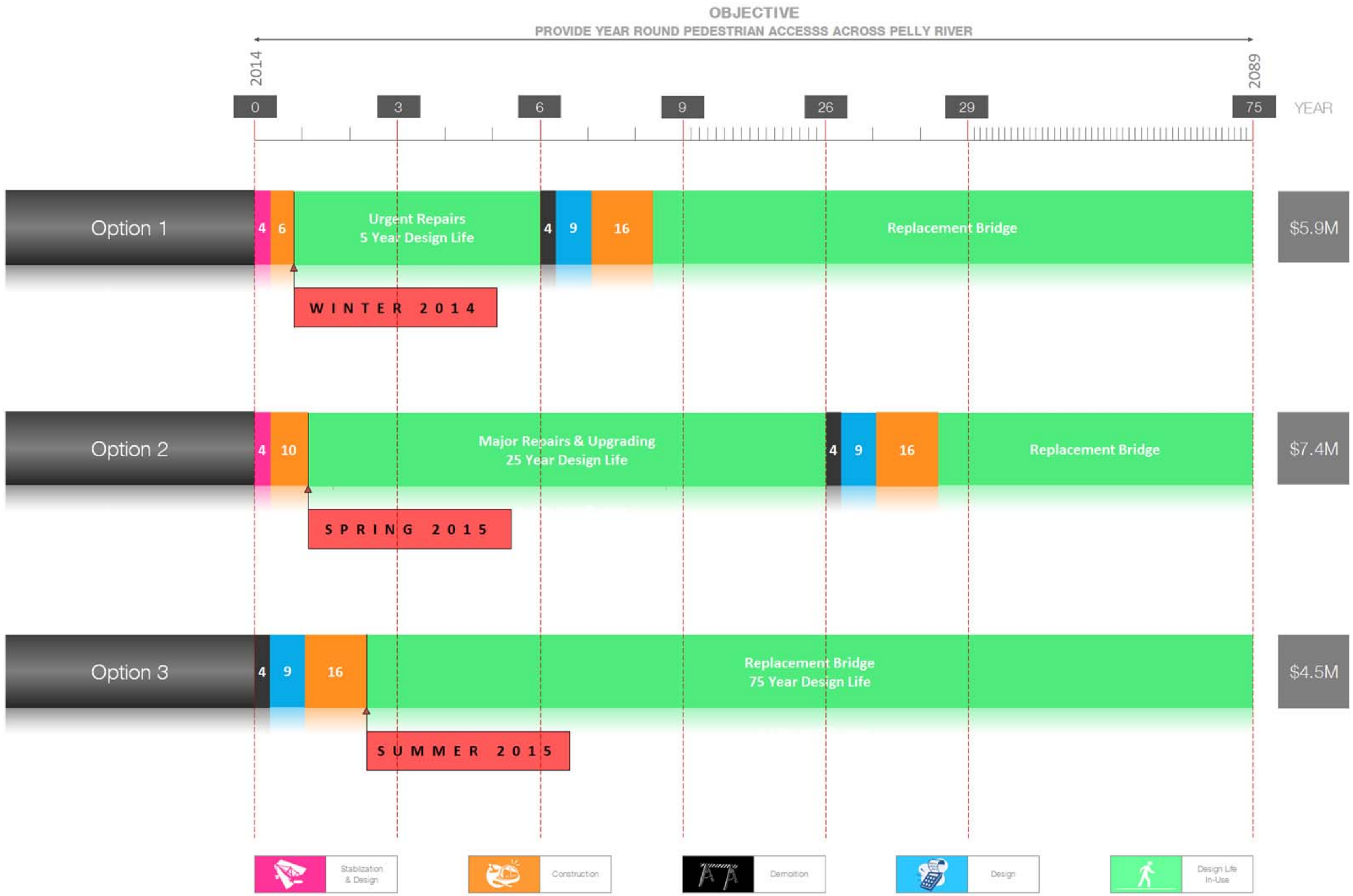
	Item	Option 1 Replace in 5 yrs	Option 2 Replace in 25 yrs	Option 3 Replace Now
Stage 1	Initial Cost	$ 1,430,000	$ 3,379,000	$ 3,944,000
	Maintenance & Inspection Cost	$ 95,000	$ 395,000	$ 608,000
	Residual Value	$ 0	$ 0	$ 0
	Subtotal	**$ 1,525,000**	**$ 3,774,000**	**$ 4,552,000**
Stage 2	Replacement Cost	$ 3,944,000	$ 3,944,000	$ 0
	Maintenance & Inspection Cost	$565,000	$ 429,000	$ 0
	Residual Value	($ 170,000)	($ 772,000)	($ 52,000)
	Subtotal	**$ 4,339,000**	**$ 3,601,000**	**($52,000)**
Total Life Cycle Cost		**$ 5,864,000**	**$7,375,000**	**$ 4,500,000**

Notes	
1	Life cycle cost analysis based on 75 year study period with all costs and values discounted back to Net Present Value based on a discount rate of 1.5%
2	The Total Life Cycle Cost in Net Present Value (NPV) is calculated as follows: NPV= Initial Cost + NPV(Maintenance & Inspection Cost + Replacement Cost) – NPV (Residual Value)
3	Replacement bridge based on a design life of 75 years
4	Cost Estimates are Class D Estimates with a 30% Contingency

5.8 Preliminary Life Cycle Time Line

To assist YTG-CS in their planning, DNA has prepared a preliminary life cycle time line for the three options presented in this report (see Figure 5). We note that the life cycle time line is subject to change and is dependent on the time required to secure funding, complete planning and public consultation activities and to obtain regulatory approvals.

Figure 5. Ross River Suspension Bridge Life Cycle Options Timeline



Note:
- i. Timeline is not to scale
- ii. Bridge re-opening dates are approximate only and based on engineering design starting in early 2014
- iii. Duration of each activity is shown in months and are estimates only and subject to revision
- iv. Life Cycle Cost Estimates are Class D Estimates with a 30% contingency in 2013 dollars over a 75 year study period

6.0 LIFE CYCLE EVALUATION

6.1 Decision Matrix

To assist YTG-CS in their evaluation and selection of a preferred option, a decision matrix is provided in Table 4. The decision matrix evaluates the three options under five separate criteria with a four point numerical scoring system ranging as described below.

Table 4 - Decision Matrix

Criteria	Option 1 Replace in 5 yrs	Option 2 Replace in 25 yrs	Option 3 Replace Now
Life Cycle Cost	1	2	4
Bridge Out-of-Service Time	4	3	2
Risk	1	2	4
Pedestrian Load Capacity	1	1	4
Maintenance Cost	2	1	2
Total Score	**9**	**9**	**16**

Scoring System: 4 = Excellent 3 = Good 2 = Fair 1 = Poor

6.2 Risk Analysis

6.2.1 Structural Risk

There are some risks associated with the life cycle options presented in this report. At almost 70 years old, the bridge has exceeded its design life and is currently at the point of collapse. Although it is technically possible to extend the life of the existing bridge by implementing either Option 1 or Option 2, there are risks that further deterioration and damage in the towers, tower foundations, cables and cable anchors will require further repairs or earlier demolition of the existing bridge. These risks are mitigated with Option 3 which replaces the existing bridge with a new bridge design to current bridge code with a design life of 75 years.

6.2.2 Cost Escalation Risk

The longer the demolition and replacement of the existing bridge is deferred, the greater the risk and uncertainty of future construction costs.

6.3 Findings

Based on our decision matrix, Option 3 scores the highest with 16 points out of a possible 20 points. Compared to other options, Option 3 has the lowest life cycle cost, the lowest risk and highest pedestrian load capacity.

7.0 CLOSURE

We trust that this Life Cycle Cost Analysis will help YTG-CS to make appropriate planning decisions with respect to the Ross River Suspension Bridge. Please contact DNA should you require further information or discussion regarding our report.

We thank you for the opportunity for DNA to assist YTG-CS with this important project.

Appendix A
Detailed Cost Estimate

Table A1 - Detailed Cost Estimate

Stage 1		Option 1 Replace in 5 yrs	Option 2 Replace in 25 yrs	Option 3 Replace Now
	General Conditions	$ 145,000	$ 215,000	$ 260,000
	Demolish existing bridge	$ 0	$ 0	$ 250,000
	Towers	$ 430,000	$ 927,000	$ 840,000
	Deck Structure	$ 185,000	$ 285,000	$ 410,000
	Suspension System	$ 81,000	$ 560,000	$ 560,000
	Subtotal	**$841,000**	**$1,987,000**	**$ 2,320,000**
	Class D Estimate Contingency at 30%	$ 253,000	$ 596,000	$ 696,000
	Contractor overhead & profit at 20%	$ 168,000	$ 398,000	$ 464,000
	Engineering & Construction Monitoring	$ 168,000	$ 398,000	$ 464,000
	Total Construction	**$1,430,000**	**$ 3,379,000**	**$ 3,944,000**
	Total Maintenance & Inspection	**$ 135,000**	**$ 485,000**	**$ 1,085,000**

Stage 2		Option 1 Replace in 5 yrs	Option 2 Replace in 25 yrs	Option 3 Replace Now
	General Conditions	$ 260,000	$ 260,000	
	Demolish Existing Bridge	$ 250,000	$ 250,000	
	Towers	$ 840,000	$ 840,000	
	Bridge Deck	$ 410,000	$ 410,000	
	Suspension System	$ 560,000	$ 560,000	
	Subtotal	**$ 2,320,000**	**$ 2,320,000**	
	Class D Estimate Contingency at 30%	$ 696,000	$ 696,000	
	Contractor overhead & profit at 20%	$ 464,000	$ 464,000	
	Engineering & Construction Monitoring	$ 464,000	$ 464,000	
	Total Construction	**$ 3,944,000**	**$ 3,944,000**	**$ 3,944,000**
	Total Maintenance & Inspection	**$ 1,015,000**	**$ 725,000**	**$ 0**

Notes	
1	The replacement bridge is based on current Canadian Highway Bridge code with a design life of 75 years. Replacement bridge to be an “in kind” replacement of the existing bridge to match the design, construction and location of existing bridge
2	Costs do not include public hearings, regulatory reviews
3	Costs above are not adjusted for Net Present Value