



QEW Garden City Skyway Niagara Street to Glendale Avenue



Risk and Value Engineering Support Major Infrastructure Decisions

Rob Kivi, P.Eng.
MMM Group Limited

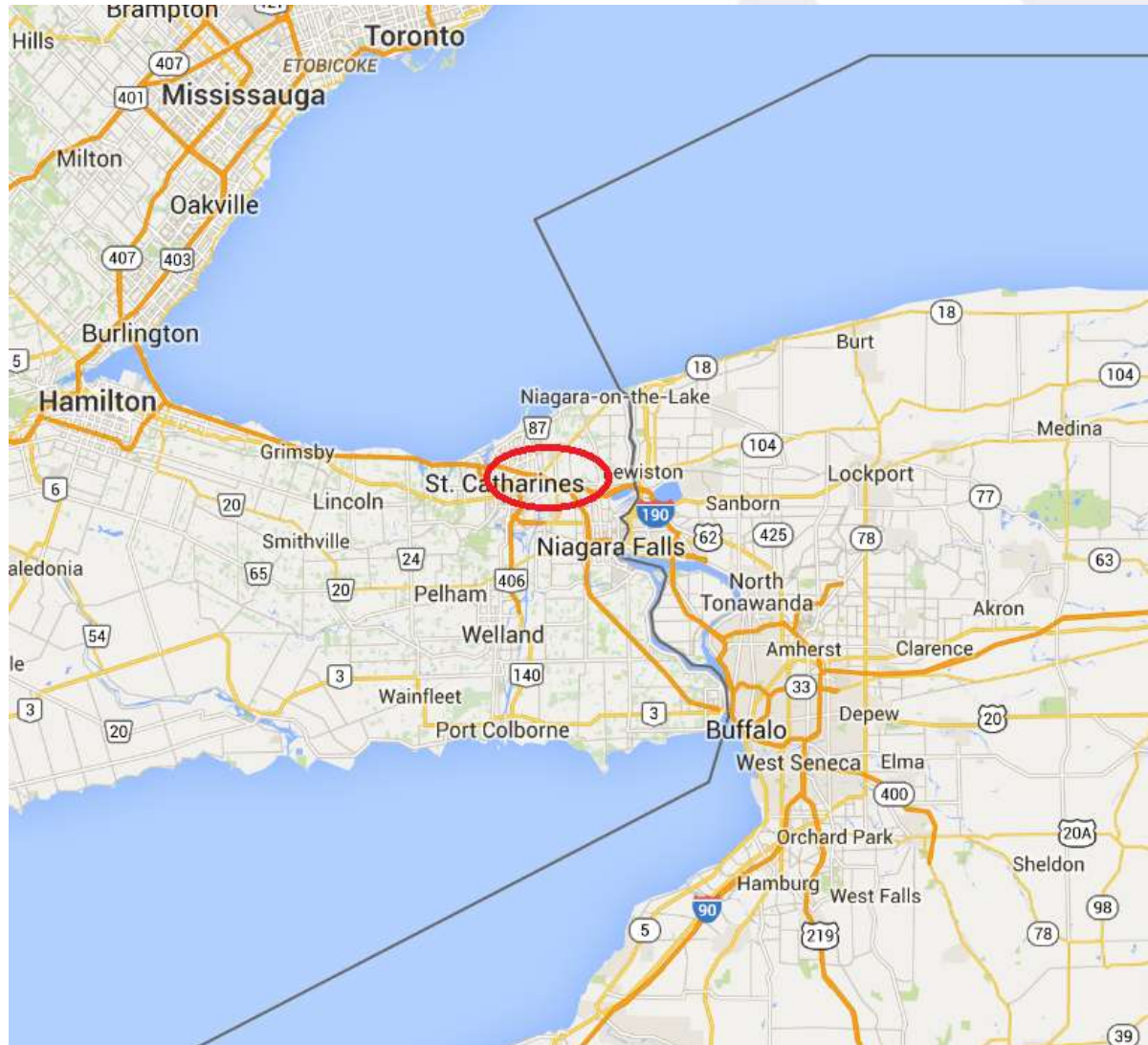


COMMUNITIES
TRANSPORTATION
BUILDINGS
INFRASTRUCTURE

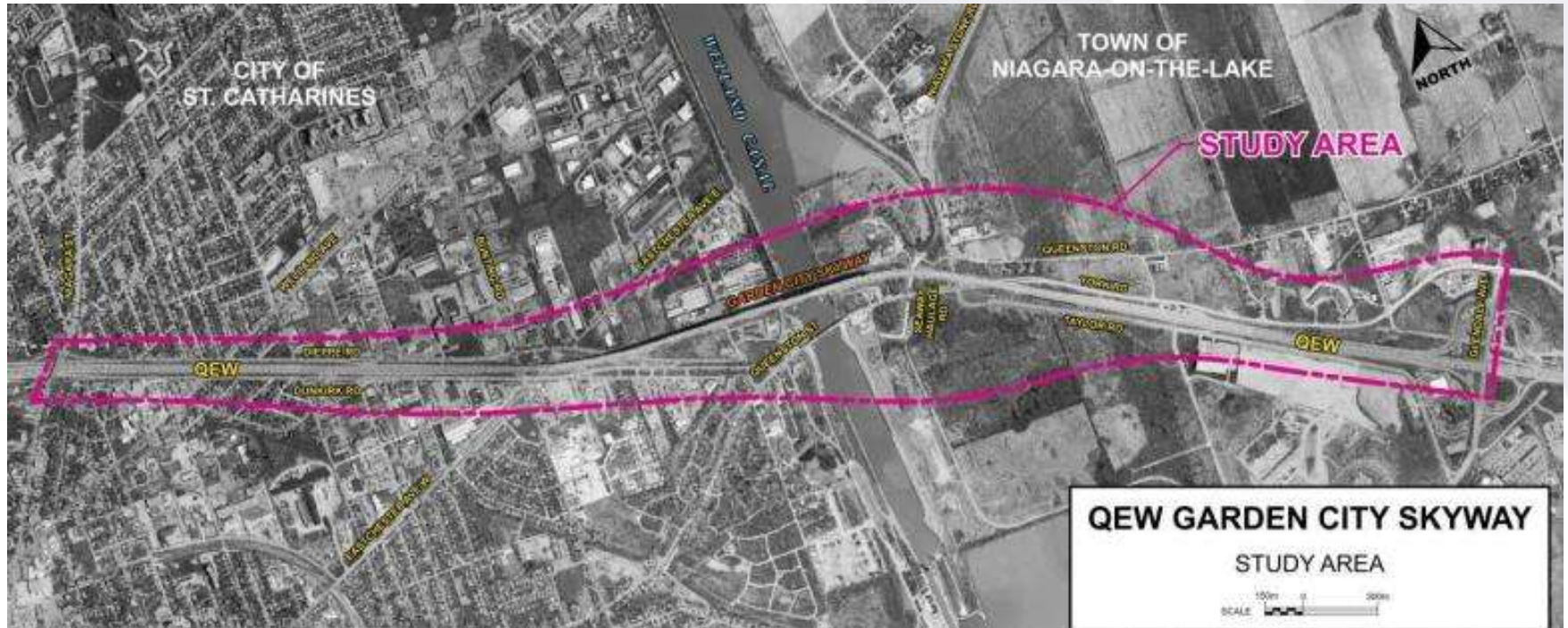
Garden City Skyway

- 48 span, 2.2 km long high level structure carrying the Queen Elizabeth Way (QEW) over the Welland Canal
- Located in western part of the City of St. Catharines and eastern part of the Town of Niagara on the Lake
- The bridge carries 6 lanes of traffic and serves significant volumes of commercial and tourist traffic travelling to/from the US border crossings in Niagara
- Welland Canal is part of the St. Lawrence Seaway; connects Lake Ontario and Lake Erie.
 - Required clearances:
 - Vertical = 36.6 m (120 ft)
 - Horizontal = 38.1 m from canal centreline (125 ft)

Location Plan



Study Area



Project Background

- The bridge was constructed in the early 1960's to replace the Homer Lift Bridge as the QEW crossing of the Welland Canal
- A study was initiated in 2011 to determine a long term strategy to address the structural, traffic, safety and operational needs of the crossing
- It is anticipated that a deck replacement of the existing Garden City Skyway will be required by approximately 2025
- Deck replacement cannot be undertaken without significant traffic impacts unless additional capacity is provided at the crossing
- Additional identified concerns include:
 - Deteriorating structural condition
 - Substandard shoulder widths/lack of refuge for disabled vehicles
 - Reduced truck speeds due to long approach grades
 - Less than desirable alignment elements

Project Background

- Heritage assessment has given the existing structure a score of 90/100, making it the highest rated structure in MTO's inventory
- The Preliminary Design Study developed and evaluated a variety of alternatives and short-listed two options:
 - North side twinning, with rehabilitation of the existing bridge
 - North side replacement, with demolition of the existing bridge
- Based on the team's evaluation, including life cycle costing for 100 years, north side twinning with rehabilitation of the existing bridge was identified as the preferred solution.

Site Conditions



Value Engineering and Risk Studies

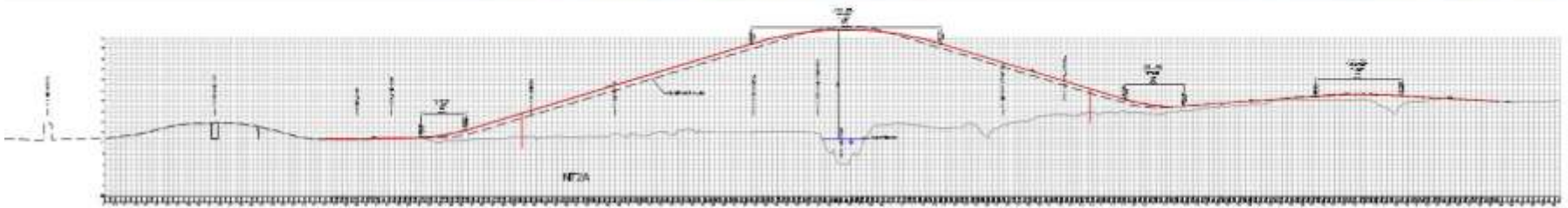
- Integrated Value Engineering and Schedule/Cost Risk studies were undertaken to review the short listed concepts for the Garden City Skyway
 - 2 day Risk workshop
 - 5 day VE workshop
 - 1 day Risk wrap-up
- For the purposes of these studies, north side twinning was assumed to be the Base Case design
- A broad range of subject matter experts and stakeholders were engaged in the VE and Risk Workshops
- Stakeholder participants include St. Lawrence Seaway Authority, City of St. Catharines, Town of Niagara on the Lake and Niagara Region

Base Case Design

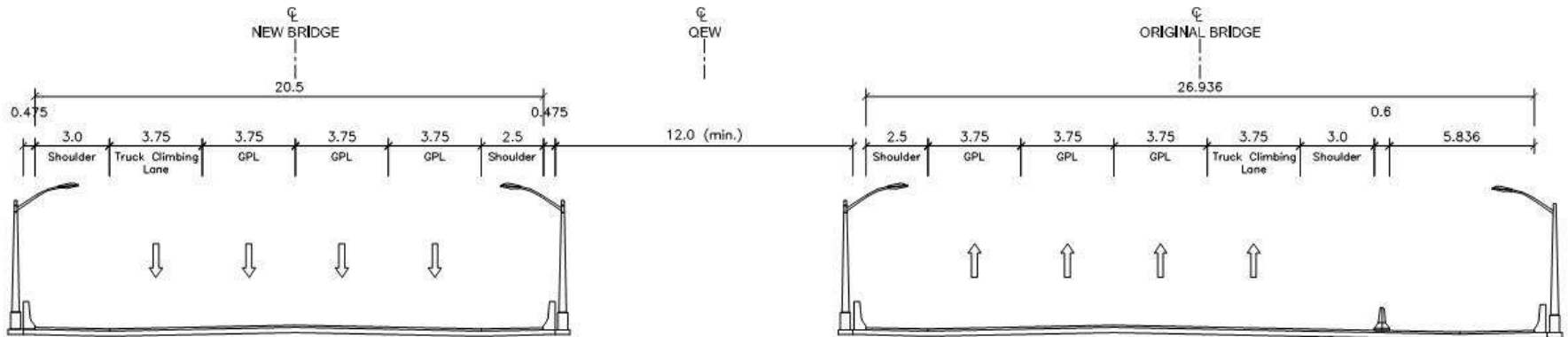
The initially recommended design was based on north side twinning, with rehabilitation of the existing bridge.

- New structure and approaches:
 - designed to 120 km/h standards, using desirable 1700 m minimum horizontal radius
 - Traffic lanes: 4 @ 3.75 m (3 General Purpose + Truck Climbing Lane)
 - Shoulders: 2.5 m (median) and 3.0 m (outside)
 - Maximum 3% grades on QEW
- Existing structure rehabilitated
 - Full deck replacement by 2025, incorporating stainless steel rebar
 - Traffic lanes: 4 @ 3.75 m (3 General Purpose + Truck Climbing Lane)
 - Shoulders: 2.5 m (median) and 3.0 m (outside) (+5.8 m excess deck)
 - Existing alignment retained (min. 870 m radius; ~90 km/h DS vertical crest)
- Estimated Life Cycle cost = \$433.7 million

Base Case Design

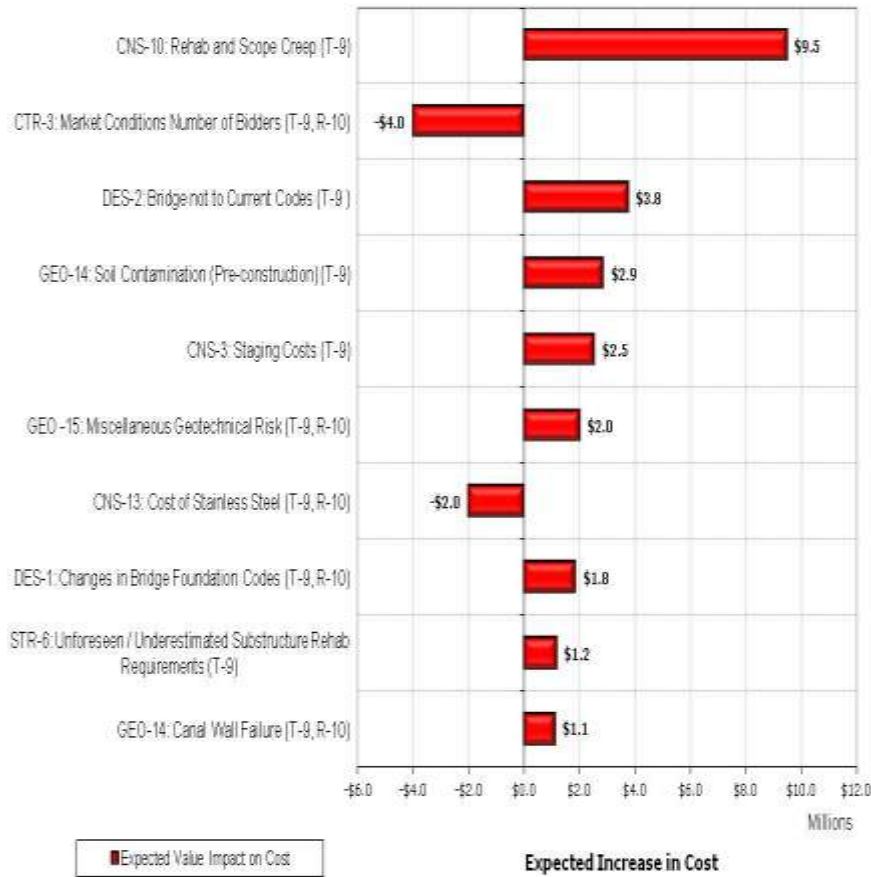


Base Case Design

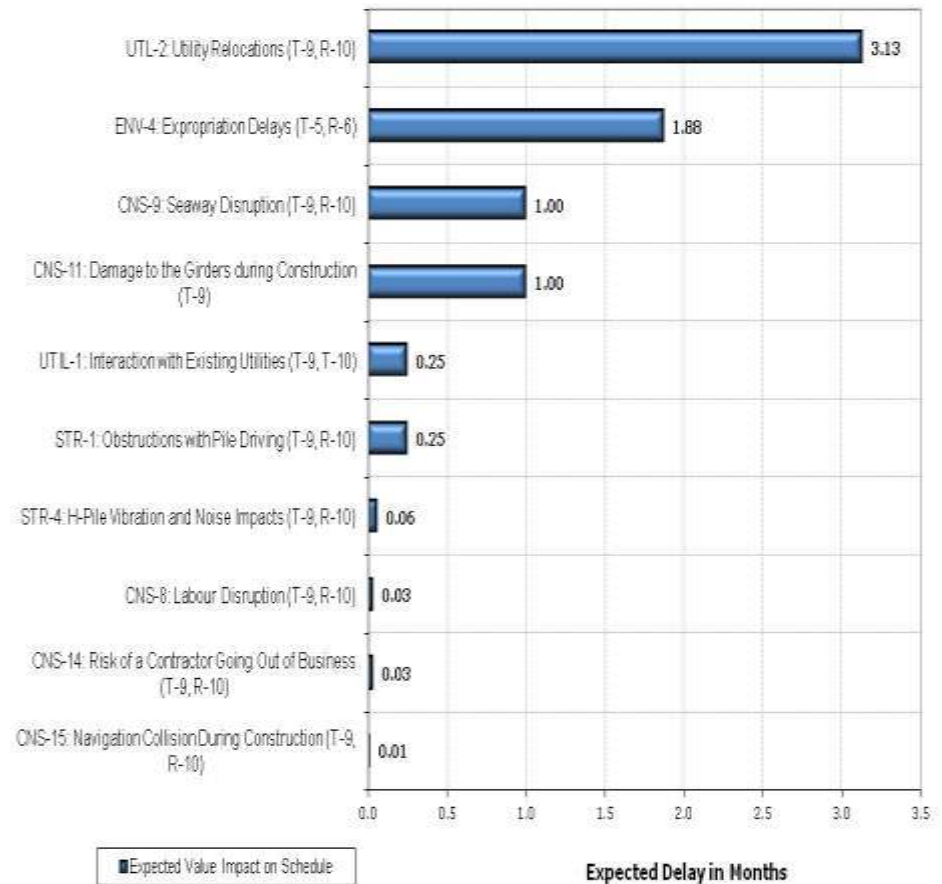


Project Risks - Twinning

Top Cost Risk Events for Twinning Option

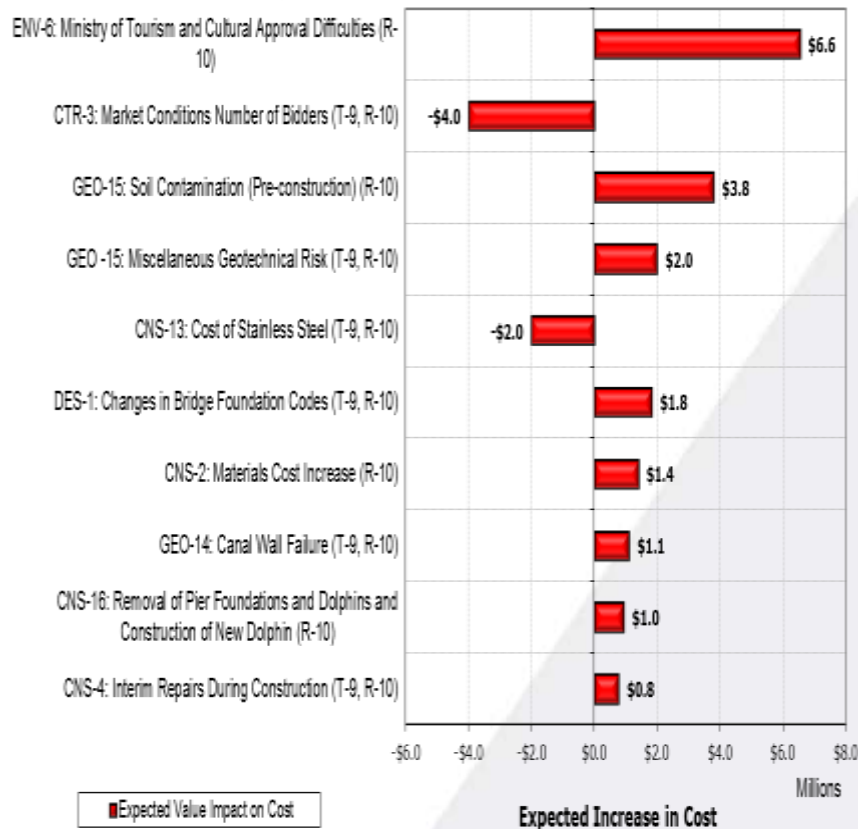


Top Schedule Risk Events for Twinning Option

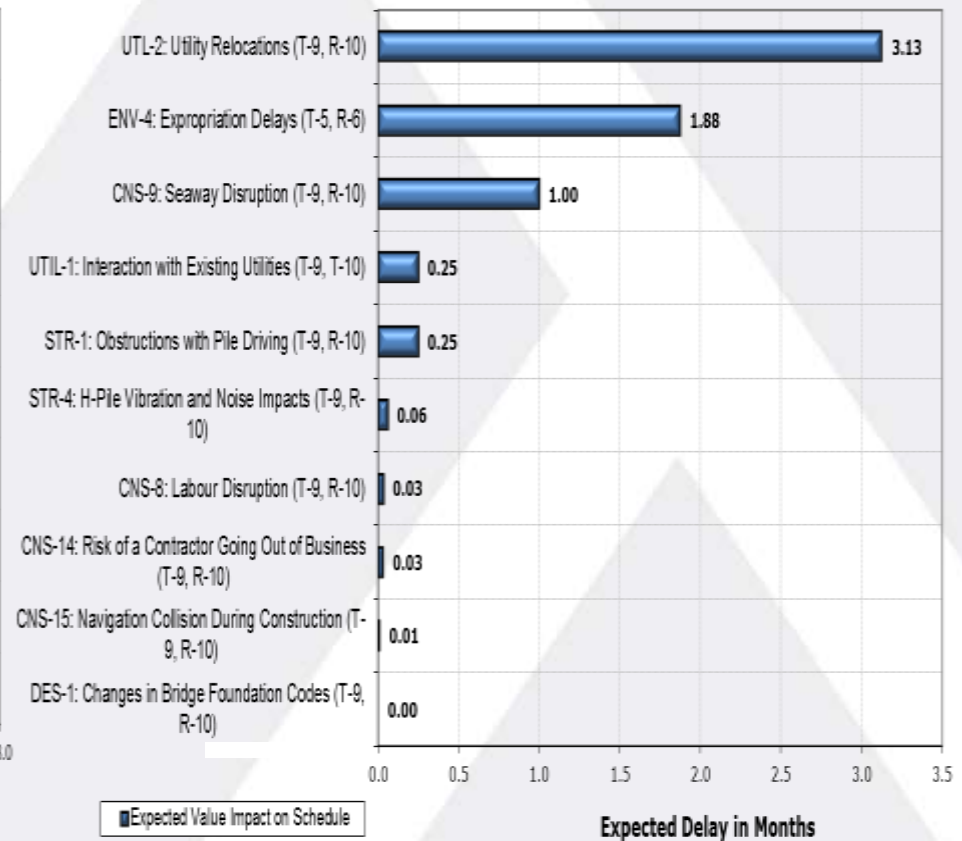


Project Risks - Replacement

Top Cost Risk Events for Replacement Option



Top Schedule Risk Events for Replacement Option



Project Risks

- There is considerable uncertainty among the Risk and VE teams about whether the existing Garden City Skyway structure would be economically viable for an additional 100 years (beyond 2020).
- There is also a high level of comfort that the structure will remain economically viable beyond 2020.
- Conclusions:
 - Replacement in 2020 is premature;
 - Expecting 100 more years from the existing bridge is optimistic.

Performance Criteria

Based on the VE Team's understanding of key project issues, six Performance Criteria were identified:

- Structural Durability
- Operations and Safety
- Constructability and Staging
- Cultural Environment
- Socio-economic Environment
- Natural Environment

Scenarios

- The various VE ideas were combined into scenarios for comparison to the base case design
- Scenarios combined design ideas with timing/phasing options.
 - Potential combinations are numerous
 - A representative cross section representing a range of perceived high value scenarios was selected for evaluation
- Each scenario was evaluated using the identified Performance Measures

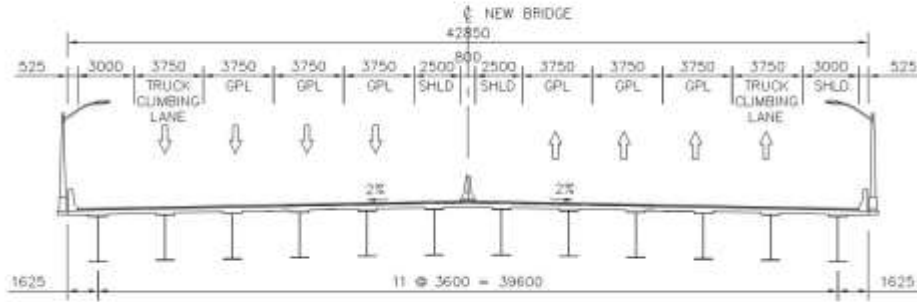
Scenario 1

Planning Alternative RB1A (north side replacement)

Includes:

- New single replacement bridge on the north side of existing, constructed beginning in 2020
- Improved horizontal and vertical alignment (both directions)
- Demolition of existing structure following opening of new bridge.

Scenario 1

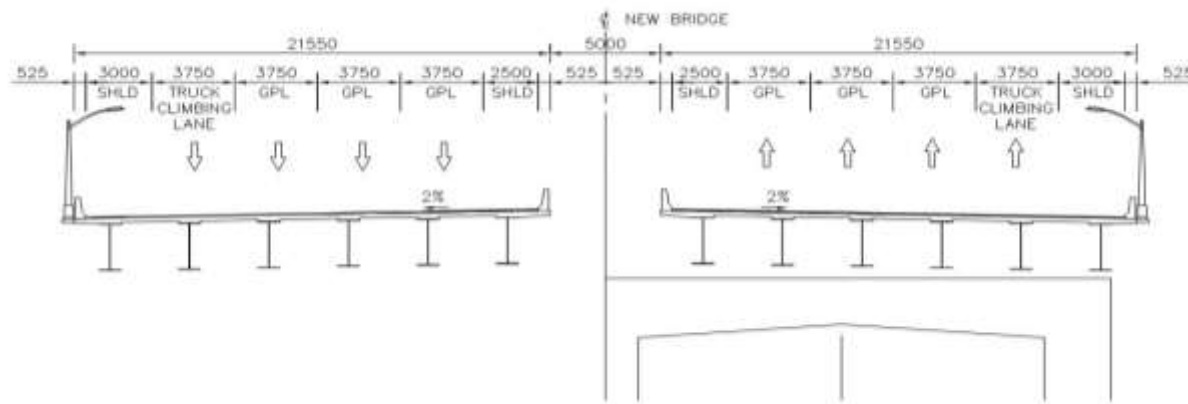


Scenario 1a

Scenario 1 optimized

Includes:

- Twin replacement bridges on the north side of existing constructed beginning approximately 2040
- Minor rehabilitation of existing to allow deferral of replacement
 - Existing geometrics retained for additional 20 years
- Improved horizontal and vertical alignment (both directions)
- Demolition of existing structure



Scenario 2

Twinning (NT2A) and Deferred Deck Replacement on Existing

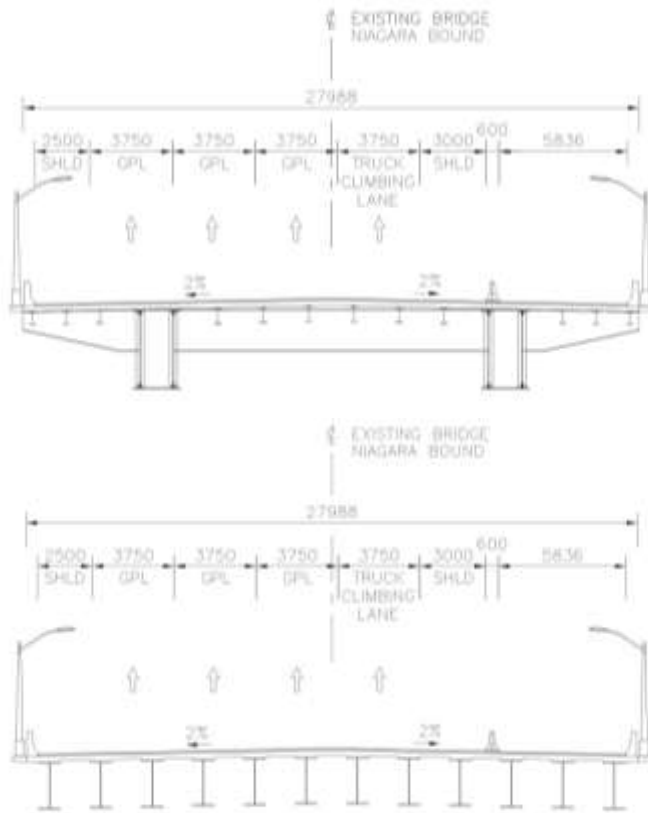
Includes:

- New twin structure on north side of existing, with reduced median shoulder (1.5 m). Constructed beginning in 2020.
- Improved horizontal and vertical alignment (one direction)
- Holding strategy rehab on existing deck to defer deck replacement
- Additional rehabilitation on existing girders and piers
- Deferred deck replacement (approx. 2030) with narrower deck to reduce cantilevers (main spans) and eliminate outside girders (approach spans)

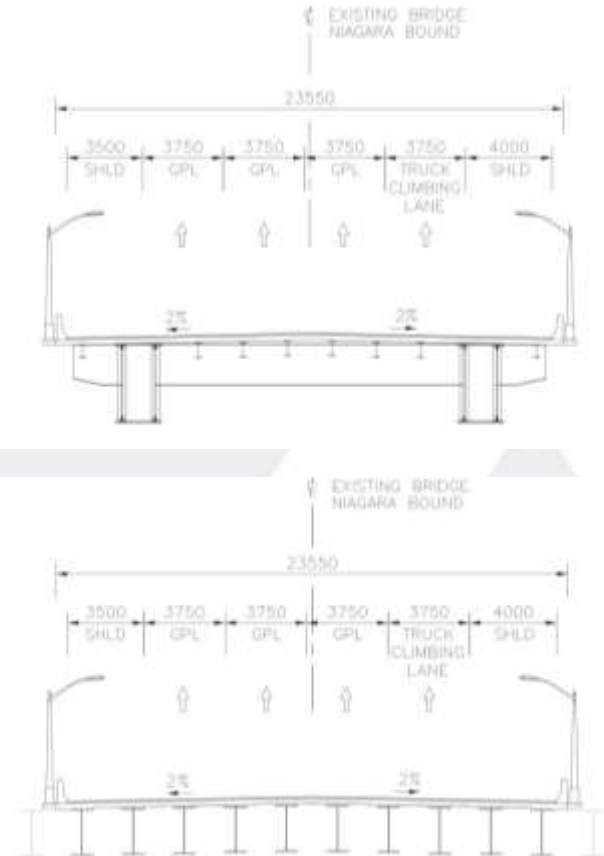
Scenario 2

Retained Structure

Present Design



Proposed Design



Scenario 2 Variations

Scenario 2a

- Scenario 2 without alignment improvement (match existing 870 m radius) on approach to new structure

Scenario 2b

- Scenario 2 with wider deck on twin structure to permit 6 lane divided operation for future construction staging (4 lanes and full shoulders for normal operation)

Scenario 2c

- Scenario 2 with twinning to the south

Scenario 2d

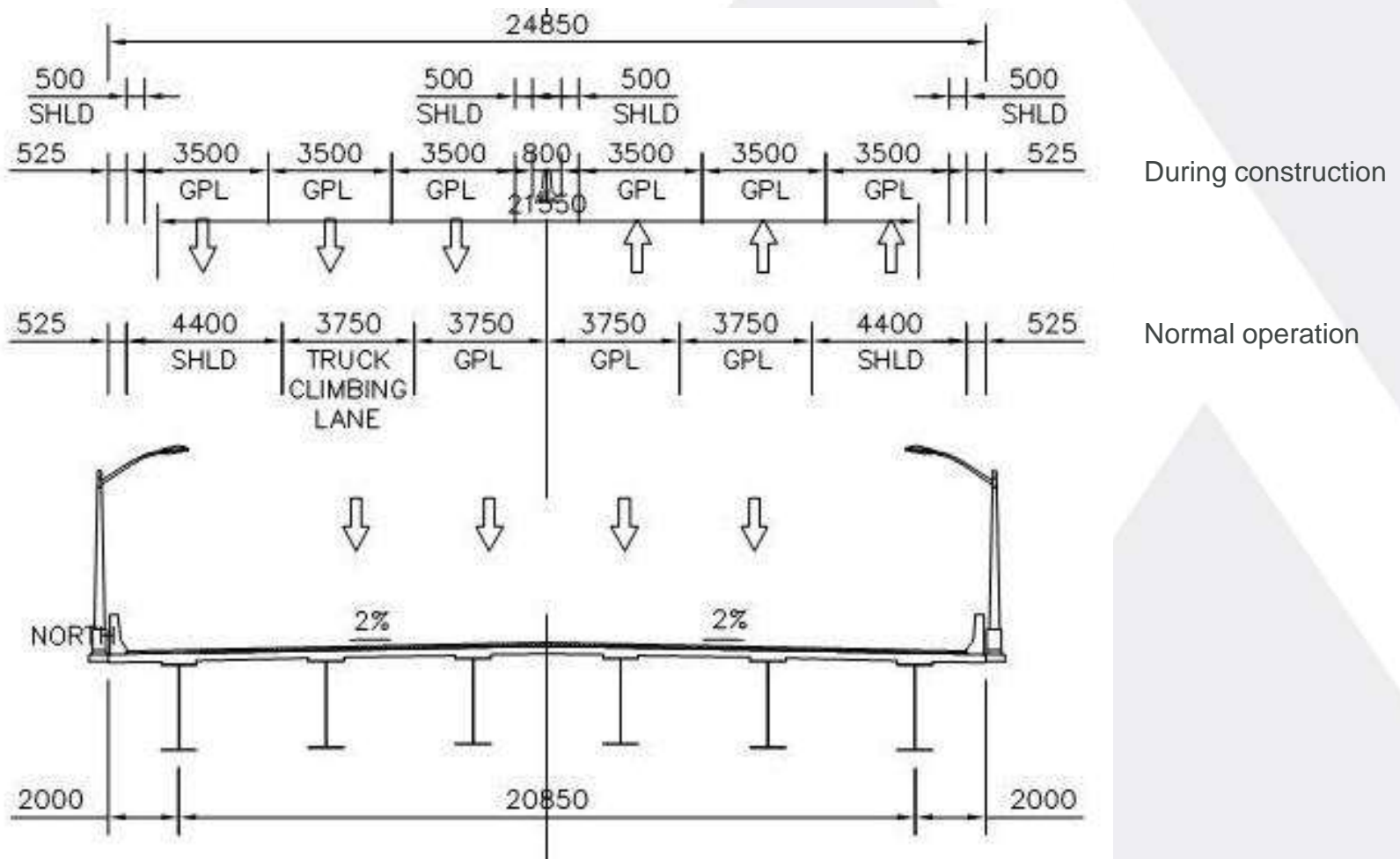
- Scenario 2 without alignment improvement on approach to new structure; wider deck on twin structure to permit 6 lane divided operation for future construction staging (4 lanes and full shoulders for normal operation)

Scenario 2e

- Scenario 2 with twinning to the south and wider deck on twin structure to permit 6 lane divided operation for future construction staging (4 lanes and full shoulders for normal operation)

Scenario 2 variations

Wider twin structure to accommodate 6 lanes during rehabs



Scenario 3

Twin and defer replacement of existing structure

Includes:

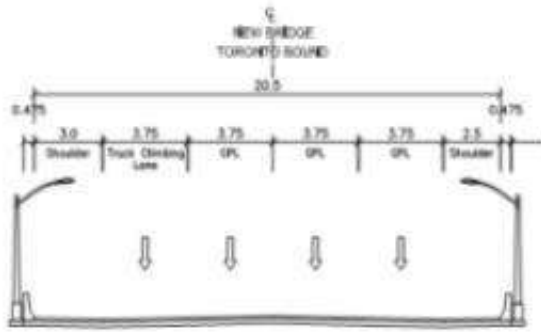
- Phased replacement bridges on the north side of existing
 - Construct first twin structure to the north of existing beginning in 2020
 - Minor rehabilitation of existing to extend service life (assumed 20 years), including centering lanes to reduce load on cantilevers
 - Deferred construction of second twin structure to the north in 2040, with 1.5 m median shoulder
- Improved horizontal and vertical alignments
- Demolition of existing structure

Scenario 3a

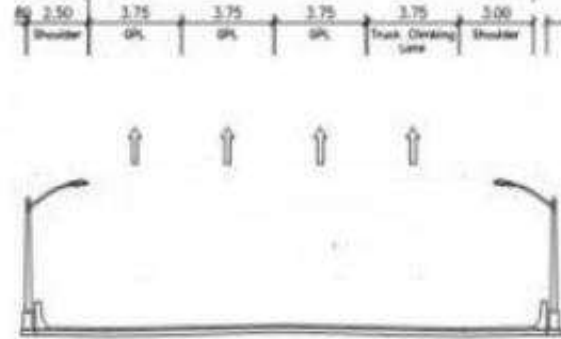
As above, with one twin structure south of existing

- 1.5 m median shoulders provided on both new structures

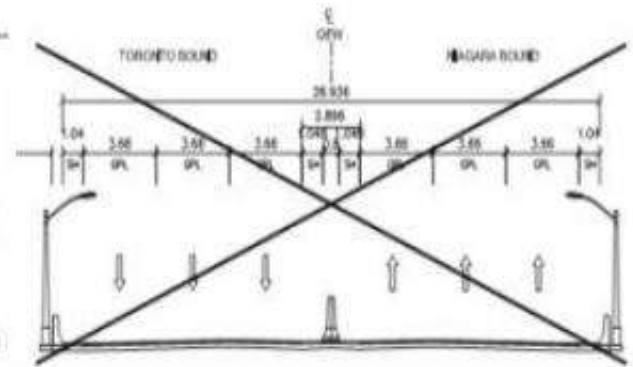
Scenario 3



Toronto bound lanes
(deferred)



Niagara bound lanes
(initially used Toronto bound)



Existing (initially converted to EB lanes
later demolished after construction of
new Toronto bound structure)

Risk Update

Following evaluation by the VE team, a number of Scenarios were returned to the Risk Team for review and modeling of risk-adjusted LCC. These included the two short listed Preliminary Design alternatives, plus:

Scenario 1a – Deferred full replacement

Scenario 2e – New twin structure to the south and wider deck on twin structure to permit 6 lane divided operation for future construction staging

Scenario 3 – Phased replacement bridges on the north side of existing

Scenario 2b – New twin structure north of existing with wider deck to permit 6 lane divided operation for future construction staging (4 lanes and full shoulders for normal operation)

Risk based costs were used to re-calculate value (P/C) scores

Risk Update

W.O. 08-2009 QEW Garden City Skyway
from Niagara Street to Glendale Avenue



SCENARIO EVALUATION MATRIX												
1. HOW WELL DOES THE SCENARIO SATISFY THE PERFORMANCE CRITERIA (ENTER RATING FROM 1-10, 10=BEST) 2. ENTER ASSIGNED WEIGHT TIMES RATING IN SUB TOTAL 3. SUM ACROSS AND RANK	Performance Criteria - Performance Measure	Structural Durability	Operations & Safety	Constructability & Staging	Cultural Environment	Socioeconomic Environment	Natural Environment	Total Performance (P)	Total Life Cycle Cost (NPV) \$ W (VE Cost Model) (C)	PIC (VE Study)	Total Life Cycle Cost (Risk adjusted) (\$M)	PIC (Post Risk)
SCENARIOS		28	28	20	10	7	4					
BASE CASE: NT2A Twinning (1700m radius) and Rehab	Rating 5-10	6.00	9.50	5.00	10.00	8.00	9.00					
	Sub Total	188.00	266.00	100.00	130.00	56.00	36.00	756	433.7	1.743	458.90	1.647
SCENARIO 1: RB1A Replacement (1700m)	Rating 1-10	9.00	10.00	10.00	3.00	5.00	7.00					
	Sub Total	252.00	280.00	200.00	39.00	35.00	28.00	834	587.5	1.42	490.20	1.67
SCENARIO 1a: Optimized Replacement (1700m) deferred for 20 years through a holding strategy (E-23) and build as a twin with 1.5m inside shoulder (S-48) on tangents	Rating 1-10	8.50	7.00	9.00	5.00	6.00	7.50					
	Sub Total	266.00	196.00	180.00	65.00	42.00	30.00	779	389.3	2.00	398.00	1.98
SCENARIO 2: Optimized Twinning (NT2A) and Rehab with 1.5m inside shoulder (S-48) on tangents	Rating 1-10	7.00	8.50	5.00	8.50	8.00	9.00					
	Sub Total	196.00	238.00	100.00	110.50	56.00	36.00	737	430.2	1.71		
SCENARIO 2a: Scenario 2 on NT2 alignment with 1.5m inside shoulder (S-48) on tangents	Rating 1-10	7.00	8.00	8.00	8.00	10.00	10.00					
	Sub Total	196.00	224.00	100.00	117.00	70.00	40.00	747	414.8	1.80		
SCENARIO 2b: Scenario 2 with 6 lanes plus 1m shoulders on twin structure during rehab of existing bridge (C-38)	Rating 1-10	7.00	9.50	7.50	8.50	8.00	9.00					
	Sub Total	196.00	286.00	150.00	110.50	56.00	36.00	815	468.8	1.737	495.10	1.645
SCENARIO 2c: Scenario 2 with twinning to the south (E-8) and a 1.5m inside shoulder (S-48) on tangents	Rating 1-10	7.00	8.50	5.00	8.50	8.00	9.00					
	Sub Total	196.00	238.00	100.00	110.50	56.00	36.00	737	403.3	1.83		
SCENARIO 2d: Scenario 2 on NT2 alignment with 6 lanes plus 1m shoulders on twin structure during rehab of existing bridge (C-38)	Rating 1-10	7.00	9.00	7.50	9.50	8.00	9.50					
	Sub Total	196.00	252.00	150.00	123.50	56.00	38.00	816	453.5	1.80		
SCENARIO 2e: Scenario 2 with twinning to the south (E-8) and 6 lanes plus 1m shoulders on twin structure during rehab of existing bridge (C-38)	Rating 1-10	7.00	9.50	7.50	9.00	10.00	9.00					
	Sub Total	196.00	266.00	150.00	117.00	70.00	36.00	835	442.7	1.9	484.60	1.80
SCENARIO 3: Twin and Deferr Replacement for 20 years (E-2, 23) and a 1.5m inside shoulder (S-49) on shoulders	Rating 1-10	10.00	8.00	8.50	5.00	8.00	7.50					
	Sub Total	280.00	252.00	170.00	65.00	56.00	30.00	863	518.1	1.65	460.70	1.85
SCENARIO 3a: Build twin structure to north & defer future replacement to south (E-18) for 20 years and a 1.5m inside shoulder (S-49)	Rating 1-10	10.00	9.00	8.50	5.00	5.00	7.00					
	Sub Total	280.00	252.00	170.00	65.00	35.00	28.00	830	500.6	1.66		

SEEK THE BEST - NOT PERFECTION

Ranking of Carry-forward options				
Performance (P)	PIC Ranking (Highest to lowest)		LC Cost Ranking (Lowest to highest)	
	VE	Post Risk	VE	Post Risk
6	3	5	2	2
3	6	4	6	6
5	1	1	1	1
4	4	6	4	5
2	2	3	3	4
1	5	2	5	3

Evaluation

Post-risk results did not significantly alter the ranking of Scenarios:

- Scenario 1a (Deferred full replacement) was determined to have the best value score, both pre- and post-risk.
 - Deferral of any significant capital investment reduces PV LCC, offsetting relatively low performance score
 - No geometric improvements for 20 years
- Scenario 3 (Phased replacement) has the best performance score; Pre- and post- risk value scores ranked 5th and 2nd.
- Scenario 2e (South side twin structure with wider deck) has second highest performance score. Pre- and post-risk value scores ranked 2nd and 3rd.

Conclusions and Observations

- There is strong consensus that replacement of the existing structure in 2020 is premature. Efforts should be made to utilize remaining service life of the existing bridge deck.
- The bridge engineers developed various recommendations to maximize the service life of the existing structure, however concerns remain whether an additional 110 years (from today) can be achieved.
- Two fundamental approaches with the existing structure:
 - With appropriate hold strategies, could continue to utilize the bridge until 2035-2040
 - With proactive asset management, including deck replacement, protection of structural steel and foundations, service life could optimistically be extended for 75 years
- There is currently insufficient information to confidently estimate the remaining service life.

Conclusions and Observations

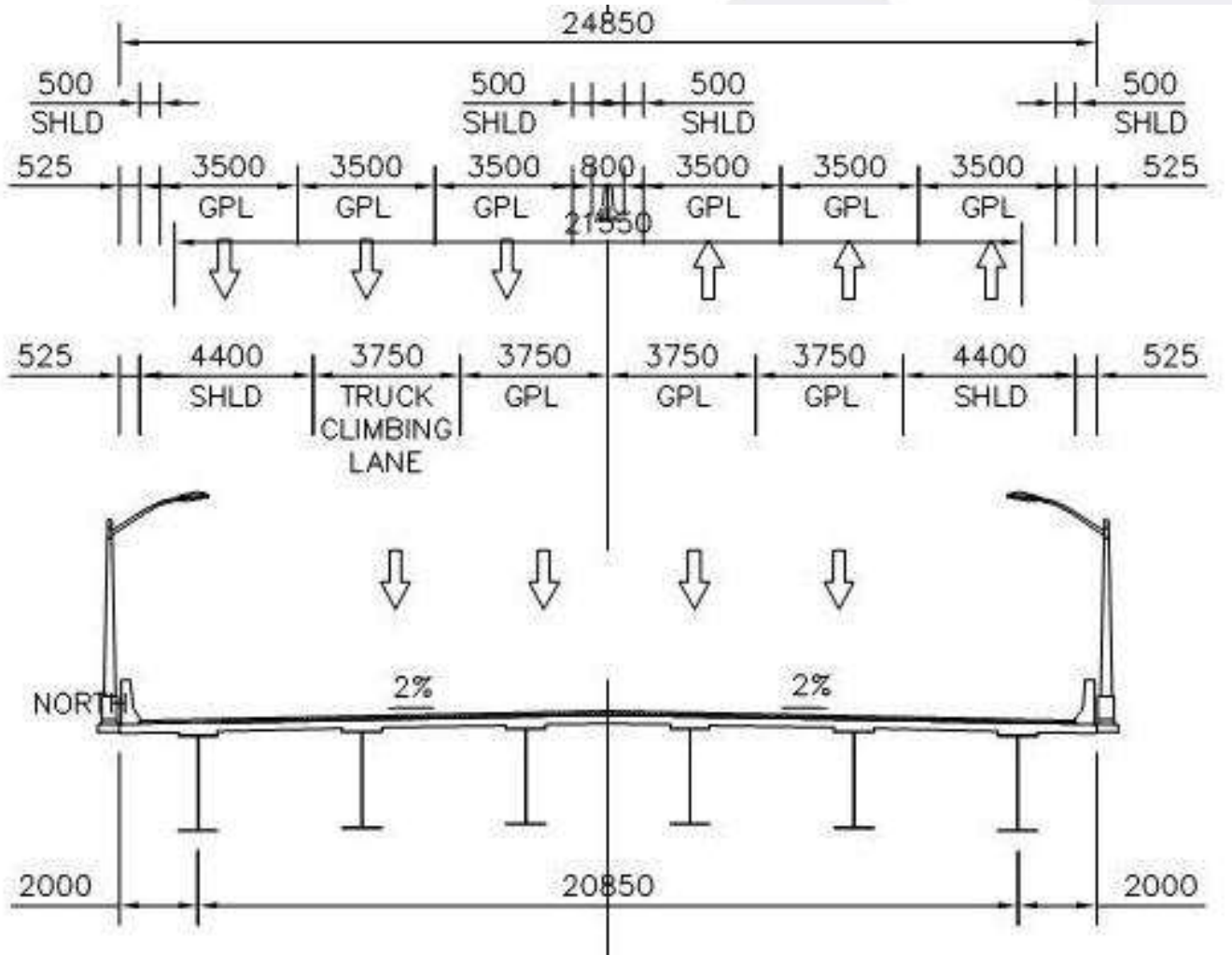
- Providing a wider deck (approx. \$39M capital cost premium) on a twin structure provides MTO with additional flexibility:
 - Facilitates single stage rehabilitation or deck replacement (traffic removed from existing bridge)
 - Allows option of full superstructure replacement
 - Would facilitate full replacement on existing alignment (with alignment correction within ROW)
 - Provides flexibility for future capacity expansion
- Allows for deferral of the decision of whether (and when) to replace or rehabilitate the existing structure until there is sufficient information to make the decision with a high degree of confidence
- Twinning retains the heritage asset as long as structurally viable

VE and Risk Study Recommendations

- Twin the existing structure in 2020 with a bridge having a wider deck to accommodate 6 lanes of traffic for future staging.
 - Scenario 2e (south side) or Scenario 2b (north side) are viable options. Preferred alignment to be confirmed following further study.
- Following completion of the twin structure, two way traffic will be placed on the new bridge to reconfigure existing. This presents an ideal opportunity to undertake detailed evaluation of the condition of the existing structure and make decisions regarding next steps.
- EA should endeavour to maintain maximum flexibility for various bridge types and span arrangements to be considered in detail design

Recommendations

Wider twin structure



Study Format Observations

- Understanding and quantifying risks was a critical part of project decision making
 - Performance risks associated with retaining 50 year old infrastructure
 - Constructability and traffic risks
 - Community impact risks
- Since the VE study was informed by the initial risk study, team could focus on solutions which mitigate risks
- Risk based life cycle costs provide owner with greater level of comfort when making decisions.

Benefits

- Maximizes flexibility – wide range of options for existing bridge
- Allows decision regarding replacement to be made at the optimum time
 - Monitoring and comprehensive condition surveys can be used to support decision.
- Wider twin structure helps manage risk – traffic can be removed from existing bridge on short notice.
- Retains the heritage asset as long as structurally viable; stronger argument for demolition when end of viable service life can be demonstrated.

Acknowledgements

The study was collaborative effort between MMM, HDR and Faithful+Gould, supported by subject matter experts from MTO and other organizations

- Risk Lead: Ken Smith, P.E., CVS (HDR)
- VE Lead: Scot McClintock, P.E., CVS, (F+G)

Questions/Discussion