STRATEGIC PLAN FOR THE REHABILITATION OF THE F. G. GARDINER EXPRESSWAY

ASSIGNMENT NO. 9117-12-5096

February 21, 2014

Prepared for the City of Toronto by:

Prepared by:

Doug Dixon, P.Eng
Project Director

Trevor Small, P.Eng
Project Manager

Han Choi, P.Eng
Project Engineer

Jae Park, P.Eng
Project Engineer

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1. INTRODUCTION

Built in segments from 1955 until 1964, the Frederick G. Gardiner Expressway has been an important and vital transportation corridor from its initial opening, providing access to downtown Toronto from the surrounding suburbs of the Greater Toronto Area. Running close to the shore of Lake Ontario, the approximately 18 km long Expressway extends from the foot of the Don Valley Parkway (DVP) in the east to the junction of Highway 427 and Queen Elizabeth Way (QEW) in the west. The section of the Expressway from the QEW and Highway 427 interchange to the Humber River, a former QEW segment, was re-designated as part of the Expressway in 1997 and the elevated sections east of the DVP were demolished in 2001, establishing the current limits.

For the purpose of this study, the Expressway has been sub-divided into the 'at-grade' section and the 'elevated' section. The at-grade section of the Expressway is located approximately from Highway 427 to 300m east of Dufferin Street. The elevated section of the Expressway is located from the eastern limit of the at-grade section to DVP and is generally located directly above Lakeshore Boulevard east of Bathurst Street. A short section of the Expressway ramping from DVP to Logan Avenue completes the limits of this study. See Figure 1.1 for a Key Plan showing the limits of the at-grade and the elevated sections of the expressway.

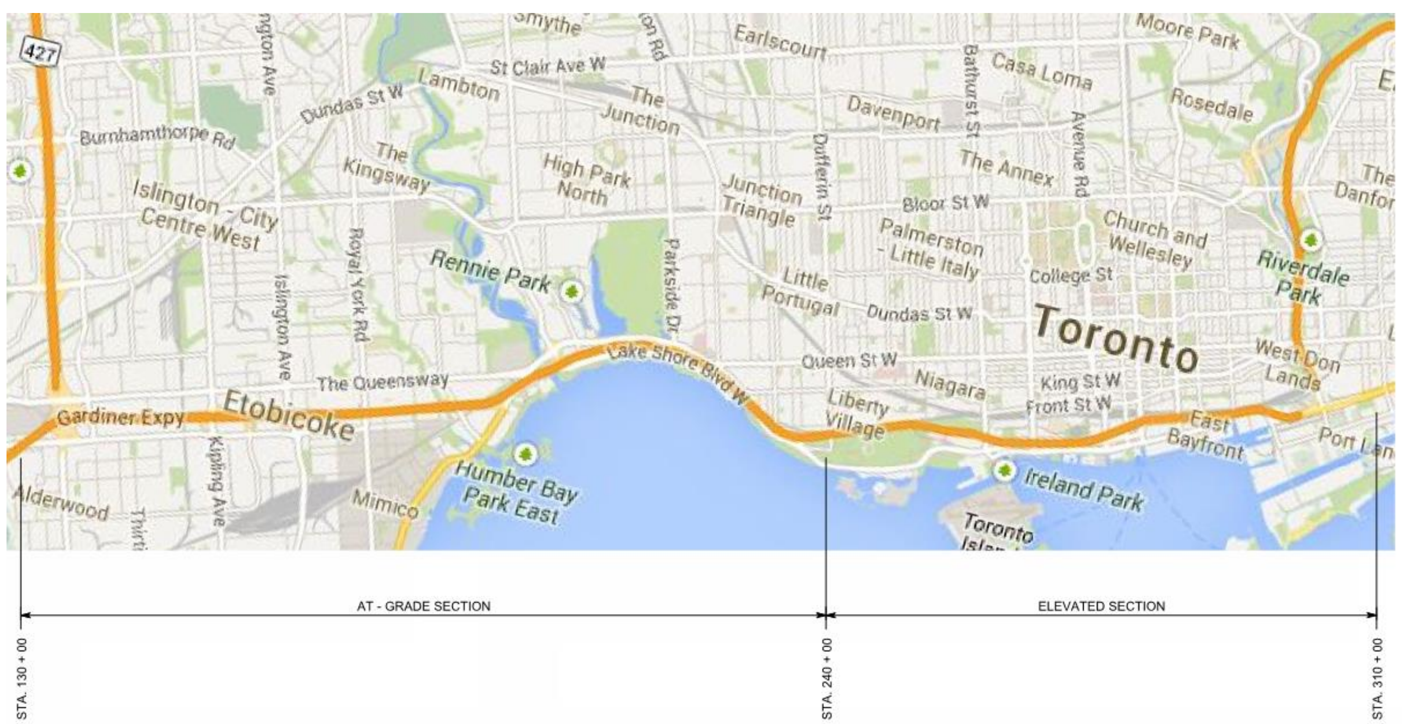


Figure 1.1 – Key Plan

The at-grade section of the Expressway is approximately 11km long and includes 32 structures of various types. See Table 3.1 for a complete list of bridge structures within the limits of the at-grade section of the Expressway. The number of driving lanes on the at-grade section ranges between six-to-ten lanes, west of the Humber River, and six lanes east of Humber River. The posted speed is 90km/h east of Humber River and 100km/h west of Humber River.

The elevated section of the Expressway extends from the west abutment (just east of the Dufferin Street Underpass) to approximately Logan Avenue in the east. The main line is comprised of three east and three westbound lanes and there are 17 ramps making for a total deck area of more than 250,000m^2.

The elevated section of the Expressway was constructed using three different structure types; these three types comprise the following:

- Reinforced concrete T-beams;
- Precast concrete box girders; and
- Reinforced concrete deck slab on steel girders

More than 80% of the elevated section consists of reinforced concrete deck slab on steel girders. Precast concrete box girders found between York Street and Lower Jarvis Street, including mainline and four ramps, comprise another 15% of the elevated Expressway. The remaining 5% of the elevated Expressway is comprised of reinforced concrete T-beam construction located within the initial 0.6km from the west abutment.

As the Expressway ages, this large and important piece of infrastructure has a variety of maintenance needs. The City strives to maintain this major artery in a state of good repair and there is also an increasing pressure to mitigate user impacts while repairs are under construction and, at the same time, doing so in a cost effective manner.

In late 2012, McCormick Rankin, a member of MMM Group, was retained to undertake a Strategic Study for the Rehabilitation of the Expressway. Initially, the study criteria included the assumption that the configuration of the Expressway was to be maintained. Elements of the Expressway were to be assessed and the needs to keep the Expressway safe and operational identified. The study criteria was modified at the start to address the implementation of current improvement initiatives as outlined in several recently completed Environmental Assessments (EA's). The schedule of recommended work is required to address the Expressway needs and make recommendations to accommodate completed EA's and the on-going EA that may decide to remove part of the Expressway at the east end. In addition, the schedule of recommended work is required to accommodate the capital works already scheduled and planned for construction prior to the start of the study.

This report identifies the repair needs of the Expressway and provides a 'year-by-year plan' to address and prioritize the needs. This Plan considers factors such as available funding, timing of the repairs, anticipated ongoing deterioration, available construction technologies and user impacts, among other factors, in establishing a plan to maintain the Expressway in a safe and serviceable condition for the next 25 years. It is recognized that the plan may need to be adjusted to account for actual rates of on-going deterioration as new data is acquired by future investigations and regulatory inspections. Therefore, the plan will be a living document that will need to be revisited as new information and results from ongoing EA's become available.

2. BACKGROUND

After being in service for almost 50 years, the Expressway is well into the latter part of its service life and requires ongoing maintenance and rehabilitation to maintain the Expressway in a safe and serviceable condition. The Expressway has an Annual Average Daily Traffic (AADT) of over 200,000 vehicles and the traffic volumes on the Expressway are sustained at peak levels in both directions for much of each weekday. Any disruptions or reduction in the capacity of the Expressway imposes significant impacts on both the Expressway and other parallel routes.

As the nearly 18 kilometers of existing Expressway comprises a large, complex and varied pieces of infrastructure in various states of condition, there is a need to have a systematic rehabilitation approach to address the various segments to ensure it is maintained in a safe and serviceable condition. Such rehabilitation must take into consideration a number of criteria and constraints.

The City has established an approved budget to rehabilitate the Expressway over the period 2013 to 2022. Approximately $495M has been assigned for both engineering and construction to rehabilitate the Expressway over that interval of time. In addition to the approved 10 year budget, an estimate of the necessary cash flow was established by the City based on an assumed project delivery schedule.

In addition, the City has established a plan, which has not yet been approved, for rehabilitation of the Expressway in the years 2023 to 2025. This combined with the approved 10 year Budget provides a preliminary 13 year Plan. This preliminary 13 year Plan was established for planning purposes. The final three (3) years of the Plan remain unfunded. The City's estimated cost for engineering and construction to implement their 13 year Plan for rehabilitation of the Expressway is approximately $666M. Both the 13 year Plan and 10 year Budget will be referenced throughout this Strategic Plan.

The purpose of preparing a Strategic Plan is to provide a 'blueprint' which can be followed to rehabilitate the Expressway. First and foremost, it must address urgent needs and provide for repairs to components which may not currently be in a state of good repair. All work should be prioritized such that the most urgent repairs required to address public safety needs are attended to first.

By prioritizing the work, the Plan will systematically lay out, year-by-year, a 25 Year Plan which will rehabilitate and maintain the Expressway. The Strategic Plan considers not only the needs of the Expressway, but also considers a number of other criteria and constraints within the Plan. These include:

1. User costs and impacts;
2. Capital cost;
3. Life cycle cost and durability of repair;
4. The City's available budget and identified cash flow; and
5. Limit traffic restrictions to no more than a single lane closure in each direction at all time.

The Strategic Plan must focus on correcting current needs in a fiscally responsible manner. Ideally, the Plan must implement those repairs within both the City's approved 10 year budget and within the limitation of cash flow within that budget. The Plan needs to follow the intent of the City's 13 Year Plan for rehabilitation while at the same time, recognizing that other factors may suggest a revision to the sequence of some of the work identified in the City's 13 year Plan.

Flexibility must also be maintained within the Strategic Plan; flexibility to implement and incorporate works in conjunction with the actual rehabilitation work (funded outside the City's 10 Year Budget), where the delivery of that work is cost effective and convenient.

Paramount within the Strategic Plan is the maintenance of traffic during its implementation. The impact of construction on traffic on the Expressway and on alternate routes must be considered as drivers divert due to delays. The actual duration of traffic restrictions within each contract, and the related user costs needs to be considered. Methods to mitigate such user costs have been explored.

The investigations have considered both new and traditional construction methods and materials for the rehabilitation. Such approaches add value to the rehabilitation by improving durability (increase life cycle) or accelerating construction (thereby reducing user costs).

The Strategic Plan will identify premium construction costs that are a consequence of non-traditional construction methods and materials as well as offsetting benefits which are an outcome from incurring the premium costs.

The City has a number of 'in-progress' Contracts/Works as a consequence of their ongoing maintenance efforts. These are addressing both long term, as well as interim rehabilitation needs. These works, as well as their costs and delivery schedule, have been incorporated into the Strategic Plan.

3. ASSESSMENT OF EXISTING CONDITIONS

3.1 General

The main line and some 17 ramps of the elevated section of the Expressway were designed using three different structure types. These three types consist of the following:

- Reinforced concrete deck slab on rolled and "built-up" steel plate girders;
- Precast (prestressed and post-tensioned) concrete box girders; and
- Reinforced concrete T-beams.

More than 80% of the elevated Expressway consists of a reinforced concrete deck slab on steel girders. Precast concrete girders, which are located between York Street and Jarvis Street (mainline and four ramps), comprise another 15% of the Expressway. The remaining 5% is comprised of reinforced concrete T-beam construction. T-beam superstructure is located within 0.6km from the west abutment.

The superstructure of the elevated Expressway is supported on reinforced concrete piers. These piers, with a few exceptions in the east end, generally consist of reinforced concrete cap beams, and rectangular vertical columns. The cap beams and supporting columns are generally referred to as a 'Bent'. The 307 main line bents are numbered from west to east along the Expressway. There are six (6) Bents with steel cap beams.

The deck surface is topped with approximately 90mm of asphalt and waterproofing system (hot rubberized asphalt). The barriers along the elevated section consist of a safety curb with parapet wall. On the parapet wall is a two-rail aluminum railing system. This barrier system does not meet the current Canadian Highway Bridge Design Code (CHBDC) requirements.

The foundations for the elevated section consist of several types. Reinforced concrete caissons or spread footings founded in the shale bedrock are generally found in the area west of Cherry Street. Driven steel piles are used in the areas of deeper overburden at the east end around the Don River.

The drainage system has been modified since the original construction and now consists of a series of elevated catch basins (hoppers) beneath each drainage outlet. These hoppers discharge into pipes to convey the drainage to the ground. At some locations, the deck drainage is discharged onto the ground beneath the Expressway. Where this is not possible due to land use under the bridge, the drainage is discharged into the City's storm sewer system.

Lighting of the elevated Expressway is provided by light poles along the exterior of the elevated mainline and ramps. These poles are mounted on top of the concrete parapet walls. Surface mounted electrical conduit provides power to the poles. This system replaces the original electrical conduit which was embedded in the parapet wall in the original design. The ramps were originally designed with 'accent' fluorescent lighting as part of the railing system. This accent lighting has been removed during previous rehabilitations in all but a few isolated locations.

The Expressway components of the at-grade section include the bridge structures, retaining walls, pavement, drainage and roadside safety measures. MRC undertook a review of previous investigations and inspection records and performed detailed field investigations to determine the condition of each component. In addition structural evaluations were performed on selected overpasses and underpasses to determine the adequacy of the existing structures according to current load demands.

Table 3.1 lists the bridge structures within the limits of the at-grade section from west to east along the Expressway. Plans showing the location of the structures are included in Appendix A. With the exception of the structures over the Humber River, which were constructed in 1996, all the other structures have been in service for more than 50 years or have at least one primary structural component that has been in service for more than 50 years.

Table 3.1 – At-Grade Bridge Structures

ID #	Structure	Type	Year Built
412	The East Mall Overpass	Post-Tensioned Rigid Frame	1966
422	N & S-E Ramp over the East Mall	Post-Tensioned Rigid Frame	1966
413	Wickman Road & CPR Overpass	Post-Tensioned Rigid Frame	1966
229	Kipling Avenue Underpass	Circular Voided Slab	1966
272	Islington Avenue Underpass	Circular Voided Slab	1966
414	Royal York Road Underpass	Circular Voided Slab	1971
415	Grand Avenue Underpass	Circular Voided Slab	1971
416	Mimico Creek Bridges	Concrete I-girders	1972
423	N & S-W Ramp over Mimico Creek	Concrete I-girders	1972
424	EB off-ramp over Mimico Creek	Concrete I-girders	1972
417	Park Lawn Road Overpass	Concrete I-girders	1971
418	CNR Overhead	Concrete box beams	1970
255	WB Off-Ramp to Lakeshore Blvd.	Rigid Frame / Concrete Box Beams	1972
425	EB Off-ramp to Lakeshore over WB Off-ramp to Lakeshore	Circular Voided Slab	1974
186	TTC Overhead	Concrete Rigid Frame	1956/1970
29	WBL over Humber River	Steel Box Girders	1996
30	EBL over Humber River	Steel Box Girders	1996
419	WB On-ramp from Lakeshore WB over Humber River	Steel Box Girders	1996
420	WB Off-ramp to Lakeshore WB over Humber River	Steel Box Girders	1996
	Lakeshore EB over Humber River	Steel Box Girders	1996
25	Lakeshore WB over Humber River	Steel Box Girders	1996
	WB Off-ramp to S. Kingsway (under CNR)	Concrete Rigid Frame	
32	Windermere Avenue Overpass	Concrete Rigid Frame	1957
33	Ellis Avenue Overpass	Concrete Rigid Frame	1957
34	Colborne Lodge Drive Overpass (Howard Avenue)	Concrete Rigid Frame	1957
37	Parkside Drive Overpass	Concrete Rigid Frame	1956
175	Sunnyside Pedestrian Bridge	Steel I-Girder	1957
7	Dowling Avenue Underpass	Concrete T-Beams	1958
6	Lakeshore Blvd West Underpass (W. of Jameson Avenue)	Steel I-Girder	1958/2011
8	Jameson Avenue Underpass	Steel I-Girder	1958/2011
9	Lakeshore Blvd West Underpass at Dunn Avenue	Steel I-Girder	1958/2011
10	Dufferin Street Underpass	Concrete Rigid Frame	1959

A total of 57 retaining walls are found at various locations throughout the limits of the at-grade section of the Expressway. Thirty-eight (38) of the aforementioned walls, accounting for 1.8km of the total length, incorporate a parapet wall along their length, protecting traffic travelling along the Expressway. The remaining 19 retaining walls (in cut sections of the Expressway), spanning an additional 3.6km, do not include parapet wall. Additionally, four (4) noise-walls with a total length of 2.15km are found at various locations within the at-grade section.

The Retaining Wall Inventory included in Appendix B shows the type and location of each retaining wall included in this study. The naming convention assumed gives each retaining wall a pre-fix of either 'RW' or 'RWP' for those with and without parapet walls respectively; the retaining walls are numbered from west to east within the limits of the at-grade section. Noise-walls follow similar naming conventions; however, they are labeled with the prefix 'NW'.

The at-grade section of the Expressway includes approximately 370,000m^2 of paved traffic lanes. The at-grade section of the Expressway was constructed using two different types of pavement structures. The main lane pavement between Highway 427 and the Humber Bridges predominantly consists of a composite pavement. The main lane pavement from the west abutment of the elevated section to the Humber Bridges and approximately 600 metres of westbound lanes west of Humber River consist of a flexible pavement.

The existing surface drainage for the at-grade section is provided by curb and gutter and catch basins located in the highway median and shoulders. Surface runoff between Highway 427 and Windermere Avenue is conveyed via storm sewers and discharged to Mimico Creek and the Humber River. Surface runoff between Windermere Avenue and the eastern limit of the at-grade section (west abutment of the elevated Expressway) is conveyed by storm sewers that are tied into the municipal sewer system.

There are many roadside hazards which exist predominantly beyond the outside shoulder. However, most of the hazards are shielded by longitudinal barriers such as steel beam guide rail (SBGR) and/or concrete barriers, which provide reasonable deflection for errant vehicles to be redirected away from the hazards in a controlled manner.

3.2 Traffic Operations

The existing traffic operations analysis consisted of the following:

- a review of existing AM and PM peak hour traffic demands on the Gardiner freeway sections, ramps, and on parallel arterial routes
- review of road network volumes and capacity from Highway 427 to the DVP using a screenline level of analysis

The results of this screenline analysis give an indication of the available capacity on the surrounding road network that could be utilized during the planned rehabilitation of the Expressway from Highway 427 to the Don Valley Parkway (DVP).

The screenline analysis was carried out on major arterial roads that parallel the Expressway to determine the amount of spare capacity that may be available to accommodate traffic diverted from the Expressway during construction. In the section between Highway 427 and Parkside Drive, the screenline analysis includes major east-west arterial road between Bloor Street and Lake Shore Boulevard and in the section of the Expressway between Parkside Drive and the DVP includes the arterial roads between Queen Street and Lakeshore Boulevard. The screenline analysis was carried out for both westbound and eastbound directions at multiple locations along the expressway for both the AM and PM peak hours. A brief summary of screenline capacity utilization throughout the Expressway corridor is presented in Table 3.2. A detailed summary of the screenline utilization are included as Table 1 and 2 in Appendix E of this report.

Table 3.2– Existing Screenline Volume/Capacity Summary

Screenline Location	AM Peak Hour Volume/Capacity	PM Peak Hour Volume/Capacity
Islington Avenue	0.82	0.93
Park Lawn Road	0.97	1.00
Parkside Road	0.98	0.99
Dufferin Street	0.96	0.92
Spadina Avenue	0.78	0.87
Yonge Street	0.71	0.75
Don Valley Parkway	0.65	0.70

A review of Volume/Capacity at the major screenlines indicates that there is very little spare capacity available on parallel arterial roads. These corridors are known to be congested during peak hours. The screenline summary results indicate that screenlines located west of Spadina Avenue are operating at close to capacity under existing conditions and there is not any available capacity to accommodate diverted traffic from the Expressway during construction. However, the screenline summary shows that the screenlines located east of Spadina appear to have some available capacity to accommodate diverted Expressway traffic.

The screenline analysis that was undertaken for existing conditions assumes that all existing capacity on parallel arterial roads is available to accommodate the diverted traffic from the Expressway. The City has indicated that a number of lane closures are programed over the next several years on the parallel arterial roads within the study area to facilitate roadway maintenance, rehabilitation of TTC infrastructure, and to facilitate construction activities on adjacent properties. Since there is little flexibility in making any changes to the programmed road closures for years 2014 to 2017, the timing and location of each Gardiner rehabilitation stage that is planned within the initial three (3) year construction period was reviewed to ensure minimal conflicts with the programed arterial lane closures.

All programed arterial road lane closures that will be implemented in the study area after year 2017 will have to be coordinated with the planned Gardiner rehabilitation schedule to ensure that minimal conflicts occur and that the greatest amount of arterial road capacity is available to accommodate diverted traffic during construction.

3.3 Structural Evaluations

Structural evaluations on various components of the Expressway for both the elevated and the at-grade section have been completed. The structural evaluations were performed in accordance with Section 3 – Loads and the applicable 'Design' sections of the Canadian Highway Bridge Design Code (CHBDC).

3.3.1 Elevated Section

The following components were evaluated for the elevated section:

<u>Superstructure</u>

- Precast concrete box girders from Bent 181 to Bent 252 (including ramps);

- Slab on steel girder section between Bents 300 and 341;
- Slab on steel girder section between Bents 35 and Bent 91; and
- Reinforced concrete T-beam section from Bent 27 to Bent 31.

Substructure

- Bents 174 to 187; and
- Bent 31.

The evaluations for the superstructure determined that the existing steel girders were capable of undergoing a rehabilitation which would result in a new conventional 225mm thick reinforced concrete deck with 90mm of asphalt and waterproofing.

In general, the remaining fatigue life of the existing shear connectors and the ends of the steel cover plates were found to be satisfactory for an additional 75+ years. Additional shear connectors may be required in some spans to satisfy the fatigue requirements.

The precast concrete box girder sections from Bent 181 to Bent 252 were found to be adequate for the current highway loading in accordance with the CHBDC assuming a 150 mm topping slab and 90mm of asphalt/waterproofing. Where broken prestressing strands reduced the capacity of the section, carbon fibre reinforced laminates are being constructed as part of the current rehabilitation contract (Contract 12SE-01S) to address the deficiency.

The T-beam segments from the west abutment to Bent 31 are found to be satisfactory for a re-decking strategy, using shored construction, with a 225mm thick deck and 90mm of asphalt and waterproofing.

3.3.2 At-Grade Section

For the at-grade section, MRC undertook structural evaluation of 10 bridge structures and retaining walls; Table 3.3 summarizes the outcome of the structural evaluations. Further details are provided in Appendix T – At-Grade Section Structural Evaluation.

From the below list of evaluated structures, only Park Lawn Road Overpass requires major work to address the noted structural deficiencies. Structural evaluation of the Park Lawn Drive Overpass suggests that the existing prestressed concrete girders would crack under the increased dead load resulting from the new thicker deck of the planned rehabilitation. While there is no immediate structural concern, prestressed concrete girders that are cracked in service are considered partially prestressed and must meet the CHBDC requirements for crack widths and fatigue. The prestressed girders of the Park Lawn Drive Overpass are inadequate in terms of crack widths and exceed the Fatigue Limit State (FLS) stress range and would, therefore, require replacement to safely carry the highway traffic load.

In addition, a review of the previous structural evaluations and original construction drawings suggest that the prestressed concrete girders of the Mimico Creek Structures (EBL & WBL, N & S-W Ramp over Mimico Creek, and EB off-ramp over Mimico Creek), which are all prestressed concrete I-girder bridges built in the same era using the same design standards, may yield similar outcome; however, structural evaluations of the Mimico Creek Structures were not included in this study. For the purpose of this study, the load capacity deficiencies for the Park Lawn Overpass are assumed to exist on the Mimico Creek structures (bridges and ramps). Accordingly, the recommendation to replace the superstructure is also applied to the Mimico Creek structures. Structural evaluation of the Mimico Creek structures is recommended prior to finalizing the scope of work for the Mimico Creek Structures. It is our understanding that a Detailed Deck Condition Survey of the Mimico Creek EBL and WBL bridges has recently been performed by others, the results of which should be included in the evaluation.

Table 3.3 – At-Grade Structures Evaluation Results

ID #	Structures	Evaluation Results
412	The East Mall Overpass	Adequate for current highway loading
413	Wickman Road and CPR Overpass	East frame leg nominally deficient in shear but within the design safety factors
417	Park Lawn Road Overpass	Existing prestressed concrete girders show in-service tensile stress exceeding modulus of rupture ($\sigma_{bot} > f_{cr}$) hence considered partially prestressed. Girders are inadequate under FLS and exceed the maximum crack widths of CHBDC;
418	CNR Overhead	1 of 3 girder types nominally deficient in shear but within the design safety factors
425	EB Off-ramp to Lakeshore over WB Off-ramp to Lakeshore	Adequate for current highway loading
186	TTC Overhead (2 bridges)	Structure is deficient in shear at edges
32	Windermere Avenue Overpass	Nominally deficient in shear but within the design safety factors
33	Ellis Avenue Overpass	Adequate for current highway loading
34	Colborne Lodge Drive Overpass	Adequate for current highway loading
37	Parkside Drive Overpass	Adequate for current highway loading
	Retaining Walls	Adequate for CHBDC PL-2 barrier loads but not PL-3

A structural evaluation was performed for the retaining walls which had drawings available depicting the structural details and require barrier replacement due to non-conformance with the current standards. For all retaining walls that were evaluated, it was determined that the retaining walls could withstand the impact load of CHBDC PL-2 barriers but not PL-3 barriers. Current MTO policy allows for PL-2 loading where PL-3 barriers are required on rehabilitated structures. Therefore, replacement of the retaining walls to meet PL-3 barrier loads is not recommended and only the barrier walls on top of the retaining walls need to be replaced to meet current standards.

3.4 Elevated Section Investigations and Inspections

3.4.1 Rehabilitation History

There have been a number of rehabilitation projects undertaken to repair/modify the Expressway since its original construction. Appendix F provides a summary of all known original construction and rehabilitations completed on the elevated portion of the Expressway since 1956. In general, the rehabilitations can be categorized according to the following types:

- Repairs to the substructure (Bents);
- Repairs to the superstructure (deck, waterproofing, expansion joints, traffic barriers, drainage, lighting);
- Repairs to the asphalt wearing surface consisting of milling and paving; and

- Cleaning and coating of the steel girders.

3.4.2 Existing Maintenance and Inspection Methodology

Maintenance can be categorized into two types. One type is major rehabilitations completed by the City using Design-Bid-Build (DBB) Contracts. Work tends to be scheduled as budget is available and as Expressway conditions warrant. Detailed inspections to assess the existing deck condition have not generally been used (detailed deck condition surveys). Such investigations are costly and disruptive to traffic. Visual assessments and inspections are more often used to determine repairs required based on both the condition of the asphalt and the condition of the deck soffit.

Visual inspections are useful; however, they may not be suitable to assess the remaining life in a bridge deck of 'advanced' years. In addition, for a large Expressway where timing of expenditures is important, such observations are not suitably precise to schedule major interventions.

The second type of maintenance relates to the ongoing maintenance of signs, lighting, railings, wearing surface and other components. This is undertaken annually on an 'as required basis' either during a maintenance closure weekend or under a DBB Contract.

In addition to the annual maintenance of components, the City has a program to scale loose concrete from the deck soffit and traffic barriers where it could become a hazard to vehicles or the public should the concrete fall. The City Engineering staff visually inspect areas of the soffit and parapets several times a year to identify concrete that may be delaminated. Once a suspect area is identified, a Contractor on retainer with the City is called in to undertake 'controlled chipping' to remove loose concrete in the area.

The effectiveness of this method of removing loose concrete can best be determined by the City based on the reduction of incidents of concrete falling from the Expressway. Visually assessing concrete for delaminations is difficult and in some situations not feasible. As a result of weather, or impact loads, or other external force, it is possible for a delamination on a bridge to progress from unperceivable to a spalled piece of concrete which can fall from the structure without warning.

In 2012, an inspection of the elevated Expressway was completed using the Ontario Ministry of Transportation, Ontario Structure Inspection Manual (OSIM) format. This inspection, which is required by regulation every two (2) years, is useful in providing an overview and comparison of the condition of various components and segments of the Expressway.

3.4.3 Previous and Current Inspections

There have been many inspections completed over the years. Some inspections have been undocumented while others have resulted in formal reports and documentation. Recent inspections consist of the following:

- 2013 - Visual Steel Girder Inspection, by McCormick Rankin;
- 2013 - Detailed Deck Condition Survey, by McCormick Rankin;
- 2012 - Ground Penetrating Radar (GPR), by McCormick Rankin;
- 2012 - F.G. Gardiner Expressway, "Falling Concrete Independent Assessment", by IBI Group;
- 2012 - Ontario Structure Inspection Manual (OSIM) Inspection of the entire F.G. Gardiner Expressway from the West Abutment to Logan Street (excluding mainline and ramps, from York Street to Lower Jarvis Street) by McCormick Rankin;
- November 2011 - F.G. Gardiner Expressway, York Street to Lower Jarvis Street – Structure Repairs – Box Girder/Deck Investigations, by McCormick Rankin;
- April 2009 - Inspection of F.G. Gardiner Expressway Precast Box Girders from Lower Jarvis Street to York Street", by McCormick Rankin;
- June 2004 - Rehabilitation of the F.G. Gardiner Expressway from Jarvis Street to the Don Valley Parkway – Structural Steel and Bearing Inspection Summary – Volume 2-Part 2, by McCormick Rankin; and
- June 2003 - Rehabilitation of the F.G. Gardiner Expressway from Jarvis Street to the Don Valley Parkway – Deck Condition Survey Summary – Volume 2-Part 1, by McCormick Rankin.

2013 Visual Steel Girder Inspection

MRC undertook a visual inspection of the girders from Bent 252 to Bent 341 in January 2013. This inspection was less detailed than the previous 2003 inspection which inspected the same spans. The purpose was to confirm the 2003 observations and assess if previously noted defects had become more significant.

The inspection focused on the same components as the 2003 inspection and looked for the same types of defects.

The conclusions of the 2013 visual steel girder inspection were:

- the steelwork was in similar condition to that observed in 2003. The perforations observed in 2003 had not grown substantially and were again limited to the secondary members/components;
- the coating condition was more advanced in the percentage of breakdown (10-15%). Some minor section loss was beginning to occur on the exterior girders and those along the edges of the deck; and
- the bearings were noted to be in similar condition to the 2003 inspection. Cracks in the elastomeric laminated bearings did not appear to be significantly more extensive. The steel bearings had some additional broken tab plates, but still appeared functional.

Given that the disposition of this segment of the Expressway was being studied by the City as part of an Environmental Assessment and that complete refurbishment or demolition of this section may occur as a result of that study, it was concluded that none of these repairs would be undertaken as part of the 2013 FG Gardiner Expressway Interim Repairs (Contract 13SE-18S).

2013 Detailed Deck Condition Survey

In May and June of 2013, a modified Detailed Deck Condition Survey (DDCS) was undertaken on approximately 10,000m^2 of the Expressway (22 spans of westbound lanes and 21 spans of eastbound lanes) as part of this Strategic Study. The work was undertaken by SPL Consultants as a sub-consultant to MRC.

The purpose of this DDCS was to determine the condition of a small percentage (4%) of the entire deck including the following:

- To provide the condition of the deck by possible correlation with previously completed Ground Penetrating Radar (GPR) survey;
- To provide the actual deck condition for approximately 4% of the entire deck surface which would be used to extrapolate the probable condition of other segments of the elevated Expressway; and
- To provide an indication of the deck condition which could then be correlated with visual observations of the deck soffit or asphalt condition.

During this DDCS, half-cell corrosion potential tests were conducted on the deck. Asphalt sawn samples and concrete cores were removed from the deck to measure the chloride ion content and to conduct the compressive strength tests. To mitigate traffic impact, the work was completed at night between 11 pm and 5 am. Lanes/spans chosen for investigations were also selected to mitigate the need to close any ramps during the deck condition survey.

The half-cell survey indicated that 28.4% of the inspected westbound deck area and 19.9% of the inspected eastbound deck area had corrosion potentials more negative than -0.35V. This (-0.35V) threshold indicates probable active corrosion of the reinforcing steel in the deck in these areas. Complete corrosion potential values of each individual span inspected can be found in the reports Detailed Deck Condition Survey, Gardiner Expressway EBL and Gardiner Expressway WBL, by SPL Consultants (Appendix R).

A total of 106 cores and 32 sawn samples were extracted from the inspected westbound spans. From those samples concrete delaminations were observed in 31 cores (29% of the extracted cores) and 13 sawn samples (39% of the samples). For the eastbound spans, a total of 100 cores and 36 sawn samples were extracted. Delaminations in the deck were found in 24 cores (24% of the extracted cores) and 7 sawn samples (19% of the sawn samples).

The extracted concrete cores were also tested for acid soluble chloride ions within the concrete as a function of the depth from the top surface. The chloride threshold value necessary to depassivate embedded reinforcing steel and to allow the onset of corrosion is taken as 0.025% by mass of concrete (after adjustment for background chlorides). The chloride content at the level of the top layer of reinforcing steel was above the threshold level in 37 of 51 tested cores (73%) from the westbound spans and in 34 out of 46 cores (74%) of eastbound spans.

The condition of the waterproofing membrane was generally fair to good and the bond of waterproofing to the concrete was generally in fair condition. Light to severe rusting was observed on the reinforcing steel in some cores.

A detailed deck condition survey had also been conducted in 2003 for 15 spans of the Expressway from Lower Jarvis Street to the Don Valley Parkway (see below for details). Table 3.4 shows the comparison of average corrosion potentials obtained from both the 2003 and 2013 DDCS within the same limit. The area exceeding the corrosion potential threshold is significantly higher in 2013 compared to the 2003 readings. This indicates more active corrosion in the steel reinforcement and expansion of the affected area since 2003. In addition, only 3 out of 47 extracted core samples (6%) exhibited delaminations in 2003 compared to 27 out of 81 extracted core samples (33%) in 2013 from the same section of the Expressway (Lower Jarvis Street to the DVP).

Table 3.4 – Comparison of Corrosion Potentials from Lower Jarvis St. to DVP

Location	Year	Corrosion Potential Readings (% of inspected area)		
		0 To -0.2V	-0.2V To -0.35V	below -0.35V
Eastbound lanes	2003	62	36	2
	2013	36	51	12
Westbound lanes	2003	57	37	6
	2013	15	59	25
Total	2003	58	37	5
	2013	25	56	19

Corrosion potential readings of the same location also support the above correlation between the 2003 and 2013 surveys. For the westbound lanes between Bents 254 and 255, only 0.9% of deck area had corrosion potential readings more negative than -0.35V in 2003. This percentage has increased significantly in 2013 to 70.6%. For the eastbound lanes between Bents 271 and 272, only 1.8% of deck area had corrosion potential readings more negative than -0.35V in 2003, and this number also increased to 6.5% of the deck area in 2013.

Despite a clear trend of on-going deterioration, the 2013 DDCS results also indicate that the condition of the reinforced concrete deck varies on a ‘span-by-span’ basis. For example, in the eastbound span between Bents 161 and 162, 81.4% of the inspected deck area has corrosion potential more negative than -0.35V, while in the adjacent span between Bents 162 and 163 only 18.1% of the area has corrosion potential more negative than -0.35V. Due to the varying condition of the deck, the small sample size of the 2013 DDCS alone is not sufficient to accurately predict the condition of the entire deck.

The highly variable deck condition found in both 2013 and 2003 DDCS is typical for large bridge decks. This variability may be explained by the fact that the Expressway was constructed with a series of contracts in which different concrete mix designs and aggregate sources were used as well as the varying climate conditions throughout its original construction (i.e. concrete poured in summer season versus concrete poured in cooler temperature).

The 2013 DDCS reports that 4% of the examined deck area is in fair to poor condition. The level of deterioration found in these areas has advanced to a point where a less extensive rehabilitation technique such as placing concrete overlay on the existing deck is not viable.

<u>2012 Ground Penetrating Radar</u>

From November 11, 2012 to November 13, 2012, Roadmap GPR Services, as a sub-consultant to MRC, undertook a ground penetrating radar (GPR) survey of the travelled lanes of the entire elevated Expressway (West Abutment to Logan Street) and all of the ramps. The report is entitled “Report on F.G. Gardiner Expressway 2012 Ground Penetrating Radar Bridge Deck Survey” (Appendix S).

GPR is a tool used to quickly assess the condition of large areas of reinforced concrete deck. During three overnight periods, more than 250,000m^2 of deck area was surveyed consisting of more than 249 identifiable spans.

The GPR uses high frequency impulses of energy directed into the deck. The GPR device records the propagation time for such signals to travel in the deck and reflect back to the emitter. A threshold index of 6dB (decibels) of energy decrease is standardized to represent 'deteriorated concrete'. Increased attenuation and lower velocity of the impulse in the concrete is accepted to indicate areas of high chloride and/or moisture content. The higher chloride and moisture zones are indicative of probable areas of current or incipient delamination induced by reinforcing steel corrosion.

Several key assumptions are inherent in interpretation of the GPR survey results. The first assumption is that the structure being investigated has a consistent composition. This includes deck type (thin slab on steel girders) as well as the density of the concrete materials. Within the Expressway, we have less than desirable conditions for the use of GPR due to:

- a variable deck type throughout the Expressway (thickness, reinforcing steel size, etc);
- concrete in the original construction was obtained from a number of sources; and
- during rehabilitation works, new patch materials (concrete) of a different density and composition have been placed.

Based on the above, it can be concluded that definitive predictions of the deck condition solely based on the GPR results is not feasible and the GPR survey results require additional data to refine and validate results to accurately predict the condition of the deck.

An attempt was made to use the 2013 DDCS results to interpret the 2012 GPR survey results which, if successful, would provide good indication of the deck condition over the entire elevated Expressway. Corrosion potential maps were obtained from the DDCS for 22 spans of westbound lanes and 21 spans of eastbound lanes, and compared with deterioration index (DI) maps from GPR. However, only limited success was found in the correlation between the two inspection results likely due to the varying deck types and inconsistent material composition from previous rehabilitation work. The details of the comparison between the DDCS and the GPR Surveys can be found in Appendix S.

<u>2012 Falling Concrete Independent Assessment –by IBI Group</u>

This Report was prepared in 2012 by IBI Group for the City of Toronto. The purpose of the report was to assess the current City practice regarding management of the Expressway. Particular emphasis in the Report was focused on future maintenance and the possible actions to be taken to lessen the occurrence of concrete falling from the Expressway.

As part of this investigation, inspections were performed where surface deterioration surveys (hammer sounding and visual inspections) of the deck soffit and parapet walls were undertaken.

The following seven (7) spans were investigated by IBI:

- Bent 53-55;
- Bent 85-86;
- Bent 91-92;
- Bent 120-121;
- Bent 131-132;
- Bent 301-302; and
- Bent 306-307

A comparison of the observed deterioration from hammer sounding and the City's previous visual inspection indicate a wide variation in the identification of delaminated areas. Visual inspections were shown to be substantially less effective in identifying delaminated areas than hammer sounding. Delaminated concrete can be visually observed only at the point where the delamination manifests itself by forming a crack or otherwise becomes partially debonded from the parent concrete. There is often no 'warning sign' when a concrete delamination, which cannot be visually perceived, falls and produces a spall.

IBI Group concluded that there was a need for more intensive field investigations during the development of the Expressway Management Strategy and the current proactive controlled chipping program. IBI also recommended other techniques be utilized to possible identify concrete delaminations such as GPR and thermography.

<u>2012 OSIM Inspection</u>

The 2012 OSIM inspection of the F.G. Gardiner Expressway is the most recently completed inspection. This inspection assessed all components of the Expressway including the asphalt, barriers, girders, bearings, deck soffit and Bents. The purpose of this type of inspection is to identify any visually distinguishable defects and to establish the condition of the components based on a numeric rating system. This numeric rating system can be used to establish the overall condition of a given structure within a family of structures. The 2012 OSIM inspection of the F.G. Gardiner also included a 25% "enhanced" visual inspection with some hammer sounding.

For this inspection, each span has been treated as an individual "bridge". Each bridge (span) can then be numerically rated in comparison to the other spans. The numeric rating can be used to provide an assessment of the condition of one segment of the Expressway relative to the adjacent segments. In addition, an extensive "resource" of photographs is being gathered to document ongoing deterioration.

Inspection findings for each individual component are summarized in Table 3.5. Note that the mainline and ramps from Bent 181 to bent 252 were not included in the OSIM inspection.

Table 3.5 – Summary of Findings from 2012 OSIM Inspection

Asphalt Wearing Surface							
Spans	**1 - 90**	**91 - 125**	**126 - 181**	**253 - 310**	**311 – 340**	**341 - 352**	**Ramps**
% in Poor condition	1 to 4%	Less than 1%	1 to 2%	Less than 1%	3 to 6%	Nil	Less than 1% except Ramp 364 (10%) and 367 (3%)
Parapet Walls							
Spans	**1 - 106**	**107 - 161**	**162 - 181**	**253 - 320**	**321 – 340**	**341 - 352**	**Ramps**
% in Poor condition (Exterior Face)	Up to 10% at 6 out of first 13 spans and from spans 40 to 48	5 to 50%	Up to 10%	5 to 20% of spans from 253 to 280. 20 to 50% of spans from 281 to 320	Up to 5%	Nil	2 to 10% at Ramps 353, 357, 366 and 367
Spans	**1 - 106**	**107 - 161**	**162 - 181**	**253 - 320**	**321 – 340**	**341 - 352**	**Ramps**
% in Poor condition (Interior Face)	Up to 10%	Up to 10%	Up to 10%	10 to 40%	Up to 5%	Nil	2 to 10% at Ramps 353, 357, 366 and 367
Soffit							
Spans	**1 - 57**	**58 - 119**	**120 - 181**	**253 - 315**	**316 – 342**	**343 - 352**	**Ramps**
% in Poor condition (Interior)	1 to 2% of 13 out of first 35 spans.	Less than 1% of 8 spans from 58 to 115. Up to 3% at 116 to 119	Less than 1% of 6 spans from 120 to 169. Up to 2% at 170 to 181	Less than 1% of 2 spans from 253 to 292. Up to 5% at 293 to 315	Up to 2% of 7 spans.	Nil	
% in Poor condition (Exterior)	1 to 2% of 11 spans.	Less than 3% of 3 spans from 58 to 97; 5 to 20% at 98 to 119	5 to 10% of spans 120 to 148; Up to 5% of spans 149 to 169; 5 to 20% of spans 170 to 181.	Less than 5% of spans 253 to 281; 10 to 15% of spans 282 to 315.	20 to 50% of spans 316 to 324; 10 to 15% of spans 325 to 331; Up to 10% of spans 332 to 342.	Nil	
Girders							
Spans	**1 - 103**	**104 - 154**	**155 - 181**	**253 - 300**	**301 – 342**	**343 - 352**	**Ramps**
% in Poor condition (Ends)	Up to 10% of 7 out of first 35 spans.	5 to 15% of 104 to 106; 2 to 5% of 5 spans.	Up to 5%	Up to 5%	3% of 3 spans.	Nil	30% at Ramp 366 & 367; Up to 6% of Ramps 353, 354 and 355.

Pier (Bent)							
Bents	**1 - 35**	**36 - 119**	**120 - 129**	**130 - 181**	**253 – 300**	**301 – 340**	**Ramps**
% in Poor condition (Cap)	More than 10% at 4 bents; 1 to 5% of 16 bents.	1% of 8 bents.	Up to 15%	1% of 1 Bent.	Nil	Less than 3 % of 10 bents; 5% of 2 bents.	16% of 359; 8% of 365; 5% of 364. Less than 3% of rest of the ramps
% in Poor condition (Shaft)	More than 10% of 5 bents; 1 to 7% of 15 bents.	Less than 3% of 9 spans.	Up to 30%	Up to 5% of 5 bents.	1 to 4% of 18 bents.	Up to 5% of 22 bents and 10% of 2 bents.	18% of 365; 10% of 364; 8% of 358; 6% of 359. Less than 2% of rest of the ramps.

<u>2011 York Street to Lower Jarvis Street Box Girder/Deck Investigations</u>

As part of the pre-design investigation for Contract 12SE-01S, "F.G. Gardiner Structure Repairs from Bent 182 to 252 (York Street to Lower Jarvis Street)", MRC undertook some destructive investigations for this portion of the elevated Expressway mainline and four adjacent ramps.

The investigation was completed in October 2011 on this 960m long section of the Expressway mainline and the 1140 linear metres of ramps. In total, the investigation undertook:

- Extraction of 26 cores from the asphalt and water proofing, topping slab and top slab of the precast concrete box girders;
- Extraction of 12 cores from the sides of the precast box girders in the ramps and mainline;
- Nine (9) asphalt sawn samples to inspect the deck for any delaminations, scaling, or cracks, as well as to assess the concrete cover to the reinforcing steel in the topping slab; and
- Hammer sounding on all of the Expressway mainline parapet walls and a representative sample of the parapet walls on the ramps.

In general, the condition of the deck was found to be in good to very good condition. The waterproofing and asphalt were both in good condition. The topping slab exhibited no defects. The epoxy coated reinforcing steel was generally in very good condition. The uncoated reinforcing steel intercepted in the top slab of the precast concrete box girders showed only light corrosion.

The waterproofing (installed in 2000) contained a layer of reinforcing fabric and was in very good condition and bonded well to both the concrete and the asphalt.

The parapet walls, curbs and railing had some delaminations (approximately 24m^2 in surface area) with surface stains and scaling and some medium sized cracks.

In general, this section of the Expressway deck, asphalt, waterproofing, expansion joints and barrier were in fair to good condition.

Inspection of F.G. Gardiner Expressway Precast Concrete Box Girders from Lower Jarvis Street to York Street - 2009

In 2009, MRC undertook an investigation and evaluation of the precast concrete box girders from York Street to Lower Jarvis Street including all four adjacent ramps.

This investigation consisted of a visual inspection, hammer sounding and a limited amount of destructive testing. Concrete cores were removed from the sides and soffit of some boxes. Compressive strength and acid soluble chloride contents tests were also completed. Concrete was removed to expose both reinforcing steel and prestressing steel.

In addition, GPR and Impact Echo (IE) test methods were employed on the concrete in the box girders to:

- Identify delaminated or void areas on some box girders (GPR);
- Identify if the ducts were fully grouted in the post-tensioned box girders (IE); and
- To identify the duct profile on the exterior girders at some locations.

The inspection identified seven precast box girders for replacement and the necessary repairs to be undertaken to the soffit of numerous girders. Where broken strands occurred in the box girders such that the girders capacity was adversely impacted, carbon fibre reinforced polymer laminates were used to restore the ultimate strength of the section. This work was completed under Contract 12SE-01S.

2003 Detailed Deck Condition Survey – F.G. Gardiner from Lower Jarvis Street to the Don Valley Parkway

On October 5, 2003, MRC undertook a limited DDCS of ten spans of the westbound direction of the Expressway from Lower Jarvis to Bent 323. On October 26, 2003, MRC inspected an additional five spans in the eastbound direction. This survey consisted of half-cell corrosion potentials on a 3m by 3m grid, removal of asphalt sawn samples and extracting concrete cores from the deck.

Table 3.6 identifies the 15 spans surveyed including the total deck area and the percentage of low, mid and high range corrosion potentials. 42% of the deck area investigated had corrosion potentials more negative than -0.20V. Six individual spans had corrosion potentials with more than 50% of the deck with corrosion potentials greater than -0.20V.

The waterproofing was generally observed to be in fair condition with a poor bond noted between waterproofing and the deck slab and also between the waterproofing and the asphalt.

Ten (10) asphalt sawn samples and 47 cores were extracted from the 15 spans. Three (3) of the cores exhibited delaminations while the remaining 44 cores showed no defects. Concrete cover ranged from 30mm to 70mm with an average of 50mm.

Two (2) cores tested for acid soluble chlorides indicate that 70mm in one core and 10mm of the second core exceeded the threshold limit for chlorides required to initiate corrosion. In both cases, the cores tested were in areas with corrosion potentials more negative than -0.35V, which is an indicator of ongoing active corrosion.

In addition, the permeability of two cores from the existing deck was investigated. The rapid chloride permeability (RCP) of the tested cores was 2260 coulombs and 4200 coulombs indicating "high" permeability. For comparison, concrete used today typically has RCP values of less than 1500 coulombs.

MRC noted significant variability in all of the parameters identified in the DDCS between various spans.

This information was intended for use in the rehabilitation of the Expressway from Jarvis Street to Cherry Street in Contract 04FS-26S. The project was cancelled by the City and never tendered.

Table 3.6 – Summary of the Corrosion Potential Readings 2003 F.G. Gardiner DDCS Bent 252 to Bent 305

SPAN	TOTAL SPAN AREA (m^2)	0.0 TO - 0.19V AREA (m^2)	% OF TOTAL SPAN AREA	-0.20 TO - 0.35V AREA (m^2)	% OF TOTAL SPAN AREA	>0.35V AREA (m^2)	% OF TOTAL SPAN AREA
Eastbound							
BENT 256-257	540	450	83.3	90	16.7	0	0.0
BENT 271-272	446	352	78.9	86	19.3	8	1.8
BENT 277-278	417	189	45.4	207	49.6	21	5.0
BENT 288-289	315	113	35.8	187	59.4	15	4.8
BENT 298-299	470	249	52.9	217	46.2	4	.09
Westbound							
BENT 254-255	571	494	86.5	72	12.6	5	0.9
BENT 261-262	376	126	33.5	238	63.3	12	3.2
BENT 269-270	434	342	78.8	80	18.4	12	2.8
BENT 273-274	422	410	97.2	12	2.8	0	0.0
BENT 278-279W	331	133	40.2	180	54.4	18	5.4
BENT 281W-282	566	346	61.2	220	38.8	0	0.0
BENT 282-283	455	35	7.7	220	48.3	200	43.9
BENT 291-292	313	248	79.2	65	20.8	0	0.0
BENT 298-299	473	188	39.7	270	57.1	15	3.2
BENT 303-304	314	102	32.4	210	67.0	2	0.6
Total							
	6442	3776	58%	2354	37%	312	5%

2003 Visual Steel Girder Inspection

MRC undertook a visual inspection of the steel girders, diaphragms and bearings from Bent 252 to Bent 327 in September 2003. This portion of the Expressway included some 27,000 linear metres of steel girders and over 2300 bearings.

The inspection investigated:

- the condition of the coating and extent of corrosion;
- identified perforations in the structural steel;
- visually inspected fatigue prone details for indications of cracks; and
- inspected the condition of both the steel and laminated bearings, bearing seats and anchor bolts.

In summary, the inspection found the structural steel to be in fair to good condition. The steel coating condition ranged from poor to very poor condition with generally greater than 10% of the surface area of coating breakdown. As a consequence of the coating breakdown, corrosion of the steel ranged from minor to extensive. Generally the primary members (girders) had corrosion with minor section loss. There were some noted perforations; however, these were limited to bracing members only and were not considered to require repair. There were no fatigue defects noted during the inspection.

The laminated elastomeric bearings had numerous cracks within the rubber. There were locations with spalled and delaminated grout beneath the bearings. There were several locations with minor steel bearing defects such as corroded anchor bolts and cracked/broken rocker bearing tab plates.

In general, the steelwork was found to be in fair to good condition. Repairs were planned for a 2004 Rehabilitation Contract, which was subsequently deferred by the City.

3.4.4 Other Observations

Spans from Bent 48 to Bent 60

Between April 2010 and October 2011, MRC prepared and administered three Contracts (10FS-26S, 10-FS-39S and 11FS-26S) for the rehabilitation of Bents from Bent 48 to Bent 60. As part of these Contracts the deck soffit was hammer sounded and soffit patches were undertaken.

During the initial Contract it was identified that some of the soffit deteriorations were extensive and could potentially become "full depth" repairs if removed from the soffit upwards. Temporary timber falsework was installed to provide some support to the deck, as well as to prevent concrete which was delaminated at that time, from falling. Several of the identified areas were repaired under Contract 11FS-26S.

This repair consisted of closing the Expressway and locally removing the deck. New reinforcement and rapid set concrete was used to replace the deck in less than 48 hours.

During the deck removal, MRC undertook observations as to the deck condition. It is important to recognize that the observed condition of the deck at these repair locations is not expected to be typical of the entire deck. The observed conditions are expected to be some of the worst conditions as hammer sounding of the soffit of the deck had identified an extensive delamination.

Photographs in Appendix G indicate the observed conditions during removal. In summary, the deck at these locations was in an advanced state of deterioration. The concrete cover in the deck slab was delaminated and became entirely debonded during removal and some of the deck reinforcing steel had lost more than 50% of the reinforcing steel bar area.

MRC concluded there is a high probability that similar areas of deterioration exist along the Expressway.

Spans from Bent 295 to Bent 297

In October 2011, during the Fall Maintenance Closure of the Expressway, MRC was asked to inspect an area between Bents 295 and 297 where City forces had removed deteriorated asphalt.

The observed conditions of the exposed deck surface are shown in Appendix H.

Following the removal of the asphalt, the exposed deck was in very poor condition. Reinforcing steel was exposed in the area; the concrete was disintegrated and friable; and water was standing on the surface of the exposed concrete deck.

This area was concluded to be at risk of a localized deck failure (punch through) and temporary timber shoring was subsequently installed in late 2011. This area of deck was replaced in September 2013 during a Fall Maintenance Closure.

As with the area repaired in 2011 between Bent 48 and Bent 60, this type of deterioration indicates that there are other areas of deck on the Expressway in similarly poor condition that pose safety concerns. Also, detection of such areas appears to be best identified by poor asphalt condition or hammer sounding of the deck soffit.

3.4.5 Summary of Findings

Based on the inspection and investigation work outlined in the preceding sections, MRC has developed a series of recommendations. These conclusions relate to both short and long term maintenance and management of the Expressway.

The priority for rehabilitation work is given to the sections where the structures/components are most deteriorated and where more immediate action is required. Interim repair work is assigned to components to ensure the integrity and serviceability in that section until the completion of the major rehabilitation. The complete proposed plan for the major rehabilitations and interim repairs of the elevated Expressway is described in Section 4.

3.4.5.1 Superstructure

Deck

MRC's conclusion is that the condition of the deck over much of the Expressway has deteriorated to the point where it is now very difficult to 'manage' the Expressway to ensure a reasonable level of risk in maintaining the serviceability of the deck. Asphalt deterioration, concrete spalling of the deck soffit, and the risk of potential localized deck failures exist throughout the Expressway.

The deck condition in general is such that rehabilitation options, such as a concrete overlay, would not be effective. It is believed that chlorides have penetrated to the bottom layer of reinforcing in many localized areas. As such, the lower mat of reinforcing in the deck is corroding and concrete is spalling from the deck soffit. The conclusion of this Study is that only complete deck replacement will provide a cost effective and durable solution in the long-term. Other methods will not reduce the risk of the deck becoming unserviceable without any warning. It is recommended that the new deck be constructed of materials capable of a life expectancy of more than 75 years with conventional maintenance.

In addition, the existing traffic barriers do not meet current Performance Level (PL) requirements. Reconstruction of the deck along with construction of new code compliant barriers is therefore recommended.

As identified in Section 4 of this report, anticipated user costs due to construction related traffic staging is very high. With more than 100,000 vehicles per day in each direction, the desirable repair (recommended as deck replacement) will be one that minimizes construction duration and results in maximum durability and life span.

Girders

There are three types of girders which serve as main load carrying element of the elevated Expressway: precast concrete box, steel, and cast-in-place reinforced concrete girders. MRC has concluded the following:

1. The existing steel beams/girders are suitable to be incorporated into the new superstructure (if suitable based on construction methodology). The steel girders have adequate remaining service life to meet the additional 75 year durability criteria;
2. The precast concrete box girders have approximately 20 to 25 years of remaining life following the recent rehabilitation work; and
3. The cast-in-place reinforced concrete beams from the west abutment to Bent 31 can be either replaced or retained depending on the construction methodology adopted (as described in Section 4.1.3.2).

Bearings

Based on the investigations and observations of the existing bearings, complete replacement of the bearings at the time of deck replacement is recommended. The existing bearings are not anticipated to maintain their functionality for the desired additional 75 year design life.

Steel Coating

The existing steel girders, should the City decide to incorporate them into the final design, will, at a minimum, need to be cleaned and coated at the ends of the girders at expansion joint locations within the next 15 years as part of the proposed deck replacement contracts. Coating of the entire girders is recommended within the next 25 years. As the existing coating contains lead, lead paint abatement will be required during these activities. There are several options for coating systems with new materials becoming available all the time.

Alternatively, the girders could be removed and replaced with new, shop coated steel girders or with the new weathering steel girders without coating. This is considered in the evaluation of rehabilitation alternatives in Section 4.

3.4.5.2 Bents

As previously mentioned the substructure components, normally referred to as 'piers' on other bridges, are called 'Bents' on the Expressway. These Bents are typically reinforced concrete; however, there are six (6) with concrete columns and structural steel cap beams. The Bents are supported on a variety of foundation types.

The City has undertaken numerous rehabilitations on many of the Bents. This originally consisted of shotcrete repairs which is believed to have been undertaken in the 1970's and the more recent repair methodologies which varies from concrete patching of localized deteriorated areas, to complete refacing of the Bents where the deterioration was found to be more extensive.

Based on inspections undertaken during this Study, the extent of the deterioration was determined for each Bent. The refacing material is assumed to be a conventional exposure class 'C1' Type self-consolidating concrete (RCP < 1500 coulombs) reinforced with galvanized welded wire fabric. The assumption has also been made that surface sealing will be complete using a two component sealer consisting of an oligomeric alkoxysilane and a pigmented methamethacrylate surface coating consistent with the previous rehabilitations.

We would recommend that consideration be given to controlling concrete shrinkage in the refacing material by both mix design and admixtures. This will ensure increased durability of the refacing. In addition, we would recommend stainless steel mesh in the "splash zone" and in the Bents where expansion joints in the deck are located.

3.4.5.3 Other Systems

The existing lighting will be replaced as part of the deck replacement. The current system has little documentation on the 'as-built' condition. In addition, grounding of the system is believed to be inconsistent and may not be in compliance with the current electrical codes.

Deck drainage would be replaced at the time of reconstructing the deck. It would be desirable to modify the existing "hopper" system to eliminate the annual maintenance requirement to clean the hoppers.

3.5 At-Grade Section Investigations and Inspections

3.5.1 Previous Investigations and Inspections

Many inspection and rehabilitation programs have been completed for the structures within the at-grade section over their service life. However, until the 1997 re-designation, the section west of the Humber River was under MTO jurisdiction, and not all documents and records were readily accessible from the City's archive. Structural inspection records made available for this study consist of the following:

- 2012 OSIM Inspection;
- 1997 Detailed Deck Condition Survey (DDCS) of Wickman Road & CPR Overpass, Kipling Avenue Underpass, Royal York Road Underpass, Grand Avenue Underpass, EB off-ramp to Lakeshore over WB off-ramp to Lakeshore
- 1997 - 1998 DDCS of Windermere Avenue Overpass, Ellis Avenue Overpass, Colborne Lodge Drive Overpass, and Parkside Drive Overpass; and
- 1995 of Dowling Avenue Underpass.
- DDCS records of The East Mall Overpass and Islington Avenue Underpass were not available.

In 2002, TSH completed a comprehensive study of the at-grade section of the Expressway. This study includes condition assessment and recommendation for rehabilitation and improvements for the following infrastructure components:

- Pavement Structures;
- Roadside Safety Measures;
- Structures;
- Traffic Operations;

- Signs, Sign Structures and Pavement Markings;
- Road Emergency Services Communications Unit (RESCU);
- Electrical and Lighting; and
- Urban Design and Landscape Design.

Records from the 2002 TSH study have been used extensively for the condition assessment of the pavement structure and the drainage components.

In addition to the 2002 TSH study, the following drainage related information provided by the City was used in the drainage analysis:

- Base Map of the study area;
- Storm sewer layout in the Expressway corridor; and
- As-built drawings for the Expressway within the study limit.

The TSH 2002 Gardiner (West Section) Rehabilitation report indicated that the condition of the existing sewer system within the Expressway corridor has been inspected at random locations using video and visual inspections. General result of the inspections is quoted as follows:

"Approximately 3000 meters of sewer were inspected at random locations in the study area. From Dowling Avenue to the Humber River 1,411 meters were inspected in both the eastbound and westbound directions. All pipes were constructed of concrete material with diameters varying between 200 and 675 mm. In general, the drainage system required cleaning and minor repairs. Inspections east of the Humber River identified 21 locations with minor cracking, 3 locations with blockages, 4 sections requiring further cleaning, and 13 locations where repair or replacement of the pipe is required. West of the Humber River, inspections identified 13 locations with minor cracking, 3 areas requiring further cleaning, and 3 locations where calcite joint repairs are recommended." (TSH, 2002).

3.5.2 Current Investigations and Inspections

As part of this Strategic Plan study, all overpasses and underpasses on the main line were inspected and hammer sounded in accordance with the 'enhanced' inspection requirements of the MTO Ontario Structural Inspection Manual (OSIM). The inspection records of the at-grade section structures are provided in Appendix Q under a separate cover. The majority of the at-grade bridge structures have identified needs to be addressed as part of this Strategic Plan; however, except for the roadside safety deficiencies for some structures, problems with spalling concrete, and expansion joints in poor condition, no structure was found to be in immediate need of a replacement or a major rehabilitation. The bridge structure summary sheets included in Appendix A provide a summary of the condition of each bridge structure on the at-grade section.

All of the retaining walls were visually inspected and current levels of deterioration, barrier type and signs of distress were noted. In general, the retaining walls with a parapet wall on top (RWP) have moderate deterioration of the parapet walls. The exposed portions of retaining wall, typically observed from roadways adjacent to the Expressway, were generally found to be in good condition with localized areas of deteriorated concrete. Similarly, the retaining walls without a parapet wall (RW) were found to be in good condition with localized areas of deteriorated concrete observed on the exposed face. The noise-walls and visible portions of their foundations were also inspected, and found to be in good condition without significant deterioration.

Applied Research Associates Inc. (ARA), as a sub-consultant to MRC, completed an update visual condition survey of the pavement in the spring of 2013, in addition to a review of the detailed condition survey records completed as part of the 2002 TSH study. Based on the update survey, the pavement is generally considered to be in fair to good condition. The majority of the distresses include reflection, alligator, moderate transverse and longitudinal cracking. Areas of distortion were encountered throughout, including areas of recent resurfacing. The majority of the shoulders has not been resurfaced and is considered to be in poor condition, especially around catch basins where significant distortions have occurred. Patches in some of the older pavement areas are in poor to fair condition. The current pavement condition is summarized in Table 3.7.

Table 3.7 – Pavement Condition Summary

Facility	Approximate Location	From	To	Condition	Comments
Eastbound					
Express	First 200 m to Pavement Change	145+50	148+60	Fair	Reflection cracking
	Exp/Coll Transfer to Food Terminal Tracks	148+60	185+72	Fair to Good	Recently resurfaced area
	Food Terminal Tracks to Humber Bridge	185+72	194+00	Poor to Fair	Segregation, distortion, moderate to severe longitudinal and transverse cracking
	Humber Bridge to Ellis Ave	194+00	203+00	Fair to Good	Reflection cracking
	Ellis Ave- West Abutment of Elevated Section	203+00	242+00	Good	Recently resurfaced with some distortion, minimal reflection cracking
Collector	Pavement Change to Express Transfer	148+60	168+40	Good	Some distortion
Westbound					
Express	West Abutment of Elevated Section to Pavement Change	242+00	236+50	Poor	Reflection and extensive low longitudinal cracking
	Pavement Change to End of Lakeshore on ramp at Dowling	236+50	228+75	Good	Recently resurfaced
	Dowling to Ellis Ave	228+75	203+50	Fair to Good	Some alligator and frequent low transverse cracking, rutting, and distortion
	Ellis Ave to Food Terminal Tracks	203+50	185+00	Poor	Distortions
	Food Terminal Tracks to Exp/Coll Transfer	185+00	163+20	Poor to Fair	Frequent moderate transverse cracking
	Exp/Coll Transfer to Wickman Road	163+20	145+50	Good	Recently resurfaced
Collector	Exp/Coll Transfer to End of Coll Jersey Barrier	163+25	147+00	Fair	Reflection cracking, frequent low transverse and centreline cracking
Ramps					
All on and off ramps are considered to be in poor to fair condition with extensive moderate to severe alligator and transverse cracking with some distortions.					

Detailed results of the drainage system inspection from the 2002 TSH study were not available. Required sewer works cannot be accurately identified without the detailed inspection results. Based on the age of the sewer system, and limited information available, for the purpose of this study, a complete replacement of the storm sewer system is assumed, which also establishes the worst case scenario.

Field investigations were undertaken to observe existing conditions of the barriers in the median, shoulders, core-collector separators and ramps. The barriers were evaluated to determine conformance with the Ontario's Ministry of Transportation standards (Geometric Design Manual and Roadside Safety Manual). The findings and measurements from the fieldwork were detailed in field notes and recorded digitally. The desk top assessment included utilizing the digital terrain model to classify potential roadside hazard locations, cataloguing and determining if appropriate shielding (per Ministry design standards) should be recommended.

Based on the above noted investigations, the following was observed and recommended for the at-grade section roadside safety measures:

- The bridge vertical clearances are adequate (per visual inspection). However, this recommendation is based on a visual inspection only and should be verified during any subsequent studies.
- The existing SBGR connections at the bridge and concrete barrier locations are substandard and should be retrofitted.
- The existing concrete illumination poles located within the clear zone on crossing roadways and at interchanges should be reviewed further to determine if shielding should be warranted.
- Overhead signs supports adjacent to the outside shoulders may require relocation or reconfiguration prior to start of construction as shoulder strengthening may be required.
- Further review should be undertaken to determine if shielding and/or upgrade to frangible posts is required at the ramp closing gates.
- Analysis should be undertaken to verify if the SBGR is mounted at adequate spacing at the concrete barrier curbs.
- Analysis should be undertaken to evaluate the existing condition of the concrete barriers and railings at the overpass bridge locations.
- For SBGR
  - Obsolete leaving end treatments should be retrofitted.
  - In the median, it is recommended that the SBGR be replaced with a concrete barrier.
  - In the core-collector separators and outside shoulders, it is recommended that the existing SBGR be replaced with a new SBGR.
- Box beam barrier should be reviewed further and upgraded as required.

The safety review including measurements, photos and recommendations are included in Appendix P.

4. PROPOSED PLAN FOR REHABILITATION AND MAINTENANCE

4.1 Elevated Section

Alternatives to rehabilitate the elevated Expressway have been developed based on a comprehensive evaluation of various factors including:

- Existing conditions;
- Current and previous Environmental Assessment (EA) studies;
- Current and previous rehabilitation work;
- Traffic impacts;
- Structure types;
- Cost;
- Schedule;
- Construction method; and
- Other restrictions.

As described in Section 3.4.5, the recommended scope of work includes complete deck replacement within the limits of the elevated Expressway. Deck replacements for different sections of the elevated Expressway have been prioritized based on numerous factors including the existing condition within specific areas of the Expressway and previous rehabilitation history. Deck replacement is typically conducted by saw-cutting and chipping the existing deck concrete designated for removal followed by forming and placing of new reinforced concrete deck. This conventional rehabilitation construction method has been typically used due to its simplicity, cost effectiveness and familiarity to local Contractors. However, the conventional method of removal and new deck construction using cast-in-place concrete is time consuming and leads to significant traffic delays and disruption during construction. Conventional removal method also generates significant noise and dust nuisance during construction.

MRC reviewed alternative deck types which could be used to replace the existing deteriorated reinforced concrete deck. The details of deck type alternatives considered are described in Section 4.1.1.

MRC has also investigated an Accelerated Bridge Construction (ABC) method to streamline the construction schedule and mitigate traffic impacts from construction. As such, the proposed rehabilitation plan for the Expressway has been developed based on two separate approaches: the Conventional construction method and the ABC method. The conventional rehabilitation method is described in Section 4.1.3 and represents the 'base case' with respect to both construction cost and duration for this Strategic study. The ABC method as detailed in Section 4.1.4 has been compared with the conventional rehabilitation method in terms of construction cost and duration, and the associated user costs. The cash flow generated under each method has been compared to the City's 10-year budget and 13-year program to identify the budget shortfall/surplus under each alternative.

The City indicated a desire to maintain a minimum of two traffic lanes in each direction on the Elevated Expressway during construction and to minimize traffic impact. Construction staging and ramp closures required for the proposed works can be found in Section 4.1.2.

The rehabilitation of the substructure (Bents) has been prioritized in this strategic plan based on current inspection and investigations.

4.1.1 Deck Replacement Alternatives

A *reinforced concrete deck* is the most common type of deck and is widely used on bridge construction projects. A reinforced concrete deck slab can be constructed with cast-in-place (CIP) or precast methods, and typically include top and bottom mats of reinforcement in the longitudinal and transverse directions. Waterproofing and asphalt wearing surface is typically overlaid on the concrete deck for durability reasons.

Many alternative deck systems which offer solutions to project specific challenges are becoming available in the industry. These other deck systems are typically lighter in weight compared to the conventional reinforced concrete deck. This is often an advantage for use in deck replacement by facilitating construction and reducing construction time. The following replacement deck types were considered for the replacement deck systems:

- Orthotropic steel deck;
- Open steel grid system;
- Filled or partially filled (half filled) steel grid using light or normal weight concrete;
- Exodermic™ deck;
- Steel Sandwich Panel System (SPS™);
- Fibre reinforced polymer deck;
- Aluminum deck; and
- Composite reinforced concrete deck made of cast-in-place or precast panels (including prefabricated components) preassembled with new steel girders off-site.

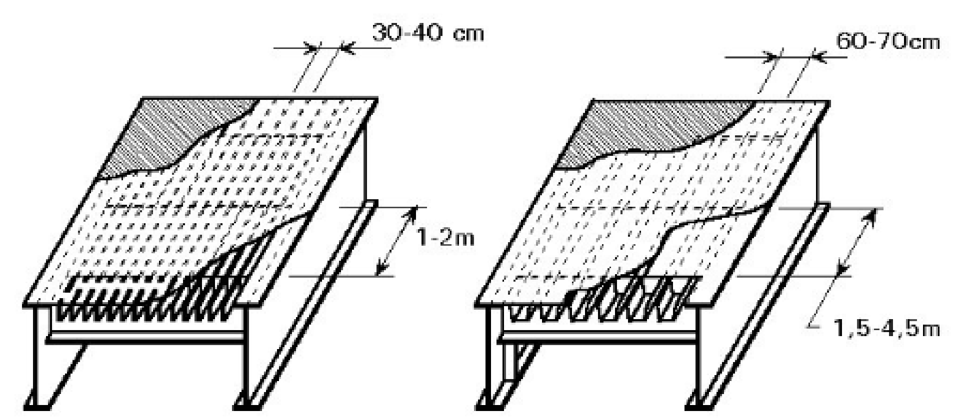


Figure 4.1 – Orthotropic Steel Deck

An *orthotropic steel deck* consists of a thin steel plate which is stiffened by a series of closely spaced longitudinal ribs that run parallel to the bridge alignment, as shown in Figure 4.1. An orthotropic steel deck is generally made integral with the supporting superstructure component, such as the top flanges of the girders and/or floor beams. A thin lightweight wearing surface (such as mastic asphalt) is typically applied over the waterproofing to provide the riding surface.

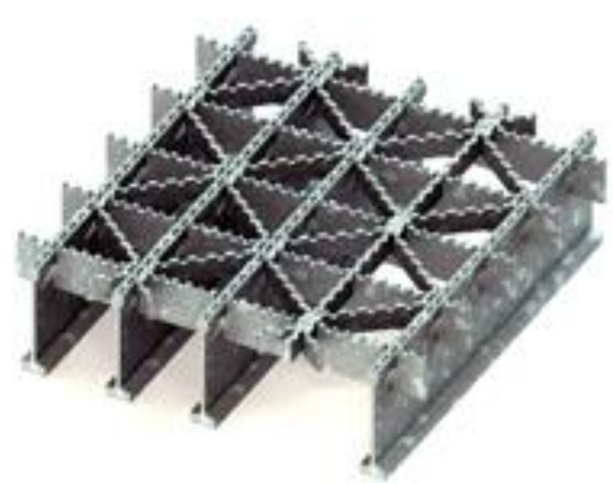
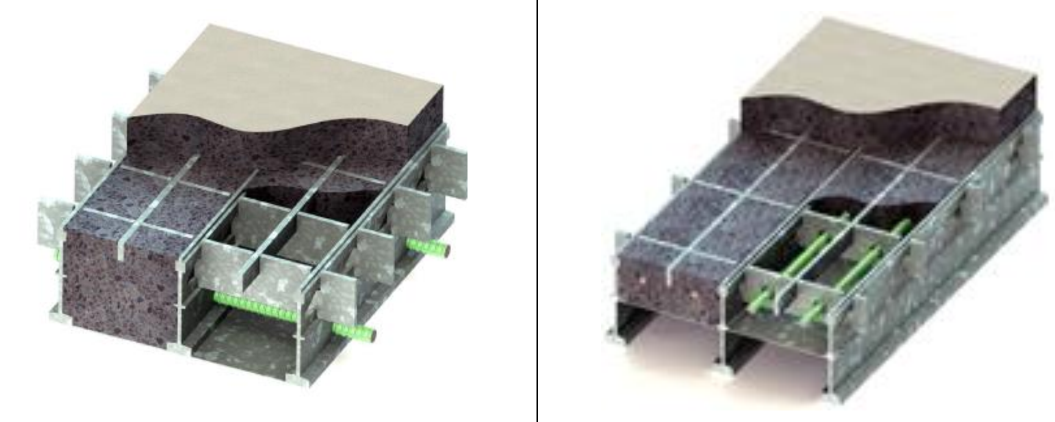


Figure 4.2 – Open Steel Grid System

An *open steel gird system* uses a pre-fabricated steel grid consisting of primary and secondary simple rectangular bars connected to the primary members as shown in Figure 4.2. No wearing surface is provided as the top surface of the steel grating is serrated to provide additional friction for vehicular traffic. Open metal grid decks are connected to the supporting components by welds or mechanical fasteners.



(a) Filled Steel Grid De ck | (b) Partially Filled Steel Grid Deck

Figure 4.3 – Filled or Partially Filled Steel Grid Deck

A *filled steel grid deck* is a deck in which the entire depth of the steel grid system (described above) is completely filled with concrete. A *partially filled steel grid deck* is a deck in which only a portion of the depth of the grid system is filled with concrete for a further reduction in weight. Filled and partially filled steel grid deck is shown in Figure 4.3. A monolithic concrete overfill is typically placed and used as a wearing surface. Filled and partially filled grid decks can be attached to the supporting components by welding, or more commonly by shear connectors (to transfer the shear between the deck and the supporting components).

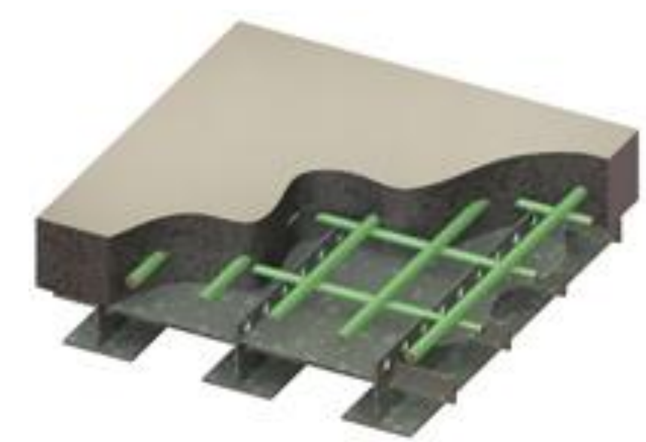


Figure 4.4 – Exodermic™ Deck

An *Exodermic™ deck* is a proprietary system consisting of a reinforced concrete slab that is cast on top of an unfilled steel gird as shown in Figure 4.4. Composite action between unfilled grid deck and the concrete slab is provided by shear connectors or other means. An Exodermic™ deck is often attached to the main supporting components by shear connectors.

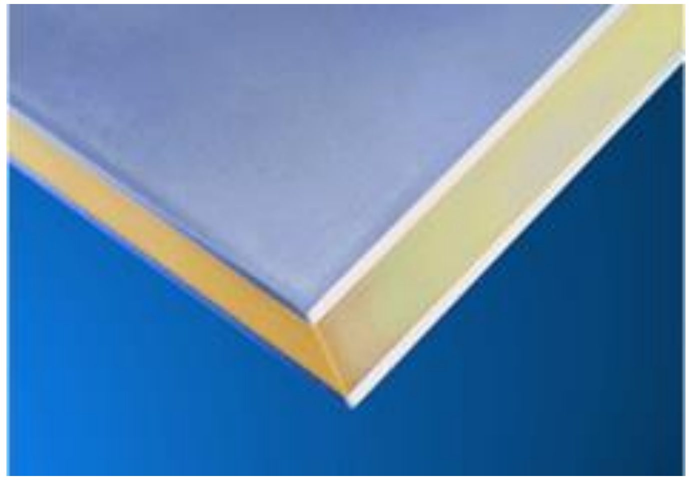


Figure 4.5 – Steel Sandwich Panel System (SPSTM)

A *Steel Sandwich Panel System (SPSTM)* is a proprietary system consisting of upper and lower steel plates with a light-weight core material 'sandwiched' between the plates as shown in Figure 4.5. The sandwich deck panel is analogous to an I-beam subjected to flexure, where the steel plates act as the flanges and the core acts as the web. Similar to the steel orthotropic deck, a thin lightweight wearing surface is applied over waterproofing to provide the riding surface. *SPSTM* panels are bolted to the supporting floor beams and include a bolted splice plate at panel joints.

A *fibre reinforced polymer (FRP) deck* is a proprietary system using pultruded panel sections which are mechanically fastened or glued together and supported by a framing system of beams and stringers. Polymer concrete is typically used as the wearing surface on FRP decks. The FRP deck system is very light in weight compared to conventional reinforced concrete deck. An FRP deck system is generally connected to the supporting components by bonding welds or mechanical fasteners.

An *aluminum deck* typically utilizes orthotropic aluminum deck panels consisting of stiffened plates supported by rib extrusions. The ribs are either parallel or perpendicular to the bridge alignment. The aluminum deck sections are typically extruded and are proprietary to the manufacturer of the specific extruded sections. Similar to the FRP deck panels, aluminum deck panels provide a lightweight alternative making them ideal candidates for deck replacement projects where a reduction in the weight of the deck provides benefits to the design. A thin epoxy type wearing surface is overlaid on the deck panels.

The replacement deck alternatives were evaluated based on the following criteria and constraints:

- Cost (capital and life cycle costs);
- Ability to maintain deck including the wearing surface;
- Product proprietorship;
- Durability under high traffic volumes for 75+ years;
- Proven in-service record in Canadian or other North American installations under similar climate conditions;
- Ability to incorporate and sustain a Performance Level (PL) traffic barrier;
- Speed of construction, thereby mitigating user costs;
- Ability to construct in late Fall/early Spring conditions to maximize construction window;
- Familiarity of local Contractors to construction of the system;
- Lead time required to fabricate components for the deck after award of a Contract; and
- Flexibility to accommodate horizontally curved alignments.

Table 4.1 – Comparison of Deck Type Alternatives

Deck types	Advantages	Disadvantages
Orthotropic Steel Deck	• Relatively lightweight deck system • Fast construction from preassembled components • Long service life • Many previous examples	• Complex design and fabrication • Possible issues on fatigue cracking and wearing surface performance
Open Steel Grid System	• Lightweight deck system • Fast construction from preassembled components	• Unpleasant ride quality and noise • Possible safety issue when wet • Possible safety issue by allowing debris and water through the deck onto the road below • Possible fatigue issue • Limited examples
Filled or Partially Filled Steel Grid Deck	•Relatively low construction and maintenance cost • Good slip resistance without the need for an overlay	• Relatively heavy deck system • Limited examples
ExodermicTM deck	•Relatively low construction and maintenance cost • Good slip resistance without the need for an overlay	• Proprietary product • Relatively heavy deck system • Limited examples
Steel Sandwich Panel System (SPSTM)	• Lightweight deck system	• Proprietary product • Very limited examples
Fibre Reinforced Polymer Deck	• Very light deck system • Fast construction from preassembled components • Low maintenance cost	• Proprietary product • No standard manufacturing process • High initial cost • Very limited in service Canadian experience
Aluminum Deck	• Light deck system • Fast construction from preassembled components	• High initial cost • Very limited examples
Reinforced Concrete Deck (Base Case)	• Low construction cost • Many previous examples and high familiarity to designers and contractors • Easy application to various configuration of the deck	• Heavy deck system

MRC contacted and/or met with manufacturers/suppliers of some of the deck systems considered in this study. In addition, a literature review was undertaken on various other systems. The advantages and disadvantages of the replacement deck alternatives, based on the criteria above, have been summarized in Table 4.1.

As shown in the table above, all of the deck types other than conventional reinforced concrete deck are typically light, and can be preassembled, delivered to the site and installed in position. Many of the deck replacement alternatives have limited precedents of use within Canada. As such, performance, durability and life cycle costs under high traffic volumes are difficult to assess and Engineers and Contractors are less familiar with these deck systems. Furthermore, the initial cost of these deck systems is anticipated to be high compared to the conventional reinforced concrete deck, and the design and fabrication of these decks are typically more complicated than the conventional reinforced concrete deck. Many of these deck replacement alternatives are also proprietary products as shown in the table which is not desirable for such a large construction project. In addition, there are very limited data from crash tests performed for the alternatives; as such, many of the deck systems have no data to support its capability of incorporating a PL-3 traffic barrier.

Based on the comparison above, the reinforced concrete deck (cast-in-place or precast including prefabricated steel girders) is recommended for the rehabilitation work under this Strategic Plan. The new deck would be protected with conventional waterproofing system and asphalt. Reinforcement in the concrete deck is recommended to be fibre reinforced polymer bars or stainless steel bars in either only top or both mats of reinforcing.

The following are the advantages of reinforced concrete deck over the other alternatives:

- Generally less costly than other deck types;
- Maintenance requirements are well understood. By using low permeability concrete combined with corrosion resistant reinforcement, maintenance effort is expected to be minimal;
- Not proprietary;
- More than 75 years of design life is achievable;
- Reinforced concrete decks have proven in-service records;
- Have standardized designs that incorporate crash-tested Performance Level (PL) traffic barriers (including barriers reinforced with corrosion resistant materials);
- Accelerated speed of construction is achievable using prefabricated components; however, cast-in-place construction tends to be slower than other deck types; and
- Use of local materials and labour which may better ensure the financial benefits from the implementation of this Strategic Plan remain within the Greater Toronto Area (GTA).

4.1.2 Construction Staging

The proposed rehabilitation work on the elevated Expressway between the west abutment and Lower Jarvis Street will generally entail three construction stages to maintain a minimum of two (2) traffic lanes in each direction during construction. Only two (2) construction stages are required from Lower Jarvis Street to the east abutment due to the wider deck section in this area. Typical construction staging configuration for the elevated Expressway is presented in Appendix D.

The conventional construction duration of the proposed contracts for the elevated section is typically two (2) or three (3) years depending on the area of the deck to be rehabilitated under each Contract. From the west abutment to Lower Jarvis Street, where three (3) construction stages are required, the first two (2) stages are expected to be completed in the first year of construction and the third stage is anticipated to be completed in the second year. Where three (3) year construction duration is anticipated for a Contract, one (1) stage is anticipated to be completed in each year. Alternatively, each Contact length could be divided into two (2) or three (3) subsections depending on the length of the Contract section and the three (3) stage construction of each subsection will be completed in one (1) year; this approach would avoid working in the winter months when poor productivity and weather related delays are anticipated.

The first option of completing one (1) stage per year requires temporary works along the construction joint in the deck prior to a winter shutdown. The second option of shortening the length of the Expressway for each year of construction does not require such work prior to the winter shutdown; however, it requires additional traffic control work since dividing a Contract section into two (2) or three (3) segments (completing all stages within a segment in one (1) construction season) will result in additional stages for traffic control thereby incurring additional cost and time for maneuvering of the traffic control devices. The same approach can be applied for the sections from Lower Jarvis Street to the east abutment where two (2) construction stages are required.

An accelerated construction methodology was developed to reduce the overall construction duration and the traffic restriction duration. Similar construction stages described above are also required to maintain two (2) lanes of traffic in each direction. However, traffic restriction on the Expressway within each Contract is limited to one construction season using the accelerated construction method.

4.1.3 Conventional Rehabilitation Method (Base Case)

In this section, the Strategic Plan for the elevated Expressway incorporates conventional construction methods to establish the base case scenario to rehabilitate the Expressway. The base case follows closely with the City's 10-year budget and 13-year program in terms of construction cost and year-over-year cash flow. The work on the elevated Expressway has been subdivided into major and minor (interim) rehabilitation Contracts to undertake the proposed deck replacements, bent repair, and structural steel coating. This Strategic Plan also considers work resulting from previously completed EA studies (replacement of York, Yonge, and Bay off-ramp from the eastbound Expressway). There is also an ongoing EA which will determine if the Expressway will be rehabilitated or removed from Jarvis Street to the east abutment. Considering the completion of this study may be upwards of five (5) years from now, the recommendations under this Strategic Plan is based on the following assumptions:

- EA study will require five (5) years with two (2) additional years for detailed design. Construction on the segment east of Jarvis Street is anticipated to be later than 2020; and
- For completeness and in accordance with the Study criteria, which includes maintaining the Expressway in its current configuration (except any modification recommended by approved EA's), for the purpose of this study, it was assumed that maintaining the Expressway and re-decking this section will be the outcome of the EA study.

In addition, the base case assumes that the City will commence the rehabilitation of the Expressway in 2014 from Bent 35 to Bent 91 as previously planned. This work is currently scheduled to take place from 2014 to 2016 inclusive.

Traditional bridge construction is based on a 10-hour shift per each working day and five (5) working days per week (Monday to Friday), and excludes statutory Holidays. Considering the timeline and the urgency of the rehabilitation work under this Strategic Plan and the extreme user impact anticipated from construction, the traditional construction schedule is deemed unsuitable; instead, the Strategic Plan assumes the following:

- two (2) 10-hour shifts (20 hours total) per day; and
- six (6) working days of construction activity per week

With the proposed, the Plan mitigates the traffic impact due to construction, provides four (4) hours per day for equipment maintenance and one (1) day per week in the construction schedule to rest the crews and/or use as ‘float’ within the schedule to mitigate risk in the construction schedule due to unforeseen delays.

The proposed schedule may have implications on noise by-laws within the City. This Strategic Plan has assumed that an exemption to the by-laws, if necessary, can be obtained.

Superstructures on the elevated Expressway consist of three structure types as follows:

- Reinforced concrete deck slab on steel girders;
- Reinforced concrete T-beams integrated with the Bent; and
- Precast concrete box girders.

Each structure type requires different rehabilitation approaches which will be detailed in the subsequent sections of this study. Section 4.1.3.1 to 4.1.3.3 provides details of the proposed work for each structure type.

4.1.3.1 Reinforced Concrete Deck Slab on Steel Girders

Reinforced concrete deck slab on steel girders are found between Bent 31 to 182 and between Bent 252 to the east abutment. More than 80% of the elevated Expressway consists of this structure type. As described in the preceding sections, in general, the existing deck of the elevated expressway is in poor condition and complete deck replacement is recommended. The existing steel girders are generally found to be in good condition and the service life of the steel girders can be extended with minor repairs.

Under the base case using the conventional method, rehabilitation consists of deck replacement while retaining the existing girders. This method offers very cost effective and simple construction methodology thereby mitigating inherent risk that may entail from a more complex system.

The following outlines the typical procedure for conventional deck replacement on steel girder including bearing replacements and the work on the bearing seats:

1. Implement traffic control measures;
2. Remove asphalt and parapet wall;
3. Saw-cut and remove the deck between girders;
4. Remove concrete above girder flanges with chipping hammers and maintain existing shear connectors;
5. Abrasive blast clean the girder top flange;
6. Jack/support girders;
7. Repair bearing seats and replace bearings;
8. Install new shear stud / repair girders as required;
9. Form deck;
10. Place reinforcing steel in the formwork;
11. Place and cure concrete in deck;
12. Construct new barrier wall;
13. Install expansion joints;
14. Complete lighting and drainage reconstruction;
15. Waterproof and pave; and
16. Repeat from 1 to 15 for the next construction stage.

The advantages and disadvantages of this conventional construction method have been summarized as follows:

<u>Advantages</u>

- Low capital construction cost;
- The scope of work is well understood by the local contractors and the contractors have the equipment readily available to undertake the work;
- Flexibility to construct irregular deck shapes; and
- Flexibility to address unforeseen conditions.

<u>Disadvantages</u>

- Long construction duration (removal of existing concrete deck is the critical path activity);
- Concrete removals generate large amount of noise and dust during the removal process;
- Risk of damaging girders during saw-cutting and chipping;
- Low productivity and quality during winter construction; and
- New deck is prone to cracking during construction if not constructed properly.

As indicated above a major disadvantage associated with the conventional construction method is the significant traffic delay and public disruption anticipated due to the lengthy construction duration. An Accelerated Bridge Construction (ABC) method using prefabricated components is proposed as an alternative to reduce the construction duration for this type of structure. Details of the alternative ABC method are provided in Section 4.1.4.

4.1.3.2 Reinforced Concrete T-Beams Integral with Bent

The reinforced concrete T-beam section of the Expressway located between the west abutment and Bent 31 comprises an integral cast-in-place (CIP) reinforced concrete deck, girder and bent cap. Within this section of the Expressway, there is also a short segment (between Bent 11 to 16) consisting of reinforced concrete deck slab on steel girders. In the T-beam segment, expansion bearings are installed at girder dapped ends. Expansion joints and bearings are located at the quarter point of every other span in this section. Figure 4.6 shows typical elevation of the T-beam section.

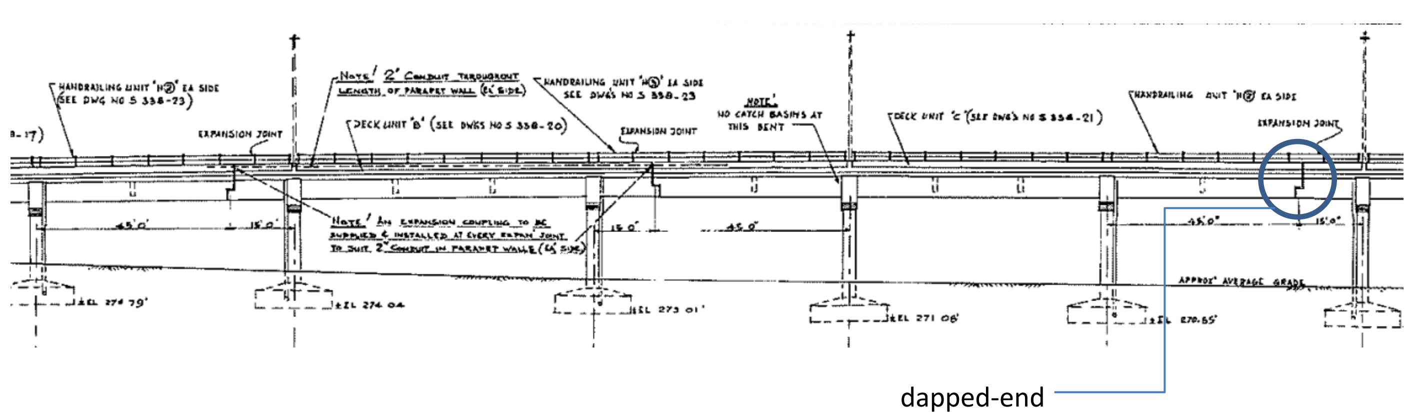


Figure 4.6 –Typical Elevation: T-beam Section

The following rehabilitation needs have been identified from the investigation of the existing conditions for the T-beam sections:

- Deck and parapet wall replacement;
- Girder end repair at expansion joint locations (including end diaphragm at some locations);
- Bearing replacement;
- Expansion joint replacement; and
- Local girder and bent repair.

The existing concrete girders are generally found to be in fair condition. Two (2) alternatives and two (2) sub-alternatives were developed for rehabilitation of the concrete T-beam section. Alternative 1A and 1B proposes to retain the existing girders and Alternative 2A and 2B proposes to replace the existing girders. The proposed rehabilitation work under each alternative is illustrated in Appendix I and described as follows:

- Alternative 1A: Concrete deck slab including the top portion of the existing girders and bents would be removed and a new cast in place reinforced concrete deck slab would be constructed. The existing girders and bents would be retained. Temporary supports for the girders are required for stability.
- Alternative 1B: The existing concrete deck slab would be removed only between the lines of girders and diaphragms. A new reinforced concrete deck slab would be constructed on top of the existing girders and bents with dowels installed to ensure composite action of the new slab and the existing girders.
- Alternative 2A: The existing concrete deck and girders would be replaced with reinforced concrete deck on new steel or precast concrete girders. The existing Bents would be modified to support the new girders on new bearings. A slight raise in the profile would be required to accommodate the increased superstructure elevation (caused by placing new girders above the bents instead of beside them).
- Alternative 2B: Existing concrete deck and girders would be replaced with reinforced concrete deck on new steel or precast concrete girder. For this alternative, the existing bents would be retrofitted to accommodate the new superstructure without a change in the vertical profile on the bridge.

Advantages/disadvantages between Alternatives 1A and 1B are summarized in Table 4.2 and advantages/disadvantages between 2A and 2B are summarized in Table 4.3.

Table 4.2 – Comparison of Deck Replacement, T-Beam Section Alternative 1 – Retain Girders

Alternative 1A	Alternative 1B
Advantages • Existing road profile is maintained • Existing reinforcement can be reused to mobilize composite action for the new concrete deck Disadvantages • Temporary support is required for the stability of structure during construction • Removal work at the top of girders, diaphragm, and bents is expected to be slow • High cost	Advantages • Temporary support is not required since there is no significant capacity reduction • Only minimal saw-cut removal is required for deck removal Disadvantages • Road profile may need to be raised up to by 200mm • Additional weight of new deck needs to be considered for the capacity and stability of the existing girders • Additional dowels are required for the new deck construction to ensure composite with girders • Poor deck section above girders is retained and incorporated into the final structure

Table 4.3 – Comparison of Deck Replacement, T-Beam Section Alternative 2 – Remove Girders	
Alternative 2A	**Alternative 2B**
Advantages • Existing bents can be used to support new girder and deck system with minor modification of the top of bent cap Disadvantages • Approximately 100m of grading work is required at the approach of the west abutment to accommodate the raised road profile • Temporary and permanent protection system is required during construction • West abutment retrofit is required to resist additional earth pressure due to raised road profile	Advantages • No grading work is required; road profile "adjustment" will be applied to each end within the concrete T-beam sections (on the bridge) • No retrofit of the west abutment is required Disadvantages • Bents #1 to #4 and #27 to #30 will need significant modification to accommodate the new profile; • Temporary support for bent is required due to staged bent retrofit

Based on the preliminary review of the comparison between the sub-alternatives using the previously established criteria and constraints, Alternative 1A and 2A are carried forward for comparison. The cost estimate and construction duration of each alternative carried forward are shown in Table 4.4 below.

Table 4.4 – Construction Cost and Duration – Concrete T-Beam Section Rehabilitation Alternatives		
Criteria	**Alternative 1A**	**Alternative 2A**
Construction Cost	$59M	$85M
Construction Duration	2 years	3 years

Although Alternative 2A is more expensive and expected to have longer construction duration than Alternative 1A, replacing the existing girders under alternative 2A is recommended due to the lower life cycle cost anticipated when the following are considered:

- The existing girder ends are severely deteriorated, and immediate repair is required;
- Continuous maintenance of the deteriorated sections is anticipated in the future; and
- Considering the delamination and spalling exhibited on the deck soffit and high chloride ion contents observed in the deck from the recent detailed deck condition survey, there is a high probability that chlorides may have penetrated deep into the existing girders possibly causing active corrosion of the top reinforcing bars.

Based on the above, the existing girders are approaching the end of their service life with only 20 to 25 years of remaining and do not satisfy one of the Strategic Plan mandate of establishing 75+ years of additional service life; therefore, Alternative 2A which replaces the existing girders are recommended for the Strategic Plan.

4.1.3.3 Precast Concrete Box Girders Section

The precast concrete box girders section is located between Bent 182 and 252 (York Street to Jarvis Street). This section of the Expressway consists of a composite reinforced concrete distribution slab on precast concrete box girders. Rehabilitation work on the girders within this section has recently been completed. This rehabilitation is expected to extend the life of the superstructure 20 to 25 years with minimum maintenance work. After 20 to 25 years, the remaining service life of the superstructure is expected to be exhausted and another cycle of repair or replacement will be required.

Complete replacement of the precast box girder and distribution slab is recommended following the rehabilitation of all other sections. The replacement superstructure type can be either precast concrete box girder similar to the existing or steel girders with a composite concrete deck consistent with the majority of the remaining elevated Expressway. The Expressway profile may require slight adjustment or modification on the Bents if steel composite girders are used due to the anticipated change in the superstructure depth.

This superstructure reconstruction using conventional construction method for this structure type is not recommended because of the limited work space available for the removal of the existing superstructure and the erection of the new superstructure. This section of the Expressway is constrained by traffic on Lakeshore Boulevard Westbound which runs directly beneath the Expressway and the numerous buildings located very close to the Expressway. As such, a special construction procedure and method is required for the superstructure replacement. Two (2) lanes in each direction will be closed at night time and cranes will be utilized from the closed lanes to lift the existing girders and to place the new girders. During day time, closed lanes will re-open and the preparation work, which does not require traffic restriction, can be undertaken. Details of this approach are illustrated in Appendix J. Deck slab on steel girder section is recommended for the replacement superstructure type to better facilitate the construction by reducing the weight of the superstructure. Construction schedule and cost were estimated based on this type of superstructure.

4.1.3.4 Contract Sections and Schedule

Appendix C shows the proposed Strategic Plan Contracts for the entire elevated section. The rehabilitation of the elevated Expressway under this Strategic Plan will take approximately 25 years to complete. Only minor repair and general maintenance work is anticipated beyond the 25 years for the current life cycle. The Strategic Plan is subdivided into two (2) parts: the 13 year plan (2013 to 2026) and the remainder of the 25 years (2027 to 2038). The 13 year component of the Strategic Plan restores the structure to a 'State of Good Repair' within the limitations of both the City's current approved 10-year Budget and 13-year rehabilitation program. The portion of this Strategic Plan beyond 13 years will complete the rehabilitation of the Expressway. Details of both parts of the Strategic Plan (13-year plan and the plan beyond 13 years) are described in the following sections.

As previously mentioned, the Strategic Plan and the construction schedules were developed based on the assumption of using a rather aggressive construction schedule to minimize the traffic delays and public disruption by reducing the overall construction duration. It is acknowledged that noise from construction work at night will be disruptive; however, this anticipated noise nuisance can be offset by taking full advantage of lane closures to advance the speed of construction thereby reducing the duration of noise nuisance. A more aggressive schedule with 24-hour work and seven (7) working days per week is not recommended because the Contractor needs equipment maintenance time in their daily work schedule, and float days in the Contract schedule to offset any unforeseen delay.

Working through winter will reduce the overall Contract duration. However, such work is not efficient and may extend the net duration of traffic restrictions thereby increasing the traffic impacts and user costs.

Furthermore, winter construction may impact snow removal operations and some construction, such as waterproofing and paving, is temperature sensitive. As such, the Strategic Plan recommends construction activities which require traffic closures take place between March and November.

4.1.3.5 13-year Plan

Appendix C shows the proposed subdivision of the elevated Expressway into a number of Contracts for development of the first 13 years of the Strategic Plan. The estimated construction schedule and capital construction cost for each Contract are also shown on the exhibits. A total of six (6) major deck replacement Contracts (E1 to E6) and three minor (interim and bent repair) Contracts (E-M1 to E-M3) are proposed to bring the condition of the elevated Expressway to a 'State of Good Repair' by 2026, within the time frame of the City's proposed 13 year plan.

The Contract sections and construction schedule were determined based on the following:

- Existing structure conditions;
- Current and previous EA studies;
- Current Contracts and rehabilitation work already scheduled by the City (Contract 13SE-19S);
- Cash flow in comparison to the City's approved 10 year budget; and
- Structure type.

As described in Section 3, field investigations have been conducted to determine the extent of deterioration of the elevated Expressway and to identify and prioritize the rehabilitation needs. The condition of the deck slab in the concrete T-beam sections from the west abutment to Bent 31 is generally better than the steel composite girder sections. In addition, the T-beam deck is expected to have lower risk of a localized deck failure compared to the steel girder sections due to the interaction between the deck slab and the concrete T-beam. Therefore, the rehabilitation of the concrete T-beam section is scheduled following the rehabilitation of the steel girder sections and is not included in the first 13-years of the base case scenario. However, the first 13 years of the base case Plan includes the interim repair (Contract E-M3) in the year of 2018, which would address the immediate safety concerns and deterioration of the girder ends (at expansion joints).

For the steel girder sections from Bent 31 to Bent 182, the deck is in generally poor condition and complete deck replacement is recommended in this section. The design for the deck replacement from Bent 35 to 91, under current Contract 13SE-19S (Contract E1 in Strategic Plan), is complete and construction is anticipated to start in 2014. The construction for this section is scheduled to be complete in 2016. Rehabilitation work from Bent 125 to 182 (Contract E2) is proposed to follow starting in 2017 to address the poor condition of the deck in this section and is expected to be complete in 2019. Lastly, the deck replacement from Bent 91 to 125 (Contract E3) is scheduled in the base case Plan to start in 2020 and complete by 2021.

For the steel girder spans from Bent 252 to 341, the deck is also in very poor condition. However, due to the current Gardiner East EA Study, the rehabilitation work from Bent 252 to 341 will be delayed to beyond 2020 to allow for completion of the EA Study. Interim repairs within this section are currently in progress and will be complete by 2014. The deck replacement of this section is divided into three (3) contracts (Contracts E4, E5 and E6) with the work scheduled from 2021 to 2026, following the completion of the current EA, as shown in the Appendix C.

The steel girder "ramp" from Bent 341 to east abutment was reconstructed between 2000 and 2001 as part of the previous demolition of the elevated Expressway from Don Roadway to Leslie Street. The ramps to the Don Valley Parkway (DVP) northbound (Ramp "Pn") and from the DVP Southbound (Ramp "Ps") had their decks replaced in 1993. A new 225mm thick reinforced concrete slab on steel girder superstructure was constructed at that time. Considering the recent rehabilitation effort and the inspection records showing good condition, these sections are expected to remain in service for many more years with only minor maintenance work. As such, rehabilitation work on these sections is not scheduled as part of this Strategic Plan.

The rehabilitation of the concrete box girder section from Bent 182 to 252 is not included in the first 13 years of the Strategic Plan due to the recent rehabilitation, which will extend the service life of the deck and girders approximately 20 to 25 more years with minimal maintenance work.

The condition of the deck on the ramp structures is generally better than the condition of the mainline portion. In addition, many of the ramp lanes carry lower traffic volumes than the mainline. The ability to repair any local deck failures (should such occur) would result in less impact to motorists than a similar repair on the mainline. Minor interim repairs are scheduled within the first 13 years of the Strategic Plan. As such complete deck replacement for the ramps can be delayed to beyond the initial 13 years of the Strategic Plan.

Bent rehabilitation has been prioritized based on results from field inspections and investigations. Two contracts (Contracts E-M1 and E-M2) are scheduled within the first 13 years of the Strategic Plan. This work will involve the complete refacing of the Bents. The Bents that are not included in the 13 year plan will be rehabilitated beyond the first 13 years.

The proposed York/Bay/Yonge Ramps reconfiguration under the approved EA study is recommended to start in 2022 after the west deck replacement work is complete to avoid further traffic impacts as a result of concurrent construction taking place on both the elevated Expressway as well as many of the 'at- grade' connectors.

The scope of the major rehabilitation work under each Contract within the first 13 years of the Strategic Plan is summarized in Table 4.5.

Table 4.5 – Elevated Section Base Case 13 year Plan

Contract	Scope of Work
E1 (2014 – 2016)	• Deck and parapet wall replacement (Bent #35 - #91, 37 main line spans) • Bearing seat repair and bearing replacement/repair • Expansion joint replacement
E2 (2017 – 2019)	• Deck and parapet wall replacement (Bent #125 - # 182, 57 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps "D", "E", "Gs", and "Ay")
E3 (2020 – 2021)	• Deck and parapet wall replacement (Bent #91 - # 125, 34 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps "As" and "Bs")
E4 (2021 – 2022)	• Deck and parapet wall replacement (Bent #313 - # 341, 28 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps "Ps" and "Pn")
E5 (2023 – 2024)	• Deck and parapet wall replacement (Bent #285 - # 313, 28 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement
E6 (2025 – 2026)	• Deck and parapet wall replacement (Bent #252 - # 285, 32 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps "Aj" and "Cj")
E-M1 (2015)	• Bent rehabilitation/refacing (Bent #120 - #129, Ay3 - Ay7, and Gs1 - Gs6)
E-M2 (2016)	• Bent rehabilitation/refacing (Bent Aj1 - Aj13, and Cj1 - Cj7)
E-M3 (2018)	• T-beam end repair including end diaphragm repair at expansion joint locations (12 locations) • Local T-beam repair • Local deck repair • Parapet wall and median barrier wall repair
E-M4 (2022)	• York-Bay-Yonge Ramp reconstruction

4.1.3.6 Beyond the first 13 years of the Strategic Plan

The plan beyond the first 13 years includes all necessary work to completely rehabilitate the elevated Expressway. This includes the sections where rehabilitation has been deferred and/or where interim repairs were conducted within the initial 13-year stage as a 'holding' strategy.

A total of 7 major Contracts (E7 to E13) for the deck replacement as well as Contracts for bent repair and structural steel coating (E-M4 and E-M5) are proposed to complete the rehabilitation of the elevated Expressway.

The T-beam section (Contract E7) will be rehabilitated from 2027 to 2029. Deck replacement of the ramp structures (Contracts E8, E9, E10, and E11), where the interim repairs were undertaken during the 13-year plan will commence in 2030 and be complete in 2034. Lastly, the replacement of the concrete box girder section from Bent 182 to 252 (Contracts E12 and E13) will be undertaken from 2035 to 2038. This is when the recently rehabilitated box girder section is expected to reach the end of its service life.

The Contracts for bent repair and structural steel coating (E-M4 and E-M5) were assigned throughout the plan beyond the first 13 years considering the existing conditions and the overall schedule of the plan.

The scope of major rehabilitation work for each Contract beyond the first 13 years of the Strategic Plan is summarized in Table 4.6.

Table 4.6 – Scope of Work: Elevated Section Base Case Plan beyond 13 years

Contract	Scope of Work
E7 (2027 – 2029)	• Parapet wall , Deck and girder replacement (West Abutment - Bent #35, 35 main line spans) • Bent retrofit (35 Bents) • Abutment retrofit and approach slab reconstruction • Grading work (100m)
E8 (2030 – 2031)	• Deck and parapet wall replacement (Ramps "Cs", "D", "E", and "F") • Bearing seat repair and bearing replacement • Expansion joint replacement
E9 (2032)	• Deck and parapet wall replacement (Ramps "Gs" and "Ay") • Bearing seat repair and bearing replacement • Expansion joint replacement
E10 (2033)	• Deck and parapet wall replacement (Ramps "As" and "Bs") • Bearing seat repair and bearing replacement • Expansion joint replacement
E11 (2034)	• Deck and parapet wall replacement (Ramps "Aj" and "Cj") • Bearing seat repair and bearing replacement • Expansion joint replacement
E12 (2035 – 2036)	• Deck, parapet wall and girder replacement (Bent #182 - # 233, 27 main line spans, Ramps "Dj" and "Ab") • Bearing seat repair and bearing replacement • Expansion joint replacement
E-13 (2037 – 2038)	• Deck, parapet wall and girder replacement (Bent #233 - # 252, 19 main line spans, Ramps "Bj" and "Cb") • Bearing seat repair and bearing replacement • Expansion joint replacement
E-M5 (2027 – 2036)	• Bent rehabilitation/refacing
E-M6 (2027 – 2028 & 2033 – 2037)	• Structural Steel coating

4.1.3.7 Cost Estimate

Capital Construction Cost

The capital construction cost of the Strategic Plan includes all major rehabilitation cost in addition to the interim repair cost from all Contracts within the Strategic Plan. The following assumptions were used to establish the capital cost for the base case:

- All capital costs are based on 2013 market prices;
- Costs include a 20% allowance for contingency;
- Costs include a 5% allowance for 'miscellaneous' items;
- Costs were developed based on approximate quantities; and
- Engineering costs have been calculated separately to compare with the City's established budget.

Table 4.7 shows the summary of the capital construction cost for each contract proposed under the base case scenario.

Table 4.7 – Capital Construction Cost for Base Case Strategic Plan (Present Value – 2013 $)

13-year plan		Plan beyond 13 years	
Contract	**Cost ($ M)**	**Contract**	**Cost ($ M)**
E1	$63.2	E7	$97.8
E2	$85.1	E8	$24.7
E3	$54.8	E9	$7.1
E4	$44.3	E10	$7.7
E5	$49.4	E11	$9.7
E6	$67.8	E12	$100.6
E-M1	$3.9	E-13	$77.6
E-M2	$1.7	E-M5	$167.0
E-M3	$2.4	E-M6	$114.5
E-M4	Funded elsewhere	-	-
Total	$372.7	Total	$606.7

The capital construction cost for the rehabilitation of the elevated Expressway through the first 13 years is approximately $373M with an additional $607M estimated for the plan beyond the first 13 years to complete the rehabilitation of the entire Expressway. Detailed cost breakdowns are provided in Appendix L.

<u>Maintenance Cost</u>

The maintenance costs of the elevated Expressway include the following:

- Annual maintenance cost including line marking, sweeping, flushing, miscellaneous repairs to snow plow damage of barriers and general repairs;
- Engineering inspection cost including the biennial OSIM inspection and detailed inspection as necessary; and
- Controlled chipping (to remove delaminated concrete).

Appendix L provides the breakdown of the maintenance cost each year of the Strategic Plan.

<u>Comparison with the City's 10-year rehabilitation budget</u>

The City's approved 10-year budget for repair of the elevated section is $338M which includes 2.5% per annum inflation (see the table provided by the City in the Appendix O). The estimated capital construction cost from the first 10 years of the base case Plan (by the year of 2022) including 2.5% per annum inflation is $301M. The maintenance cost estimated for the same period is $25M. The total cost estimate including the rehabilitation and maintenance work to year 2022 is $326M which is within the financial constraints of the City's approved 10-year budget.

The year-over-year cash flow is compared between the proposed plan and the City's 10-year budget in Section 4.3.

4.1.3.8 Concluding Remarks

The proposed conventional rehabilitation method under the base case scenario enables the Strategic Plan to meet the established budget restraints for the first 10 years as well as the City's pre-study 13 year program (2013 to 2025). The base case plan beyond 13 years has also been presented for the complete rehabilitation of the Expressway.

The conventional rehabilitation method is reliable and typically cost effective. However, significant traffic delays and public disruption is anticipated. User costs from the delays are expected to be high. To mitigate the traffic impacts and user costs, an accelerated rehabilitation method has been developed as an alternative to the conventional rehabilitation method, and is presented in the subsequent sections for consideration.

4.1.4 Accelerated Rehabilitation Method (Alternative Plans)

Accelerated Bridge Construction (ABC) methods have been developed as an alternative methodology for deck replacement on the elevated Expressway. As the name implies, ABC methods were explored to streamline construction schedule and thereby mitigate user costs due to construction related traffic restrictions. Under this alternative method, new girders and deck segments would be prefabricated in advance off-site. Prefabricated girder and concrete deck segments would then be transported to the site and placed in their final locations. The existing deck and girders would be removed in segments utilizing the same equipment developed to handle the prefabricated components.

A significant traffic delay is anticipated during construction once the existing six (6) lanes of Expressway traffic are reduced to accommodate construction. As a result, the drivers using the Expressway will spend more time on the road due to this delay or will divert to alternating routes (longer distance) to avoid the delay, and will incur additional costs. The proposed ABC method mitigates the user costs by accelerating the construction procedure and reducing the duration of construction related traffic restriction.

Bridge replacements or rehabilitation using ABC method has become more widely employed in recent years to mitigate traffic delays during construction. ABC method is typically applied to single span bridge reconstruction projects; however, similar concept is proposed for use on the Gardiner Expressway to mitigate traffic impact and user costs.

MRC developed a basic concept of prefabricating new girders and deck panels at an off-site facility and shipping them to the site for erection. Under this method, rapid replacements including the removal of the existing girders and deck and the installation of the new deck panels were required while maintaining a minimum of four (4) lanes of traffic.

Two (2) mechanical/millwright companies, Western Mechanical Electrical Millwright Services Ltd., and IF Engineering Corporation, were consulted regarding the feasibility of the ABC method for the elevated Expressway. The following constraints were provided to the specialist consultants during the feasibility study:

- Maintain a minimum of two (2) lanes of mainline traffic in each direction;
- Conduct all replacement work from the Expressway with minimum traffic disruption to the road(s) below;
- Be able to accommodate variable deck width, various span lengths, and curved plan alignment; and
- Have a procedure applicable to the ramp structures.

Several concepts were investigated during the feasibility study. Appendix K shows the preferred method developed from the feasibility study. This method would utilize specially designed equipment called 'Deck Track Schnabel' to remove the existing deck and girder segments. Once the existing section is removed, the equipment would also be used to install the new pre-fabricated girder/deck panels. A typical replacement segment consists of a prefabricated composite concrete deck slab and two steel girders. With this configuration, each segment is stable and can safely carry load without further work to connect to the adjacent segments for stability. Once the new segment is placed into position, temporary steel plates will cover the longitudinal gap between the segments so that Deck Track Schnabel and other equipment can travel on the new segments; this way, the replacement work can progress continuously, without delay.

With the proposed ABC method, all deck replacement work can be performed with minimal disruption to the traffic below. A debris platform is required to be installed underneath the existing girders, and anchored to the existing Bents prior to commencement of the work to collect debris from the removal operation as well as provide access during installation of the replacement sections. The following summarizes the key construction procedures for the deck and girder replacement under this alternative for each construction stage. A detailed construction schedule for the ABC method can be found in Appendix N.

The general sequence of the proposed ABC method is as follows:

1. Install debris platform;
2. Repair the Bents in locations to accept the new bearings for the new prefabricated (girder) panels;
3. Implement traffic control measures;
4. Remove and salvage existing parapet wall railings;
5. Saw-cut and remove the existing parapet wall;
6. Saw-cut existing deck;
7. Drive Deck Track Schnabel to lift position;
8. Lift existing girder and deck with the Schnabel;
9. Drive Deck Track Schnabel laterally to waiting transport;
10. Lower girder and deck and disconnect the Schnabel from girder;
11. Drive Deck Track Schnabel laterally out of the way of transporter;
12. Transporter and girders/deck leave site;
13. New girder segments with composite precast deck arrive on site;
14. Drive Deck Track Schnabel to position and lift new girder segments off transport;
15. Drive Deck Track Schnabel to position and install new girders/deck on new bearings;
16. Install temporary steel plates between joints;
17. Advance lifting device to next segment/span;
18. Construct longitudinal and transverse closure joints between the segments using ultra high performance concrete after several spans of panels are replaced;
19. Repeat step 6 to 18 for all spans within a stage;
20. Construct barrier wall and expansion joints;
21. Waterproof and pave; and
22. Repeat all steps for the next stage of construction.

Appendix K shows the typical cross section of the Expressway and construction stages for the ABC method. New bearing seats to receive the new prefabricated deck and girder segments are proposed to be constructed prior to the commencement of replacement work. By constructing the bearing seats and installing the bearings in advance, the removal and replacement work can proceed continuously. The replacement girders are typically located between the existing girders, so that the new bearing seats can be constructed without jacking of the existing superstructure. However, where the new girder locations conflict with the existing girders, the existing girders will be jacked and the bearing seat repaired prior to the start of installing new panels. Work for the bearing seat repair and new bearing installations will be performed from underneath the Expressway and have no traffic impact on the mainline.

The advantages and disadvantages of the ABC method are summarized below:

<u>Advantages</u>

- Construction duration is greatly reduced;
- Traffic delays and public disruption on the Expressway is minimized by reducing the duration of reduced lanes thereby mitigating the user cost;
- Noise and dust from the removal work is mitigated;
- Construction quality is improved since the replacement components are fabricated in a more controlled environment; and
- Construction with prefabricated components is less weather dependent.

Disadvantages

- More capital construction cost is required due to the cost of the new girders and the cost premium of the ABC method;
- Tight tolerance is required during fabrication and construction to avoid possible installation problems;
- Precise survey data and detailed design is required; and
- Unforeseen risks inherent with unconventional methods exist.

4.1.4.1 Applicability to Gardiner Expressway

The proposed ABC method is suitable only for the deck replacement of the steel composite girder sections of the Expressway which comprises more than 80% of the elevated Expressway. For concrete T-beam sections of the Expressway the deck and girders are integral with the bent; therefore, a temporary support system is required during the deck and girder removal to maintain the stability of the existing girders and bents. In addition, the Bent caps need to be retrofitted to receive a new superstructure, which will also slow down the overall construction process. For these reasons, it is not proposed to apply the same ABC method to the T-beam sections. Other methods for the T-beam portion of the Expressway have been considered to accelerate construction including construction of new Bents in advance beneath the exiting superstructure. New prefabricated girder and deck segments are then erected following the demolition of the existing structure. However, this method requires a significant temporary support system and a large working area during demolition and erection processes. As such, the ABC method for the concrete T-beam section is deemed not practical and conventional replacement method described in the preceding sections of this study is recommended.

For the side-by-side precast box girder section of the Expressway, it is not feasible to repair the Bent bearing seat or to construct the new bearing seat prior to the existing deck and girder being removed. Therefore, the bearing seat needs to be repaired following the removal of the existing girders and prior to the placement of the new girders. This will significantly slow down the replacement of the box girder superstructure compared to the ABC method employed for the steel girder sections. The accelerated method described in the preceding section is only practical where the removal and erection process can be performed in a continuous manner. As such, it is concluded that the ABC method outlined in this section is not applicable for the box girder portion of the Expressway and the approach described in the preceding sections is also recommended for this section.

4.1.4.2 Contract Sections and Schedule

Each precast segment will be fabricated off-site at a remote facility then delivered to the Expressway when it is ready for installation. Shop drawings and the fabrication of the segments will require a significant lead time which would take up a large portion of the total contract duration; however, these activities will not affect traffic operations on the Expressway. Once the segments are ready to be delivered to the site, the Contractor will implement traffic staging and reduce the number of lanes to create a working area. A detailed construction schedule is included in the Appendix N.

The total estimated time for the removal and erection process of a single prefabricated panel segment is 2.5 hours as shown on the schedule in Appendix K. Each segment consists of a composite concrete deck slab precast on two new steel girders. Based on two 10-hour shifts each working day, up to eight (8) segments can be replaced per day. However, the construction schedule in Appendix N is based on replacement of six (6) segments per day to account for unforeseen difficulties.

Construction of the closure joint and barrier walls will follow the panel installations. Once all the segments within a construction stage are replaced and the closure joint and barrier walls is completed, the new segments will be waterproofed and paved, which completes construction for that stage. Traffic will then be diverted to the newly constructed superstructure for the next construction stage. The preparation work for the next construction stage, which includes shifting of the traffic control devices, is estimated to take three (3) weeks from the completion of the previous stage work.

Approximately 240 segments are included in a typical two-year conventional contract. Based on the proposed schedule, replacement of 240 segments will take 10 weeks with the deck track schnabel. The total working time on the Expressway is estimated to be only 17 weeks for two stage construction, and 20 weeks for three stage construction.

Although site preparation work and pre-fabrication of panels will require significant lead time, the time during which traffic would be restricted is only approximately 17 weeks for a two (2) stage Contract (and 20 weeks for a three (3) stage Contract). Such Contracts would also replace more deck area than a similar Contract using conventional construction method. Accordingly, the ABC method is able to extend the limits of construction compared to a conventional construction Contract and is capable of rehabilitating more deck area with less traffic impact.

The extended Contract limits have been applied to the development of an Alternative Strategic Plan (for the elevated portion) using the ABC method. A modified plan for both the first 13 years and for the period beyond has been developed under this alternative.

4.1.4.3 13-Year Plan – Accelerated Construction

Appendix C shows the Contract sections and schedule based on the ABC method. The same construction schedule assumptions used for the conventional construction method also apply (i.e. two (2) 10-hour shifts per day and six (6) working days per week). Extended Contract limits, compared to the conventional method, completing larger areas of deck replacement under each Contract, have been used. Contracts E-A1 and E-A2 represent the Contracts where the ABC method is proposed. Contract E-A1 is from Bent 91 to 182 has the same Contract limits as the two conventional construction contracts, Contract E2 and Contract E3 combined. Contract E-A2 from Bent 252 to 341 corresponds to the combined limits for conventional construction Contracts E4, E5, and E6.

Contract E1 has been tendered already and construction for this section is anticipated to begin in 2014 and be complete in 2016. This Contract will utilize conventional deck replacement methods. Contract E-A1 in the Alternative Strategic Plan will start in 2017 following the completion of Contract E-A1 and be complete in 2019. The bent repair (Contract E-M1 and E-M2) and the interim repair for the T-beam section (Contract E-M3) will take place between 2015 and 2018. Contract E-A2 can start in 2020 when the EA study (east of Jarvis Street) is anticipated to be complete. York/Bay/Yonge Ramps reconfiguration (Contract E-M4) is proposed to take place in 2020 after the west mainline deck rehabilitation work is complete.

With the ABC method, rehabilitation work can be completed over a larger area on the elevated Expressway within the 13-year plan compared to the conventional construction method. As such, complete deck and girder replacement for the T-beams Section (Contract E2) is included in the 13-year plan and can start in 2023 and be complete in 2025. Deck replacement of some ramp sections (Contract E3) is also included in the 13-year plan and scheduled in 2026.

Scope of the major rehabilitation work for each Contract under the Alternative Strategic Plan is summarized below.

Table 4.8 – Elevated Section Alternative Plan I (Accelerated Construction) 13 year Plan

Contract	Scope of Work
E1 (2014 – 2016)	• Deck and parapet wall replacement (Bent #35 - #91, 37 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement
E-A1 (2017 – 2019)	• Deck and parapet wall replacement (Bent #91 - # 182, 91 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps “D”, “E”, “Gs”, “Ay”, “As” and “Bs”))
E-A2 (2020 – 2022)	• Deck and parapet wall replacement (Bent #252 - # 341, 88 main line spans) • Bearing seat repair and bearing replacement • Expansion joint replacement • Interim repair (Ramps “Ps”, “Pn”, “Aj” and “Cj”)
E2 (2023 – 2025)	• parapet wall , Deck and girder replacement (West Abutment - Bent #35, 35 main line spans) • Bent retrofit (35 Bents) • Abutment retrofit and approach slab reconstruction • Grading work (100m)
E3 (2026)	• Deck and parapet wall replacement (Ramps “Gs” and “Ay”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E-M1 (2015)	• Bent rehabilitation/refacing (Bent #120 - #129, Ay3 - Ay7, and Gs1 - Gs6)
E-M2 (2016)	• Bent rehabilitation/refacing (Bent Aj1 - Aj13, and Cj1 - Cj7)
E-M3 (2018)	• T-beam end repair including end diaphragm repair at expansion joint locations (12 locations) • Local T-beam repair • Local deck repair • Parapet wall and median barrier wall repair
E-M4 (2020)	• York-Bay-Yonge Ramp reconstruction

4.1.4.4 Plan Beyond 13 years – Accelerated Construction

Since more work can be completed using accelerated construction during the first 13 years of the Alternative Strategic Plan, only a small amount of work including the deck replacement of some ramp structures, and the superstructure replacement for precast box girder sections, remains beyond the first 13 years. Deck replacement for several Ramps (Contracts E4, E5, and E6) will begin in 2027 and be complete in 2030. The precast box girder replacement (Contract E7 and E8) is proposed from 2035 to 2038 which remains unchanged from the conventional construction plan since recent interim repairs are expected to extend the life of that section of the Expressway until that time and no major rehabilitation work is anticipated prior to that time.

The scope of major rehabilitation work for each Contract in the Alternative Strategic Plan beyond 13 years is summarized below.

Table 4.9 –Elevated Section Alternative Plan I (Accelerated Construction) Beyond 13 years

Contract	Scope of Work
E4 (2027 – 2028)	• Deck and parapet wall replacement (Ramps “Cs”, “D”, “E”, and “F”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E5 (2029)	• Deck and parapet wall replacement (Ramps “As” and “Bs”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E6 (2030)	• Deck and parapet wall replacement (Ramps “Aj” and “Cj”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E7 (2035 – 2036)	• Deck, parapet wall and girder replacement (Bent #182 - # 233, 27 main line spans, Ramps “Dj” and “Ab”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E8 (2037 – 2038)	• Deck, parapet wall and girder replacement (Bent #233 - # 252, 19 main line spans, Ramps “Bj” and “Cb”) • Bearing seat repair and bearing replacement • Expansion joint replacement
E-M5 (2027 – 2036)	• Bent rehabilitation/refacing
E-M6 (2029 – 2031)	• Structural Steel coating (Only for the remaining existing steel girders)

A second accelerated plan, Alternative Plan II, was developed per City’s request, where the Contract E1 is also converted to the accelerated construction contract (Contract E-A0) and scheduled from 2017 to 2018. The remainder of the Alternative Plan II remains unchanged from Alternative Plan I. Proposed contract schedules for both Alternative Plan I and Alternative Plan II are included in Appendix C.

4.1.4.5 Cost Estimate

Construction Cost – Accelerated Construction

Table 4.10 shows the summary of the capital construction cost for each Contract under the proposed Alternative Strategic Plans (Alternative Plan I and II) and total capital construction cost for the 13-year plan and plan beyond the first 13 years. The same cost estimating assumptions indicated for the conventional construction method in Section 4.1.3.7 was applied to the accelerated construction costs except a higher contingency allowance of 30% was used which reflects the relatively higher risk compared to the conventional method. Detailed cost breakdowns are provided in Appendix L.

Table 4.10 – Capital Construction Cost for Alternative Plans (Present Value – 2013 $)							
Alternative Plan I				Alternative Plan II			
13-year plan		Plan beyond 13 years		13-year plan		Plan beyond 13 years	
Contract	**Cost ($ M)**	**Contract**	**Cost ($ M)**	**Contract**	**Cost ($ M)**	**Contract**	**Cost ($ M)**
E1	$63	E4	$24.7	E-A0	$112.1	E4	$24.7
E-A1	$253.2	E5	$7.7	E-A1	$253.2	E5	$7.7
E-A2	$293.3	E6	$9.7	E-A2	$293.3	E6	$9.7
E2	$97.8	E7	$100.6	E2	$97.8	E7	$100.6
E3	$7.1	E8	$77.6	E3	$7.1	E8	$77.6
E-M1	$3.9	E-M5	$167.0	E-M1	$3.9	E-M5	$167.0
E-M2	$1.7	E-M6	$34.0	E-M2	$1.7	E-M6	$18.0
E-M3	$2.4	-	-	E-M3	$2.4	-	-
E-M4	Funded elsewhere	-	-	E-M4	Funded elsewhere	-	-
Total	$722.8	Total	$421.3	Total	$771.7	Total	$405.3

Using the ABC methods, the capital construction cost for the rehabilitation of the elevated Expressway through the first proposed 13-years is estimated to be $723M and $727M for Alternatives Plan I and II, respectively. An additional $421M and $405M are estimated for the implementation of the plan beyond 13 years to complete the rehabilitation of the entire Expressway for Alternative Plan I and II, respectively. This proposed expenditure of money for the accelerated method exceeds the City's current approved budget for the period up to and including 2022. This is further discussed in Section 4.1.4.6.

Comparison with the City's 10-year rehabilitation budget

The City's approved 10-year budget for the elevated Expressway is $338M (including inflation of 2.5% per annum). The estimated capital construction cost from the accelerated construction to the year of 2022 is $753M and $811M for Alternatives I and II, respectively (including maintenance cost and 2.5% inflation). The cost estimates for both alternative plans are more than two times the City's approved 10-year budget because the Alternative Strategic Plans, over the first 13 years, completes more rehabilitation work (i.e. larger m^2 of deck) compared to the base case plan using conventional construction. The longer portion of the Expressway rehabilitation using the accelerated method combined with higher "per m^2" costs for that method (due in part, to the cost of replacing the existing steel girders with all new girders in each pre-fabricated component) and result in the additional expenditure of more than $400M. If additional funding is available, the rehabilitation work of the Expressway may be advanced and will complete the rehabilitation of the Expressway earlier than outlined in the City's 13 year plan by utilizing the accelerated construction method. Although more costly, traffic delays are significantly reduced using accelerated construction methods.

The year-over-year cash flow for the proposed strategic plan alternatives, including comparison to the City's current budget, is provided in Section 4.3.

4.1.4.6 Comparison of Accelerated Methods with Conventional Methods

The same contract limits were selected between conventional and accelerated rehabilitation construction to enable a comparison of the construction cost and overall duration based on equivalent deck area. Contract E-A1 (from Bent #91 to #182) has the same contract limit as the combination of the conventional Contracts E2 and E3. Contract E-A2 (from Bent #252 to #341) corresponds to equivalent deck areas of the conventional Contracts E4, E5 and E6. Table 4.11 shows the construction cost and duration comparison within these contract limits.

Table 4.11 – Comparison of Construction Cost and Duration (Present Value – 2013 $)				
Criteria	**Section from Bent 91 to 182 (1.960km)**		**Section from Bent 252 to 341 (2.083km)**	
	Conventional	**ABC**	**Conventional**	**ABC**
Number of Contract	2 Contracts (Contracts E2 and E3)	1 Contract (Contract E-A1)	3 Contracts (Contracts E4, E5 & E6)	1 Contract (Contract E-A2)
Construction Cost	$140M ($31M)*	$253M	$162M ($45M)*	$293M
Construction Duration	5 years	3 years	6 years	3 years
*Cost of steel coating during service life				

The construction cost for accelerated construction is some 80% higher than the conventional construction. Note that the cost estimate for the conventional rehabilitation method is based on the use of the existing steel girders. These girders will require cleaning and coating as maintenance work during their service life. Considering the life cycle cost of such steel cleaning and coating, the actual cost difference between conventional and accelerated construction is reduced. See Section 4.1.5 for details on life cycle cost and present value analysis.

The construction duration with the accelerated method is significantly reduced from that of conventional construction (3 years versus 5 or 6 years for each construction limit above). Furthermore, only one out of three years of construction under the ABC method will require traffic restriction on the Expressway thereby eliminating nine (9) years of traffic impacts on this section of Expressway.

Despite the anticipated construction cost premium of the accelerated method compared to the conventional method as shown above, the user costs savings of the accelerated method are expected to be significant due to the reduced period of traffic restriction. User cost comparison between the base case and the alternative plans can be found in Section 4.4.

4.1.4.7 Concluding Remarks

In this section, a feasibility study on the possible use of an Accelerated Bridge Construction (ABC) method for re-decking some of the elevated Expressway has been presented. The ABC alternative significantly reduces the construction duration thereby mitigating traffic impacts and the user costs while providing additional benefits compared to the base case. However, there is a cost premium associated with the ABC method which will exceed the City's approved 10 year budget and cash flow. Since the traffic delays and resulting user costs are affected by the work on the at-grade section, the at-grade section work needs to be synchronized with the elevated section for maximum benefit. The comparison of the conventional and accelerated construction alternatives are included in section 4.4.

4.1.5 Life Cycle Cost and Present Value Analysis

4.1.5.1 Introduction

The “true” cost of bridges consists of both the capital and maintenance costs during their service life as well as residual and salvage values at the end of the bridge’s life. The following sections present the assumptions and methodologies adopted for calculating the life cycle cost (LCC) of the entire elevated section based on the 1993 MTO Structural Financial Analysis Manual.

The major rehabilitation of the elevated section of the Expressway is scheduled to start in 2014 and continue over 25 years in a series of Contracts. The construction of the first Contract (section) will finish in 2016 and is expected to last for 75 years until 2091. After the first cycle of its service life, a major rehabilitation will be required again. As such, the LCC for the Expressway will be analysed until 2091.

Financial Analysis Level 3 was used which includes Capital Cost, Maintenance Cost and Residual Value. Residual Value was determined using the Second Cycle Replacement Method. A comparison of life cycle cost between alternatives in present values is provided in Section 4.1.5.7.

4.1.5.2 Capital Construction Cost

Capital construction cost includes the major rehabilitation cost of all the Contracts as detailed in Section 4.1. The following assumptions were used to determine the capital cost:

- All capital costs are based on the 2013 dollars; and
- Costs include contingency.

Detailed breakdowns of capital construction cost are provided in Appendix L.

4.1.5.3 Maintenance Cost

The life-cycle assumed for the rehabilitated elevated Expressway is 75 years. The maintenance costs for the entire elevated section were determined for this period and include the following:

- Costs for replacement of bridge components at the following frequency:
  - Asphaltic Concrete Pavement 15 years
  - Expansion Joint Strip Seal 15 years
  - Waterproofing 30 years
  - Expansion Joint Assembly 30 years
  - Structural Steel Coating 30 years
  - Bent repairs 30 years
- Annual maintenance cost including line marking, sweeping, flushing, miscellaneous repairs to snow plow damage of barriers and general repairs; and
- Engineering inspection cost including OSIM for every 2 years and detailed inspection as necessary.

In addition, interim maintenance/repair cost is required to maintain structure serviceability until the entire section of the Expressway is rehabilitated. This work includes the following:

- Localized deck reconstruction and parapet wall repair;
- Installation of temporary timber falsework; and
- Controlled chipping (to remove falling concrete).

Detailed breakdowns of the maintenance cost are provided in Appendix L.

4.1.5.4 Present Value Analysis

All costs were converted to 2013 dollars using the following Present Value (PV) equation based on the 1993 MTO Structural Financial Analysis Manual:

$$PV = \frac{C_0(1+f^1)^N}{[(1+r)(1+f)]^N}$$

Where: C_0 is the real cost at year 0 ($)

r is real discount rate (%)

f is the general inflation rate (%)

f^1 is the construction inflation rate (%)

N is the time to occurrence of maintenance work (years)

To calculate the PV of each cost, a 5.0% real discount rate was applied to the PV equation above. To account for inflation, a general inflation rate of 2.5% in addition to a construction inflation rate of 5.0% was considered. The construction inflation rate of 5.0% is the 100-year average construction inflation rate calculated by the Engineering News Record.

The present value calculation is performed until 2091 when the first section rehabilitated under this Strategic Plan is expected to reach the end of its service life. For other sections, where there is remaining service life in 2091, the residual values were calculated as described in the following section for the net present value calculation.

4.1.5.5 Residual Values

The residual value of a structure can be determined from its residual life and the replacement cost. In this study, residual value is the value of the Expressway at the end of the 75-year life cycle. There are several methods available in calculating the residual value. The Second Cycle Replacement Method was used for the residual value calculation in accordance with the 1993 MTO Structural Financial Analysis Manual.

4.1.5.6 Net Present Value

Net Present Value (NPV) is the sum of present value of Capital Cost and Maintenance Cost minus the residual value.

4.1.5.7 Comparison of Net Present Values between Alternatives

The present values of all alternatives are shown in the table below. The difference of the net present values between conventional and accelerated construction is $158M and $180M for Alternatives I and II, respectively. This difference is smaller than the premiums from the accelerated construction because of the use of corrosion resistant steel for new girders and elimination of re-coating during their service life.

Table 4.12 – Elevated Section Life Cycle Cost Comparison (Present Value – 2013 $)

Alternative	Present Value	Residual Value	Net Present Value
Base Case (Conventional Construction)	$914M	$37M	**$877M**
Alternative Plan I (Conventional + Accelerated Construction)	$1,071M	$36M	**$1,035M**
Alternative Plan II (Accelerated Construction)	$1,093M	$36M	**$1,057M**

4.2 At-Grade Section

Traffic delays from a Work Zone on the at-grade section are not in addition to traffic delays on the elevated section. The first Work Zone encountered effectively meters traffic downstream such that the overall delay from multiple Work Zones is not significantly higher from that due to the first Work Zone encountered. This means user costs from each Work Zone cannot be calculated independently and simply added together to determine the total “user cost”. Furthermore, the amount of work required to address the needs on the elevated section outweighs the work on the at-grade section in terms of construction cost, traffic impact, and duration. Therefore, the alternatives considered for the at-grade section have been developed with consideration of the work planned for the elevated section alternatives. For the accelerated method of construction, the consideration includes coordinating the schedule of traffic restrictions on the at-grade section to match the schedule of traffic restrictions on the elevated section.

Three alternatives have been considered for the Contract sequence for the at-grade section of the Expressway as described as follows:

- Base Case: Lowest capital construction cost;
- Alternative Plan I: Work scheduled to mitigate traffic impact and user cost by synchronizing traffic restriction with the elevated section Alternative Plan I using Accelerated Bridge Construction (ABC) method excluding preprogrammed work (i.e. Contract E1);
- Alternative Plan II: Work synchronized with elevated section Alternative Plan II using ABC methods to including preprogrammed work (i.e. Contract E-A0).

The proposed base case for the at-grade section is consistent with the base case for the elevated section using the conventional deck replacement method which has the lowest capital construction cost. Alternative Plans I and II have been developed to improve traffic operations and mitigate user cost from construction related traffic congestion by synchronizing the traffic restriction on the at-grade section of the Expressway with the traffic restriction on the Elevated section.

4.2.1 Completed & Proposed Environmental Assessments

The Strategic Plan for the at-grade section includes work from two completed and one pending Municipal Class Environmental Assessment (EA). The EA work will be included with a suitable Contract; however, its cost will not be included in the Contract cost estimates and Strategic Plan cash flow as this EA work will be funded separately from the Strategic Plan.

Gardiner Expressway Improvements from Kipling Avenue to Park Lawn Road

In April 2012, an EA for the Gardiner Expressway Improvements from Kipling Avenue to Park Lawn Road was completed by the City of Toronto and subsequently approved. The original study area was the existing Gardiner Expressway interchanges at Kipling and Islington, the study area was later extended easterly just past Park Lawn Road to the Lakeshore Boulevard eastbound exit.

The EA recommendations for the Kipling Avenue interchange ramp reconstruction are not included in this study as the property acquisition required for the interchange reconfiguration does not have a defined timeline. The City Council has directed that the property acquisitions required to implement the approved EA recommendations only be acquired when the current owners make the property available for sale or there is a change in ownership. Therefore, an interim traffic improvement recommendation is proposed for the Kipling interchange ramp reconstruction, which will be included with the other EA recommended works in this Strategic Plan.

At the Kipling Avenue interchange, the interim recommendation includes re-routing the southbound Kipling Avenue to Gardiner westbound from the existing free flow ramp with a new southbound left turn lane connected to the existing N-W loop ramp in the northeast quadrant. The removal of the existing S-W on-ramp would improve the weaving operations on the Expressway west of Kipling Avenue. The long term (approved EA) recommendation is to increase the two existing loop ramps in the northeast and southwest quadrant to 55m radius and relocate the existing signalized intersection at end of the northeast quadrant ramp slightly to the north to accommodate the enlarged loop ramp.

At the Islington Avenue interchange, on the north section, both free flow ramps will be replaced with a "half diamond" configuration with a new signalized intersection on Islington Avenue and include the removal of the westbound Expressway exit to St. Lawrence Avenue. The result of these upgrades would be improved weaving operations on the Expressway and on Islington Avenue.

On the south section of the Islington interchange, the loop and the free flow ramp in the southeast quadrant will be removed as the traffic will be re-routed through the improved ramp system in the south west quadrant. Improvement will include a signalized intersection to connect the existing ramps and northbound left turn lane on Islington Avenue. The results of the upgrades would be improved weaving operation on the Expressway and eliminate the weaving between the southwest and southeast loop ramp.

The recommendations from the EA include the widening of the Expressway to five lanes in each direction between Islington Avenue and Park Lawn Road. The widening of the expressway at this location had been previously recommended in the 2002 TSH study. The combination of the core/collector lanes decreases from five lanes to four becoming a localized bottleneck along the Expressway between Humber River Interchange and Islington Avenue. The eastbound and westbound four lane sections are aggravated by complex weaving movements that are approaching or are at critical levels.

The recommended widening in the westbound direction can be accomplished by extending the on-ramp from Park Lawn Road to the proposed new off-ramp at Islington Avenue. This can be constructed within the existing Expressway right-of-way and within the existing configuration of the Royal York Road Underpass and Grand Avenue Underpass.

The approved EA study recommends minor widening along the eastbound and westbound lanes, within the existing right-of-way, to construct an auxiliary lane to provide a continuous five lane cross-section that will improve traffic safety and operations.

For the eastbound direction the recommended widening would extend the collector-to-core lanes east of Royal York Road to the Lakeshore Boulevard exit. The widening will have a slightly narrow left shoulder at the Grand Avenue Underpass. The widening can be constructed within the existing Expressway right-of-way with minor widening of the Mimico Creek and Park Lawn Road structures.

Dufferin Street Bridges Class Environment Study

In 2011, the City of Toronto, in combination with the Toronto Transit Commission (TTC) and Metrolinx/GO Transit, completed a Municipal Class Environmental Assessment (EA) for the replacement of Dufferin Street bridges over the Expressway and the adjacent rail corridor. The EA recommends that the Dufferin Street bridges be replaced on the existing alignment with a span over the Expressway and a second span over the rail corridor. The span over the Expressway would consist of prestressed precast concrete box beams and the span over the rail corridor would comprise steel box girders.

Dowling Avenue Bridges Class Environment Study

The City of Toronto proposes to initiate an EA to determine the replacement strategy for the Dowling Avenue Underpass. The City anticipates commencement of this EA in 2014. Anticipated alternatives to be considered in the EA are:

- Replace the bridge;
- Replace the bridge with a pedestrian bridge; and
- Remove the bridge and do not reconstruct.

This Strategic Plan assumes replacement of Dowling Avenue providing the same level of service currently provided. The schedule for the replacement allows for the EA to be performed such that the Strategic Plan can be modified in the future according to the outcome of the EA.

4.2.2 Interim Repairs

Unsafe conditions which require immediate attention were noted during the inspections and reported to the City as follows:

- Structure 229 – Kipling Avenue Underpass:
  - A longitudinal reinforcing steel bar is exposed and suspended from the deteriorated soffit adjacent to the longitudinal joint and it presents an impact and piercing hazard to the public should it fall. Immediate removal of the suspended steel bar is recommended;
- Structure 425 – EB off-ramp to Lakeshore over WB off-ramp to Lakeshore:
  - The existing parapet walls are in very poor condition and rapidly crumbling. Additional protection such as temporary concrete barrier in front of the existing parapet wall is recommended to improve protection for errant vehicles; and
  - Repair of a large (sink) hole on the north shoulder adjacent to the east expansion joint end dam is recommended to prevent loss of vehicle control.

In addition to the above, many structures that span over roadway and sidewalks exhibit loose delaminated concrete in deck soffit, fascia, and the exposed surfaces of substructures, which is a falling hazard for pedestrians and motorists. Addressing these "public safety" deficiencies is the first priority in the Strategic Plan.

4.2.3 Drainage

Replacement of Catch Basins from Highway 427 to Humber River

Reconstruction of the median from Highway 427 to Humber River is recommended. This work requires the replacement of approximately 82 catch basins along the median.

Sewer Upgrade from Kipling Avenue to Mimico Creek

Highway widening is proposed for the Expressway between Kipling Avenue and Mimico Creek. As a result of the widening, increased road runoff is expected. A hydraulic assessment of the existing sewer network's capacity is required to determine the appropriate sewer sizes to accompany the increased runoff. Due to a lack of background data, the detailed hydraulic assessment is recommended for final design of the proposed work. For the purpose of this study complete sewer replacement of approximately 12km of sewers is assumed.

Storm Water Management (SWM) Opportunities at Kipling Interchange

Stormwater management strategy will be considered for water quality and quantity control of the widened section of the Expressway at final design of the rehablitation. However, there is an opportunity to build SWM ponds at the loops of the Kipling Avenue interchange. This location is upstream of the proposed widening section. Flows collected at the potential ponds discharge to the same outlet (Mimico Creek) as the widened section. Treatment provided by the potential ponds can be considered as compensation for the increased runoff from the widened section.

Where feasible, storm sewers will be redirected to the proposed SWM ponds located at the Kipling Avenue interchange. The ponds will ultimately discharge to Mimico Creek.

The SWM pond design should be completed such that it will:

- Provide an Enhanced Level of Protection (80% long-term suspended solids removal) per MOE requirements;
- Provide extended detention of the 25mm rainfall event for erosion control plus 40m^3/ha for water quality enhancement (24-hour drawdown time);
- Provide flood attenuation to control the 2-year to 100-year peak flows to existing levels; and
- Serve as large an area as is practical.

The feasibility of these SWM ponds needs to be further verified based on the new sewer design, existing City of Toronto sewer connections to the highway sewer, grading of the highway, and required storage. Rough estimation of the land available within the Kipling Avenue interchange for pond construction is approximately 0.57ha based on available mapping. Further feasibility analysis of the ponds needs to be assessed in the future designs.

Sewer works from Humber River to eastern limit of the "at-grade" section

Reconstruction of median and paving of shoulders are recommended between the Humber River and the eastern limit of the at-grade section (west abutment of the elevated Expressway). To accommodate the proposed road works, replacement of approximately 3.8km of mainline sewers and 69 median catch basins is considered within the Expressway corridor.

Sewers Replacement from Highway 427 to Humber River

Replacement and upgrade of sewers within the Expressway corridor depend on the detailed sewer inspection result and capacity assessment. Both require further assessment in the design stages of the project.

To approximate the maximum cost under the assumed worst case scenario (replacement of all sewers between Highway 427 and the Humber River), the total length of the existing mainline sewers were estimated using available sewer data. The cost estimate is presented in Table 4.13.

Table 4.13 - Cost Estimate of Complete Sewer Replacement between Highway 427 and Humber River (Present Value – 2013 $)

Diameter (mm)	Length (m)	Unit Price ($/m)	Total ($)
250	11	$140	$1,540
300	2627	$150	$394,050
375	1740	$155	$269,700
450	1116	$160	$178,560
525	733	$200	$146,600
600	837	$250	$209,250
675	747	$320	$239,040
750	1075	$350	$376,250
825	524	$425	$222,700
900	296	$525	$155,400
1050	305	$650	$198,250
1200	1116	$760	$848,160
1950	845	$1,000	$845,000
Total	11972		$4,084,500

Catch Basin Replacement from Highway 427 to Humber River

Replacement cost of a single catch basin is assumed to be approximately $2000. The overall cost is estimated to be $164,000 for catch basin replacement required due to median reconstruction between Highway 427 and the Humber River.

SWM Ponds

Assuming the pond footprint to be 5% of the contributing catchment area, the amount of land available at the Kipling Avenue interchange (0.57 ha) is able to accommodate a catchment of up to 11.4 ha. This catchment is divided into two components comprising highway drainage area and external municipal drainage area. The highway drainage area is approximately 8 ha from Highway 427 to Kipling Avenue. Available data is not sufficient to identify the external municipal drainage area to the highway sewers and should be evaluated at the design stages.

Sewer Works from Humber River to Eastern Limit of the At-Grade Section

Trunk sewers replacement along the mainline of the Expressway from the Humber River to the eastern limit of the at-grade section is considered in this cost estimate. Approximately 3.8 km of sewers are identified using available sewer data and the estimated replacement cost is presented in Table 4.14.

Table 4.14 - Cost Estimate of Complete Sewer Replacement between Humber River and Eastern Limit of the "at-grade" Section (Present Value – 2013 $)			
Diameter (mm)	**Length (m)**	**Unit Price ($/m)**	**Total ($)**
200	80	$130	$10,400
300	530	$150	$79,500
375	780	$155	$120,900
450	440	$160	$70,400
525	314	$200	$62,800
600	370	$250	$92,500
675	625	$320	$200,000
750	420	$350	$147,000
900	280	$525	$147,000
Total	3839		$930,500

In addition to sewer replacement, catch basin replacement is also considered to accommodate the median replacement works. Approximately 69 catch basins along the median are identified to be in need of replacement. Assuming $2,000 for the replacement of a single catch basin, total replacement cost of catch basins along the median is approximately $138,000 for this section.

The estimated cost of drainage work is included in the highway improvement cost for the respective contracts.

4.2.4 Base Case: Lowest Capital Construction Cost

This alternative has been selected as the base case scenario for the rehabilitation of the at-grade section of the Expressway based on its merits of lowest estimated capital construction cost. This alternative uses conventional construction method and schedules which presents a relatively low risk compared to the accelerated construction alternative. However, the cash flow for this alternative slightly exceeds the City of Toronto 10 year budget and may require additional funding to cover the costs if this alternative is selected for implementation.

The following is a summary of each contract proposed under this alternative.

Contract G1 – CNR Overhead to Humber River & Median Barrier Replacement Ellis to Dufferin

This Contract was scheduled by the City prior to this study. The scope of work of this Contract includes median barrier replacement from Ellis Avenue to Dufferin Street and the rehabilitation of the following structures:

- Structure 418 – CNR Overhead;
- Structure 186 – TTC Overhead;
- Structure 255 – Westbound Off-Ramp to Lakeshore Blvd.

Detail design for this Contract is currently in progress and is expected to be ready for tender by January 2014. Construction is anticipated to begin in the spring of 2014 and be complete by the spring/summer of 2015 prior to the Pan-Am Games.

The cost estimate provided by the City for this Contract is $29.0M.

Inspection programs indicated in the preceding sections of this study identified that the expansion joints at the Park Lawn Road Overpass and the Mimico Creek Bridges are in very poor condition. Signs of leakage and extensive deterioration to the substructure and girder ends have been noted as a result of the poor expansion joint. Due to the proximity of the structures to the Contract limit for G1, it is recommended that Contract G1 include expansion joint reconstruction of the two (2) structures to slow down the rate of deterioration until a more extensive rehabilitation work can take place in one of the future contracts. The anticipated cost to undertake this work is approximately $1.0M.

Contract G2 – Dowling Avenue to Elevated Section including Miscellaneous Structure Repairs

The scope of work for Contract G2 includes:

- Patching program for bridge structures spanning over traffic lanes and sidewalks including:
    - Structure 412 - The East Mall Overpass;
    - Structure 422 - N & S-E Ramp over The East Mall;
    - Structure 413 - Wickman Road & CPR Overpass ;
    - Structure 229 - Kipling Avenue Underpass;
    - Structure 272 - Islington Avenue Underpass;
    - Structure 414 - Royal York Road Underpass;
    - Structure 415 - Grand Avenue Underpass;
    - Structure 417 - Park Lawn Road Overpass;
    - Structure 425 - EB off-ramp to Lakeshore over WB off-ramp to Lakeshore;
    - Structure 32 - Windermere Avenue Overpass;
    - Structure 33 - Ellis Avenue Overpass;
    - Structure 34 - Colborne Lodge Drive Overpass; and
    - Structure 37 - Parkside Overpass;
- Replacement of Structure 10 - Dufferin Street Underpass;
- Replacement of Structure 7 - Dowling Avenue Underpass (subject to outcome of EA);
- Structural rehabilitation of retaining walls (RW 16, 17, 19; RWP 34-38);
- Replacement of outside shoulder Steel Beam Guide Rail (SBGR); and
- Pavement resurfacing of the mainline pavement from STA 226+00 (Dowling Avenue) to STA 241+00 (elevated section west abutment).

The patching program proposed in this Contract is intended to address the falling hazard of loose delaminated concrete from the structures that span over the traffic lanes and sidewalks until more extensive rehabilitation can take place. This work can be done with temporary traffic control during nights and weekends outside the peak traffic demand periods to mitigate impact to the Expressway traffic.

Dufferin Street Underpass and Dowling Avenue Underpass have been given high priority based on the very poor existing condition of these structures. In 2011, the City of Toronto completed Environmental Assessment (EA) for the replacement of Dufferin Street Bridges over the Expressway and the adjacent rail corridor. Following the completion of the EA, in June 2013, the City closed the Dufferin Street Grade Separation over the rail corridor and the Dufferin Street Underpass to vehicular traffic due to the unsafe condition of the structure over the rail corridor. Construction is currently in progress to replace the grade separation superstructure with a temporary modular bridge and to undertake the required utility relocations for the eventual replacement of the bridges.

The City of Toronto anticipates initiation of an EA for the replacement of Dowling Avenue Underpass in 2014. The proposed EA for the replacement of Dowling Avenue Underpass is expected to be completed within two years following initiation of the process. Anticipated alternatives to be considered in the proposed EA for Dowling Avenue Underpass include removal of the structure (and not replacing it); replacement with current function; and replacement with a pedestrian bridge. For the purpose of this study, as directed by the City, replacement of the underpass with current function and configuration is assumed in the Strategic Plan.

The City requested that the reconstruction cost of the Dufferin Street Bridges and Dowling Avenue Underpass be excluded from the Strategic Plan cost estimate due to the City's funding mechanism. The preliminary cost estimate for Contract G2, excluding the reconstruction of Dufferin Street Underpass and the Dowling Avenue Underpass, is $8.2M. Estimated cost for the reconstruction of Dufferin Street Underpass including reconstruction of the adjacent railway bridge and all other improvements as provided in the approved Environmental Study Report (ESR) is $17M. Table 4.15 summarizes the cost estimate for Contract G2.

The first construction stage of the Contract G2 roadway improvements is the replacement of the right shoulder steel beam guide rail for public safety reasons. The stage one construction can be completed with a single lane closure during night time construction with no peak hour lane closures. In the following stage, the milling and overlay of the Expressway can be completed during night time construction with no peak hour lane closures. A pre-study scheduled Contract will replace the median barrier with precast tall wall in the same section of Expressway from 2013 to 2014 (included in Contract G1).

Structural works which may impact the Expressway traffic such as demolition of the existing structures and construction of protection systems can also be completed during night time and weekend closures and long term lane closures on the Expressway are not anticipated for Contract G2.

It is anticipated that construction under Contract G2 will start in the spring of 2016 and be complete by the end of 2017.

Table 4.15 – Contract G2 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Sub-Total - Patching Program on Bridge Structures	$ 1,690,000
• *Patch Repair of The East Mall Overpass*	*$ 115,000*
• *Patch Repair of N & S-E ramp over The East Mall*	*$ 59,000*
• *Patch Repair of Wickman Road & CPR Overpass*	*$ 247,000*
• *Patch Repair of Kipling Avenue Underpass*	*$ 179,000*
• *Patch Repair of Islington Avenue Underpass*	*$ 178,000*
• *Patch Repair of Royal York Road Underpass*	*$ 78,000*
• *Patch Repair of Grand Avenue Underpass*	*$ 45,000*
• *Patch Repair of Park Lawn Road Overpass*	*$ 70,000*
• *Patch Repair of EB off-ramp to Lakeshore over WB off-ramp to Lakeshore*	*$ 56,000*
• *Patch Repair of Windermere Avenue Overpass*	*$ 94,000*
• *Patch Repair of Ellis Avenue Overpass*	*$ 63,000*
• *Patch Repair of Colborne Lodge Drive Overpass*	*$ 269,000*
• *Patch Repair of Parkside Drive Overpass*	*$ 237,000*
Replacement of Dufferin Street Bridges (excluded from Contract Total)	*$ 17,000,000*
Replacement of Dowling Avenue Underpass (excluded from Contract Total)	*$ 4,185,000*
Structural Rehabilitation of Retaining Walls	$ 53,000
Roadway improvements - STA 226+00 to STA 241+00	$ 3,373,000
Sub-Total Contract G2	**$ 5,116,000**
Utilities (5% of Sub-Total)	$ 256,000
Miscellaneous Items (15% of Sub-Total)	$ 767,000
Engineering & Contract Administration (20% of Sub-Total)	$ 1,023,000
Contingency (20% of Sub-Total)	$ 1,023,000
Total – Contract G2	**$ 8,200,000**

Contract G3 – Highway 427 to Park Lawn Road

The scope of work for Contract G3 includes:

- Structural rehabilitation of Structure 412 - The East Mall Overpass;
- Structural rehabilitation of Structure 422 - N & S-E Ramp over The East Mall;
- Structural rehabilitation of Structure 413 - Wickman Road & CPR Overpass;
- Structural rehabilitation of Structure 229 - Kipling Avenue Underpass;
- Structural rehabilitation of Structure 272 - Islington Avenue Underpass;
- Structural rehabilitation of Structure 423 - N & S-W Ramp over Mimico Creek;
- Structural rehabilitation of retaining walls (RWP 1-7, 12-18; and RW 1-6);

- Expressway improvements recommended under the 2012 Class Environmental Assessment – Gardiner Expressway Improvements from Kipling Avenue to Park Lawn Road (excluding the eastbound widening between Royal York and Lakeshore ramps); and
- Pavement reconstruction of the mainline and core-collector lanes eastbound from STA 130+00 (Hwy 427/QEW interchange) to STA 172+50 (Wesley St), westbound from STA 130+00 (Hwy 427/QEW interchange) to STA 176+50 (Grand Avenue), and the Park Lawn to Gardiner Expressway westbound on-ramp.

The recommended structural works are based on a review of existing data and inspections conducted as part of this study. Update Detail Deck Condition Surveys (DDCS) are recommended prior to finalizing the scope of work for the structural rehabilitations under this Contract.

A preliminary cost estimate for Contract G3 is $55.6M; a breakdown of the cost estimate is presented in Table 4.16.

Table 4.16 – Contract G3 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of The East Mall Overpass	$ 975,000
Structural rehabilitation of N & S-E ramp over The East Mall	$ 397,000
Structural rehabilitation of Wickman Road & CPR Overpass	$ 1,590,000
Structural rehabilitation of Kipling Avenue Underpass	$ 1,889,000
Structural rehabilitation of Islington Avenue Underpass	$ 1,568,000
Structural rehabilitation of N & S-W Ramp over Mimico Creek	$ 1,568,000
Structural Rehabilitation of Retaining Walls	$ 2,625,000
Expressway improvement per approved EA (excluded from Contract Total)	*$ 21,000,000*
Expressway Pavement Reconstruction STA 130+00 to STA 176+50	$ 24,121,000
Sub-Total Contract G3	**$ 34,733,000**
Utilities (5% of Sub-Total)	$ 1,737,000
Miscellaneous Items (15% of Sub-Total)	$ 5,210,000
Engineering & Contract Administration (20% of Sub-Total)	$ 6,947,000
Contingency (20% of Sub-Total)	$ 6,947,000
Total – Contract G3	**$ 55,600,000**

The construction staging for Contract G3 is divided into three construction phases, herein known as Phase A, Phase B, and Phase C.

Phase A construction staging consists of the roadway reconstruction and structural rehabilitation of the Kipling Avenue (Stage 1 and 2) and Islington Avenue (Stage 3 and 4) that will require reducing the Kipling Avenue and Islington Avenue traffic to a two lane roadway and require temporary closures of the ramps.

Construction of the temporary button hook at St. Lawrence Avenue (Stage 2) will allow for an alternative ramp during the reconstruction of the on-ramp from Islington Avenue to Expressway westbound collectors.

The reconstruction of the ramps that connect the Expressway and Highway 427 will be completed during Stage 3 and 4, and will include shoulder strengthening, guide rail replacement and storm sewer reconstruction. The ramps will remain open but the staging will require two lane ramps (W-Hwy 427 N and W-Brown's Line S/Sherway Gardens) to be reduced to a single lane during construction.

Stage 5 will consist of the reconstruction of the Homer Avenue ramps and the eastbound off-ramp to Park Lawn Road.

Reconstruction of the collector lane right shoulder will require the closure of one collector lane.

Phase B construction consists of the Stage 1 shoulder strengthening, guide rail replacement and storm sewer replacement on the outside shoulders of the Expressway. This construction will require the closure of the outside lane at the five lane cross-section locations on the Expressway. At locations where the Expressway consists of a three lane express and a two lane collector system, Stage 1 construction consists of shoulder strengthening, guide rail replacement, storm sewer replacement and pavement reconstruction on the collector lanes. At these locations the three express lanes and one collector lane will remain open to traffic. Stage 2 construction consists of Expressway median shoulder strengthening, guide rail replacement, and storm sewer replacement. Stage 2 construction can be completed with a single lane closure on the inside express lane during night time construction with no peak hour lane closures.

Phase C is the pavement reconstruction of the Gardiner Expressway that will be completed in three stages and require a single lane closure in each of the three stages.

Plans showing the proposed traffic staging for Contract G3 are included in Appendix D.

It is anticipated that the construction under this contract will start in the spring of 2018 and complete by the end of 2020.

<u>Contract G4 – East of Humber River to Dowling Avenue Plus Royal York Road Underpass and Grand Avenue Underpass Rehabilitations</u>

The scope of work for Contract G4 includes:

- Structural rehabilitation of Structure 414 - Royal York Road Underpass;
- Structural rehabilitation of Structure 415 - Grand Avenue Underpass;
- Structural rehabilitation of Structure 32 - Windermere Avenue Overpass;
- Structural rehabilitation of Structure 33 - Ellis Avenue Overpass;
- Structural rehabilitation of Structure 34 - Colborne Lodge Drive (Howard Avenue) Overpass;
- Structural rehabilitation of Structure 37 - Parkside Drive Overpass;
- Structural rehabilitation of retaining walls (RWP 19-33); and
- The Expressway pavement work from STA 198+00 (Humber River) to STA 226+00 (Dowling Avenue).

The 1997 detail deck condition surveys (DDCS) of the four reinforced concrete rigid frame overpasses (Windermere Avenue Overpass, Ellis Avenue Overpass, Colborne Lodge Drive Overpass, and Parkside Drive Overpass) indicate large areas of high chloride contents at the top rebar level. In addition, the DDCS's indicate no waterproofing membrane at Windermere Avenue Overpass, Ellis Avenue Overpass and

Parkside Drive Overpass resulting in high rates of chloride penetration. However, records show subsequent structural rehabilitation in 1997 included new waterproofing membrane on Windermere Avenue Overpass where the other two structures are assumed to be in service without any waterproofing system to date. The MTO Structural Rehabilitation Manual suggests that concrete overlay will not stop active corrosion unless the chloride contaminated concrete is removed. For the purpose of this study, we have assumed partial depth removal from the top of the entire deck to remove chloride contaminated concrete is viable for the four rigid frame overpasses; however, the feasibility and effectiveness of the proposed rehabilitation must be confirmed with update DDCS and financial analyses as part of the detail design for this Contract. If the future DDCS indicates significant steel section loss on the top reinforcing steel mat or chlorides approaching the bottom rebar mat, then replacement of the overpasses would be warranted.

A preliminary cost estimate for Contract G4 is $17.6M. Table 4.17 provides a summary of the cost estimate for Contract G4.

Table 4.17 – Contract G4 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of Royal York Road Underpass	$ 1,755,000
Structural rehabilitation of Grand Avenue Underpass	$ 1,022,000
Structural rehabilitation of Windermere Avenue Overpass	$ 879,000
Structural rehabilitation of Ellis Avenue Overpass	$ 1,032,000
Structural rehabilitation of Colborne Lodge Drive (Howard Avenue) Overpass	$ 986,000
Structural rehabilitation of Parkside Drive Overpass	$ 1,072,000
Structural rehabilitation of Retaining Walls	$ 222,000
Expressway Pavement Reconstruction STA 195+00 to STA 226+00	$ 4,046,000
Sub-Total Contract G4	**$ 11,014,000**
Utilities (5% of Sub-Total)	$ 551,000
Miscellaneous Items (15% of Sub-Total)	$ 1,652,000
Engineering & Contract Administration (20% of Sub-Total)	$ 2,203,000
Contingency (20% of Sub-Total)	$ 2,203,000
Total – Contract G4	**$ 17,600,000**

Structural rehabilitation including partial depth removal of the existing concrete deck and concrete overlay on the four reinforced concrete rigid frame overpasses will be completed in three (3) stages and require a single lane closure in each direction during each stage. The first stage includes replacement of the existing median and elimination of the longitudinal joint in the structures. Stage 2 consists of outside shoulder strengthening, mill and overlay of the outside lanes of the Expressway, overlaying of the outside shoulders and lanes on the structures, and replacement of the outside shoulder SBGR. Stage 3 consists of overlaying of the inside shoulders and lanes on the structures, and mill and resurfacing of the inside shoulders and lanes of the Expressway.

A pre-study construction Contract is scheduled to replace median barrier on the Expressway with precast tall wall in 2013 to 2014; however, existing medians on the structures will not be replaced as part of the work scheduled for 2013 to 2014. Proposed traffic staging for Contract G4 is included in Appendix D.

Construction under this Contract is anticipated to start in the spring of 2021 and be completed by the end of 2022.

Contract G5 – Grand Avenue to Humber River

The scope of work for Contract G5 includes:

- Structural rehabilitation of Structure 416 - Mimico Creek Bridges;
- Structural rehabilitation of Structure 424 - EB Off-Ramp over Mimico Creek;
- Structural rehabilitation of Structure 417 - Park Lawn Road Overpass;
- Structural rehabilitation of Structure 425- EB Off-Ramp to Lakeshore Blvd. over WB Off-Ramp to Lakeshore Blvd.;
- Structural rehabilitation of retaining walls (RWP 8-11; RW 8);
- Expressway improvement recommended under the 2012 Class Environmental Assessment for the eastbound widening between Royal York and Lakeshore ramps; and
- Pavement reconstruction of the mainline and core-collector lanes eastbound from STA 172+50 (Wesley St) to STA 198+00 (Humber River) and westbound from STA 176+50 (Grand Avenue) to STA 198+00 (Humber River).

Structural evaluation of the Park Lawn Drive Overpass suggests the existing prestressed concrete girders would crack under the increased dead load resulting from the new thicker deck of the planned rehabilitation. While there is no immediate structural concern, prestressed concrete girders that are cracked in service are considered partially prestressed and must meet the CHBDC requirements for crack widths and fatigue. The prestressed girders of the Park Lawn Drive Overpass are inadequate in terms of crack widths and exceed the Fatigue Limit State (FLS) stress range and would, therefore, require replacement to carry the highway traffic load according to current design codes.

Furthermore, a review of the previous structural evaluations and original construction drawings suggest that the prestressed concrete girders of the Mimico Creek Structures (EBL & WBL, N & S-W Ramp over Mimico Creek and EB off-ramp over Mimico Creek), which are all prestressed concrete I-girder bridges built in the same era using the same design standards, may also be deficient according to current standards. Structural evaluations of the Mimico Creek Structures were not included in this study and a detailed deck condition survey of these structures was recently performed by others under the design contract for Contract G1. For the purpose of this study it was assumed that superstructure replacement of the Mimico Creek Structures is required.

A preliminary cost estimate for Contract G5 is $29.4M. Table 4.18 provides a summary of the cost estimate for Contract G5.

Table 4.18 – Contract G5 Estimated Cost (2013 $)	
Scope of Work	**Estimated Cost**
Structural rehabilitation of Mimico Creek Bridges	$ 7,408,000
Structural rehabilitation of EB off-ramp over Mimico Creek	$ 1,875,000
Structural rehabilitation of Park Lawn Road Overpass	$ 4,095,000
Structural rehabilitation of EB off-ramp to Lakeshore over WB off-ramp to Lakeshore	$ 830,000
Structural rehabilitation of Retaining Walls	$ 117,000
Expressway Pavement Reconstruction STA 176+50 to STA 195+00	$ 4,046,000
Sub-Total Contract G5	**$ 18,371,000**
Utilities (5% of Sub-Total)	$ 919,000
Miscellaneous Items (15% of Sub-Total)	$ 2,756,000
Engineering & Contract Administration (20% of Sub-Total)	$ 3,674,000
Contingency (20% of Sub-Total)	$ 3,674,000
Total – Contract G5	**$ 29,400,000**

Stage 1 construction consists of the shoulder strengthening, guide rail reconstruction, and storm sewer reconstruction of the outside shoulder. Stage 1 construction can be completed with a single lane closure during night time construction with no peak hour lane closures. Stage 2 construction consists of reconstructing a portion of the median shoulder to provide for temporary cross-overs west of Mimico Creek and east of Park Lawn Road. Stage 2 construction can be completed with a single lane closure during night time construction with no peak hour lane closures. Stage 3 to 6 will reconstruct the Park Lawn off-ramp south of the Expressway and the Expressway mainline which will be completed in conjunction with the staging requirements for the bridge replacements.

Several alternatives have been developed for the traffic staging of the structures; however, two alternatives have been shortlisted and presented in Appendix D. The suggested traffic staging is selected based on providing maximum lanes and shoulder widths while maintaining the existing number of lanes. However, the suggested traffic staging results in having a traffic lane over the low-point of the cross section which may create unsafe condition for motorists during heavy precipitation and requires a special drainage solution such as installing trench drain along the low point of the cross-section to address the unsafe condition during storms.

It is anticipated that construction under this Contract will start in the spring of 2023 and be completed by the end of 2024.

Contract G6 – Humber River Bridges

The Expressway and Lakeshore Boulevard bridges over the Humber River were replaced by steel box girder type structures in 1998 and 1999 after the old bridge piers settled up to one metre creating unsafe conditions for the motorists.

The waterproofing system on the Humber River Bridges is expected to reach the end of its serviceable life by year 2029, after being in service for 30 years. The existing barriers of the Humber River Bridges have uncoated reinforcing steel and the existing barriers are expected to deteriorate to a condition requiring replacement by the time of construction for this Contract.

The anticipated scope of work for the Humber River Bridges includes barrier replacements and only minimal impact to traffic is anticipated with no lane reduction on the Humber River Bridges considering the existing wide shoulders. Replacement of the waterproofing system and the pavement on the Humber River Bridges can be completed during weekend maintenance closures.

A preliminary cost estimate for Contract G6 is $17.7M. Table 4.19 provides a summary of the cost estimate for Contract G6.

Table 4.19 – Contract G6 Estimated Cost (2013 $)	
Scope of Work	**Estimated Cost**
WBL over Humber River	$ 2,860,000
EBL over Humber River	$ 2,860,000
WB on-ramp from Lakeshore WB over Humber River	$ 1,141,000
WB off-ramp to Lakeshore WB over Humber River	$ 1,870,000
Lakeshore EB over Humber River	$ 1,512,000
Lakeshore WB over Humber River	$ 1,154,000
Sub-Total Contract G6	**$ 11,397,000**
Utilities (0% of Sub-Total)	$ -
Miscellaneous Items (15% of Sub-Total)	$ 1,710,000
Engineering & Contract Administration (20% of Sub-Total)	$ 2,279,000
Contingency (20% of Sub-Total)	$ 2,279,000
Total – Contract G6	**$ 17,700,000**

It is anticipated that construction under this Contract will start in the spring of 2030 and be complete by the end of that year.

Base Case Strategic Plan Cost Estimates

Table 4.20 summarizes the total capital construction cost to rehabilitate the at-grade section under the base case Strategic Plan. The cost estimate excludes engineering and contract administration which is consistent with the elevated section and the City's 10 year budget.

Table 4.20 –At-Grade Section Base Case Capital Construction Cost (Present Value – 2013 $)	
Contract	**Cost ($ M)**
G1	$29.0
G2	$7.2
G3	$48.6
G4	$15.4
sub-total (10-year budget)	**$100.2**
G5	$25.7
G6	$15.4
Total	**$141.3**

The cash flow generated under this alternative exceeds the approved 10 year budget of $84.3 million. The holding strategies to defer work outside the 10-year budget require expensive interim maintenance which results in higher long-term cost than the recommended plan.

4.2.5 Alternative Plans: Reduced Traffic Impact

Alternative Plans I and II mitigate traffic impact and user costs by synchronizing traffic restrictions with the elevated section Contracts. As discussed in the preceding sections of this report, under Alternative Plan I the preprogrammed work to replace the deck from Bent 35 to Bent 91 which is scheduled to start in 2014 (Contract E1) will proceed using conventional construction method and Alternative Plan II considers revisiting the pre-programmed work to use ABC method and further reduce user costs and improve traffic impact due to construction. Proposed contracts under both alternative plans have been presented in Appendix C.

Under both alternative plans, the pavement reconstruction of the mainline and core-collector west of the Humber River will be deferred to year 2023 to 2025 so the traffic restrictions to undertake this work coincide with the traffic restrictions on the elevated section for the rehabilitation of the reinforced concrete T-beam section, which cannot be rehabilitated using the ABC method, and require traffic restrictions on the Expressway for three (3) consecutive construction seasons. However, due to the existing poor condition of the pavement structure, numerous maintenance resurfacing contracts will be required to keep the Expressway in a serviceable condition until the reconstruction takes place in 2023. The estimated cost of the pavement resurfacing program is $13.9 million. These maintenance resurfacing contracts would be performed at night and not impact peak traffic flows.

Contract G-A1 and G-A2 remain same as the base case Contract G1 and G2 since these two contracts are pre-programmed. The revised contract sequence that follows G-A2 under this alternative is summarized as follows.

Contract G-A3 – Kipling Avenue Underpass and Royal York Road Underpass

The scope of work for Contract G-A3 includes structural rehabilitation of Kipling Avenue Underpass and Royal York Road Underpass. The work will require traffic restrictions on the overpassing arterial municipal roads but it will not impact the traffic on the Expressway. The adjacent arterial roads (Islington Avenue and Grand Avenue) will be maintained to mitigate traffic impacts on the arterials in this area.

A preliminary cost estimate for Contract G-A3 is $5.8M. Table 4.21 provides a summary of the cost estimate for Contract G-A3.

Table 4.21 – Alternative 2 Contract G-A3 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of Kipling Avenue Underpass	$ 1,889,000
Structural rehabilitation of Royal York Road Underpass	$ 1,755,000
Sub-Total Contract G-A3	**$ 3,644,000**
Utilities (5% of Sub-Total)	$ 182,000
Miscellaneous Items (15% of Sub-Total)	$ 547,000
Engineering & Contract Administration (20% of Sub-Total)	$ 729,000
Contingency (20% of Sub-Total)	$ 729,000
Total – Contract G-A3	**$ 5,800,000**

Under Alternative Plan I the construction for this Contract is anticipated to start in the spring of 2018 and be completed by the end of that year and under Alternative Plan II this contract will take place in 2020.

Contract G-A4 – East of Humber River to Dowling Avenue

The scope of work for Contract G-A4 includes structural rehabilitation of the four reinforced concrete rigid frames overpasses east of the Humber River similar to the base case Contract G4. Table 4.22 provides a summary of the cost estimate for Contract G-A4.

Table 4.22 – Alternative 2 Contract G-A4 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of Windermere Avenue Overpass	$ 879,000
Structural rehabilitation of Ellis Avenue Overpass	$ 1,032,000
Structural rehabilitation of Colborne Lodge Drive (Howard Avenue) Overpass	$ 986,000
Structural rehabilitation of Parkside Drive Overpass	$ 1,072,000
Structural rehabilitation of Retaining Walls	$ 222,000
Expressway Pavement Reconstruction STA 195+00 to STA 226+00	$ 4,046,000
Sub-Total Contract G-A4	**$ 3,644,000**
Utilities (5% of Sub-Total)	$ 412,000
Miscellaneous Items (15% of Sub-Total)	$ 1,236,000
Engineering & Contract Administration (20% of Sub-Total)	$ 1,647,000
Contingency (20% of Sub-Total)	$ 1,647,000
Total – Contract G-A4	**$ 13,200,000**

It is recommended that this Contract include a provision for two (2) 10-hour shifts per each working day for six (6) days per week to advance the construction schedule to complete the work within one construction season, which would synchronize the traffic restriction from this contract with Contract E-A1 on the elevated section. Under both Alternative Plan I and II the construction for this Contract will start in the spring of 2019 and be completed by the end of that year.

Contract G-A5 – Islington Avenue Underpass and Grand Avenue Underpass

The scope of work for Contract G-A5 includes structural rehabilitation of the remaining two underpasses west of the Humber River; Islington Avenue Underpass and Grand Avenue Underpass. The adjacent arterial roads (Kipling Avenue and Royal York Road), which had their underpass structures rehabilitated under Contract G-A3, will be maintained to mitigate traffic impacts on the arterials in this area.

Alternative Plan I proposes to complete construction for this Contract in 2020 and Alternative Plan II proposes to complete construction for this Contract in 2021.

Table 4.23 – Alternative 2 Contract G-A5 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of Islington Avenue Underpass	$ 1,568,000
Structural rehabilitation of Grand Avenue Underpass	$ 1,022,000
Sub-Total Contract G-A5	**$ 2,590,000**
Utilities (5% of Sub-Total)	$ 130,000
Miscellaneous Items (15% of Sub-Total)	$ 389,000
Engineering & Contract Administration (20% of Sub-Total)	$ 518,000
Contingency (20% of Sub-Total)	$ 518,000
Total – Contract G-A5	**$ 4,100,000**

Contract G-A6 – Grand Avenue to Humber River

The scope of work for Contract G-A6 includes:

- Structural rehabilitation of Structure 416 - Mimico Creek Bridges;
- Structural rehabilitation of Structure 424 - EB Off-Ramp over Mimico Creek;
- Structural rehabilitation of Structure 417 - Park Lawn Road Overpass;
- Structural rehabilitation of Structure 425 - EB Off-Ramp to Lakeshore Blvd. over WB Off-Ramp to Lakeshore Blvd.;
- Structural rehabilitation of retaining walls (RWP 8-11; RW 8); and
- Expressway improvement recommended under the 2012 Class Environmental Assessment for the eastbound widening between Royal York and Lakeshore ramps; and
- Pavement reconstruction of the mainline and core-collector lanes eastbound from STA 172+50 (Wesley St) to STA 198+00 (Humber River) and westbound from STA 176+50 (Grand Avenue) to STA 198+00 (Humber River).

It is anticipated that the construction under this Contract will start in the spring of 2021 and be completed by the end of 2022 for Alternative Plan I. For Alternative Plan II, the construction for this Contract is anticipated to start in the spring of 2017 and be completed by the end of 2018.

To make the traffic restriction from this Contract coincide with the period of traffic restriction on the elevated section contracts, the superstructure replacements of the two mainline structures under Contract G-A6 will utilize the same accelerated bridge construction method proposed for the elevated section. Preparatory work will take place in 2021 with minimal traffic restriction and impact to the Expressway to limit the traffic impacts to year 2022 when the existing superstructures will be removed and replaced with prefabricated components with traffic staging with lane restriction in place.

Table 4.24 – Alternative 2 Contract G-A6 Estimated Cost (2013 $)

Scope of Work	Estimated Cost
Structural rehabilitation of Mimico Creek Bridges	$ 7,408,000
Structural rehabilitation of EB off-ramp over Mimico Creek	$ 1,875,000
Structural rehabilitation of Park Lawn Road Overpass	$ 4,095,000
Structural rehabilitation of EB off-ramp to Lakeshore over WB off-ramp to Lakeshore	$ 830,000
Structural rehabilitation of Retaining Walls	$ 117,000
Expressway Pavement Reconstruction STA EB 172+50 / WB 176+50 to STA 195+00	$ 4,046,000
Sub-Total Contract G-A6	**$ 19,971,000**
Utilities (5% of Sub-Total)	$ 999,000
Miscellaneous Items (15% of Sub-Total)	$ 2,996,000
Engineering & Contract Administration (20% of Sub-Total)	$ 3,994,000
Contingency (20% of Sub-Total)	$ 3,994,000
Total – Contract G-A6	**$ 32,000,000**

Contract G-A7 – Highway 427 to Park Lawn Road

The scope of work for Contract G-A7 includes:

- Structural rehabilitation of Structure 412 - The East Mall Overpass;
- Structural rehabilitation of Structure 422 - N & S-E Ramp over The East Mall;
- Structural rehabilitation of Structure 413 - Wickman Road & CPR overpass;
- Structural rehabilitation of Structure 423 - N & S-W Ramp over Mimico Creek;
- Structural rehabilitation of retaining walls (RWP 1-7, 12-18; and RW 1-6);
- Expressway improvements recommended under the 2012 Class Environmental Assessment – Gardiner Expressway Improvements from Kipling Avenue to Park Lawn Road (excluding the eastbound widening between Royal York and Lakeshore ramps); and
- Pavement reconstruction of the mainline and core-collector lanes eastbound from STA 130+00 (Hwy 427/QEW interchange) to STA 172+50 (Wesley St), westbound from STA 130+00 (Hwy 427/QEW interchange) to STA 176+50 (Grand Ave), and the Park Lawn to Gardiner Expressway westbound on-ramp.

For both Alternative Plans I and II it is anticipated that the construction under this Contract will start in the spring of 2023 and be completed by the end of 2025. Traffic restrictions will be imposed along the Work Zone during construction with winter shutdowns from December to February which will be consistent with the elevated section schedule.

Table 4.25 – Alternative 2 Contract G-A7 Estimated Cost (2013 $)	
Scope of Work	**Estimated Cost**
Structural rehabilitation of The East Mall Overpass	$ 1,073,000
Structural rehabilitation of N & S-E ramp over The East Mall	$ 437,000
Structural rehabilitation of Wickman Road & CPR Overpass	$ 1,749,000
Structural rehabilitation of N & S-W Ramp over Mimico Creek	$ 1,568,000
Structural rehabilitation of Retaining Walls	$ 2,625,000
Expressway improvement per approved EA (excluded from Contract Total)	*$ 21,000,000*
Expressway Pavement Reconstruction STA 130+00 to STA 176+50	$ 24,121,000
Sub-Total Contract G-A7	**$ 31,572,000**
Utilities (5% of Sub-Total)	$ 1,579,000
Miscellaneous Items (15% of Sub-Total)	$ 4,736,000
Engineering & Contract Administration (20% of Sub-Total)	$ 6,315,000
Contingency (20% of Sub-Total)	$ 6,315,000
Total – Contract G-A7	**$ 50,500,000**

Contract G-A8 – Humber River Bridges

The scope of work and schedule to rehabilitate the Humber River Bridges remain unchanged from the base case Contract G6.

Alternative Strategic Plans I and II Cost Estimates

Table 4.26 summarizes the total capital construction cost to rehabilitate the at-grade Section under the two Alternative Plans. The construction cost estimate for the two alternative plans is same because the only difference between the two plans for the at-grade section contracts are timing of the work and there is no change in the scope of work.

Table 4.26 – Alternative Plans Capital Construction Cost (Present Value - 2013 $)	
Contract	**Cost ($ M)**
G-A1	$29.0
G-A2	$7.2
G-A3	$5.1
G-A4	$11.6
G-A5	$3.6
G-A6	$28.0
Pavement Resurfacing (2014-2023)	$ 13.9
sub-total (10-year budget)	**$98.4**
G-A7	$ 44.2
G-A8	$15.4
Total	**$158.0**

The cash flow generated under this alternative exceeds the approved 10 year budget of $84.3 million and the total capital construction cost under this alternative is $158.0M which is a net increase of $16.7million over the base case.

4.3 Cost Estimates and Cash Flow

Anticipated cash flows from year 2013 to 2038 for the base case and the alternative plans have been summarized and compared to the City's 10 year budget in Table 4.27 and Figures 4.7 to 4.9 graphically illustrate the accumulative cash flows under each scenarios through the end of the strategic plan in 2038. The year-by-year cash flow includes 2.5% per annum inflation rate.

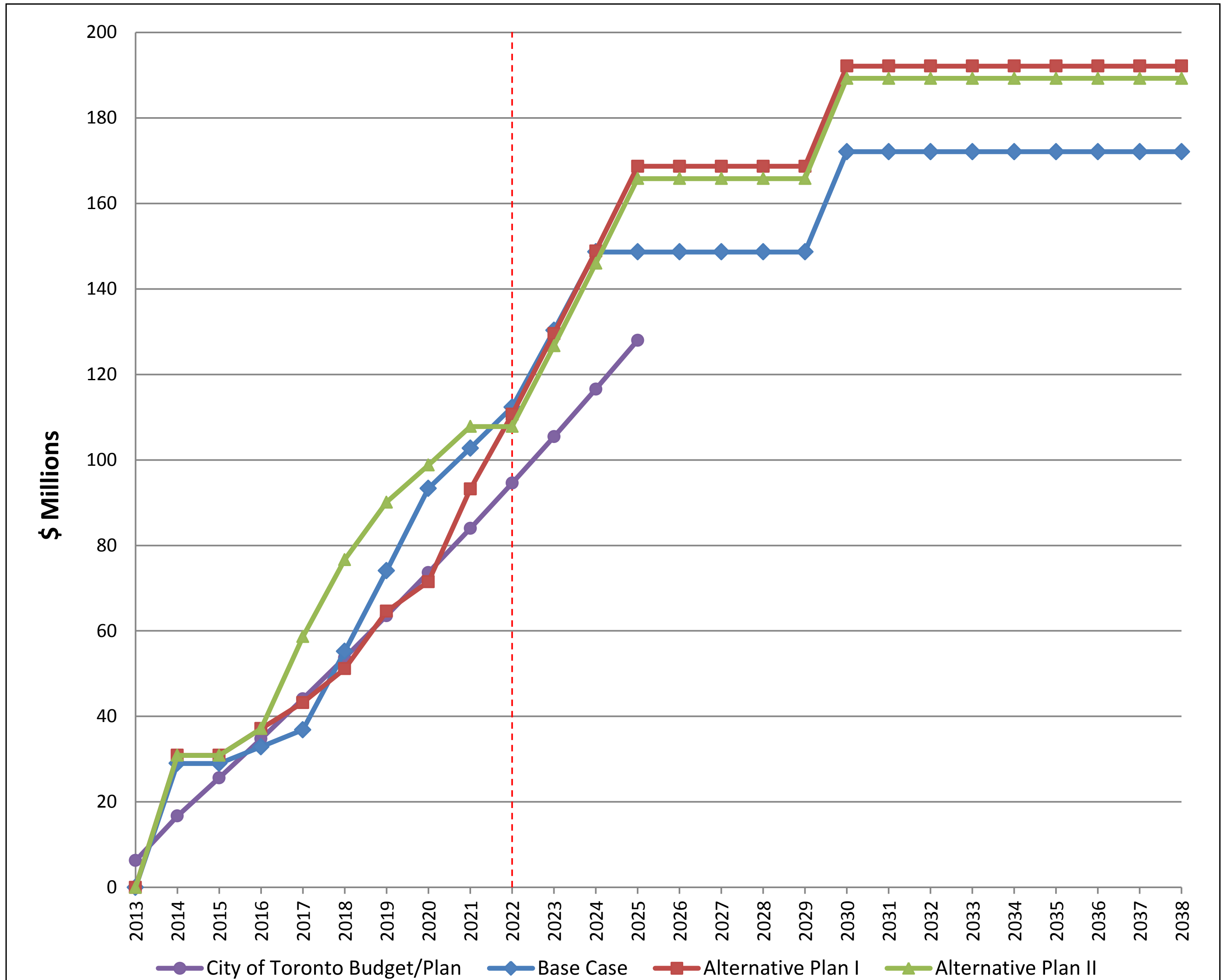


Figure 4.7 – At-Grade Section Accumulative Cash Flow Comparison

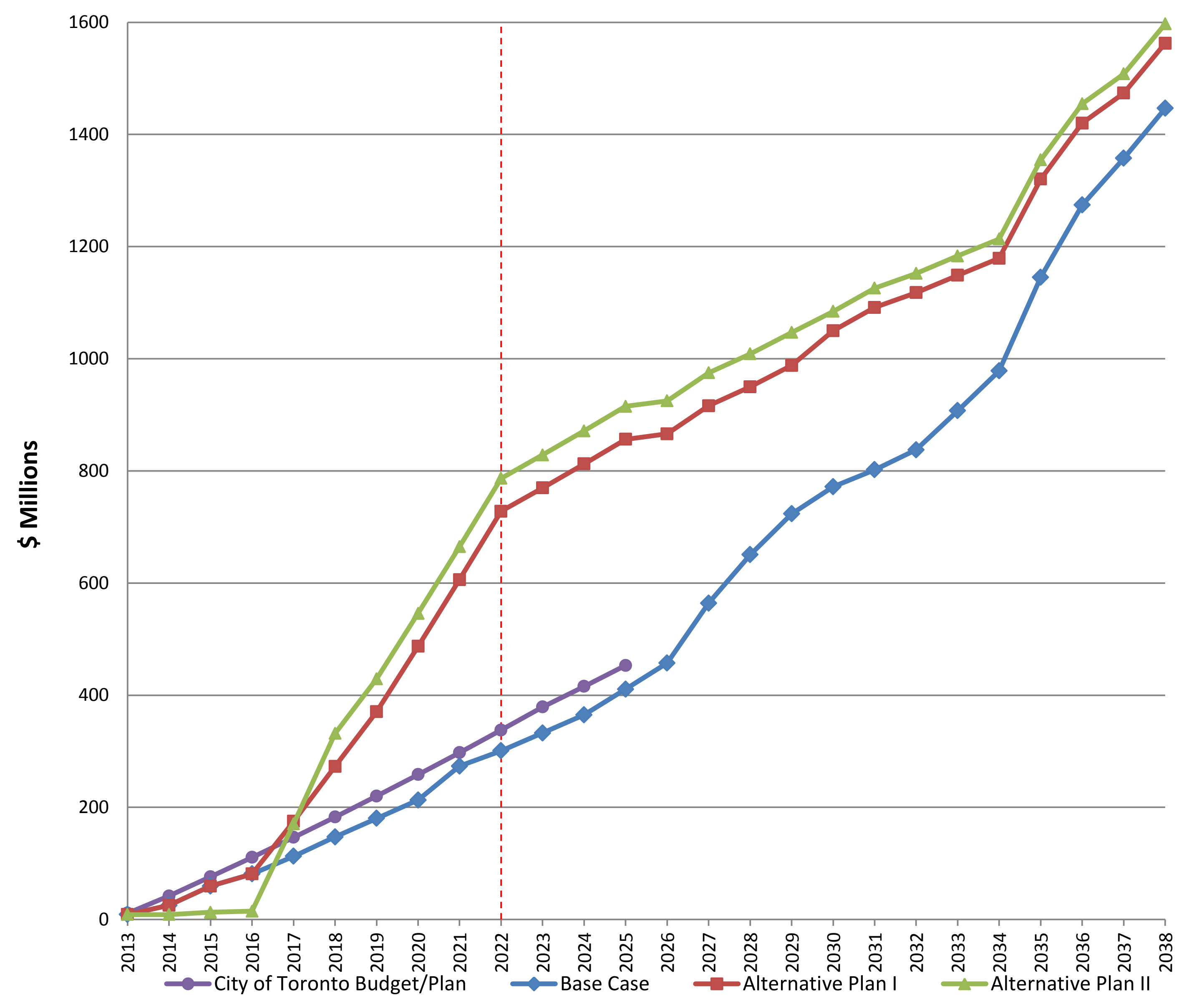


Figure 4.8 – Elevated Section Accumulative Cash Flow Comparison

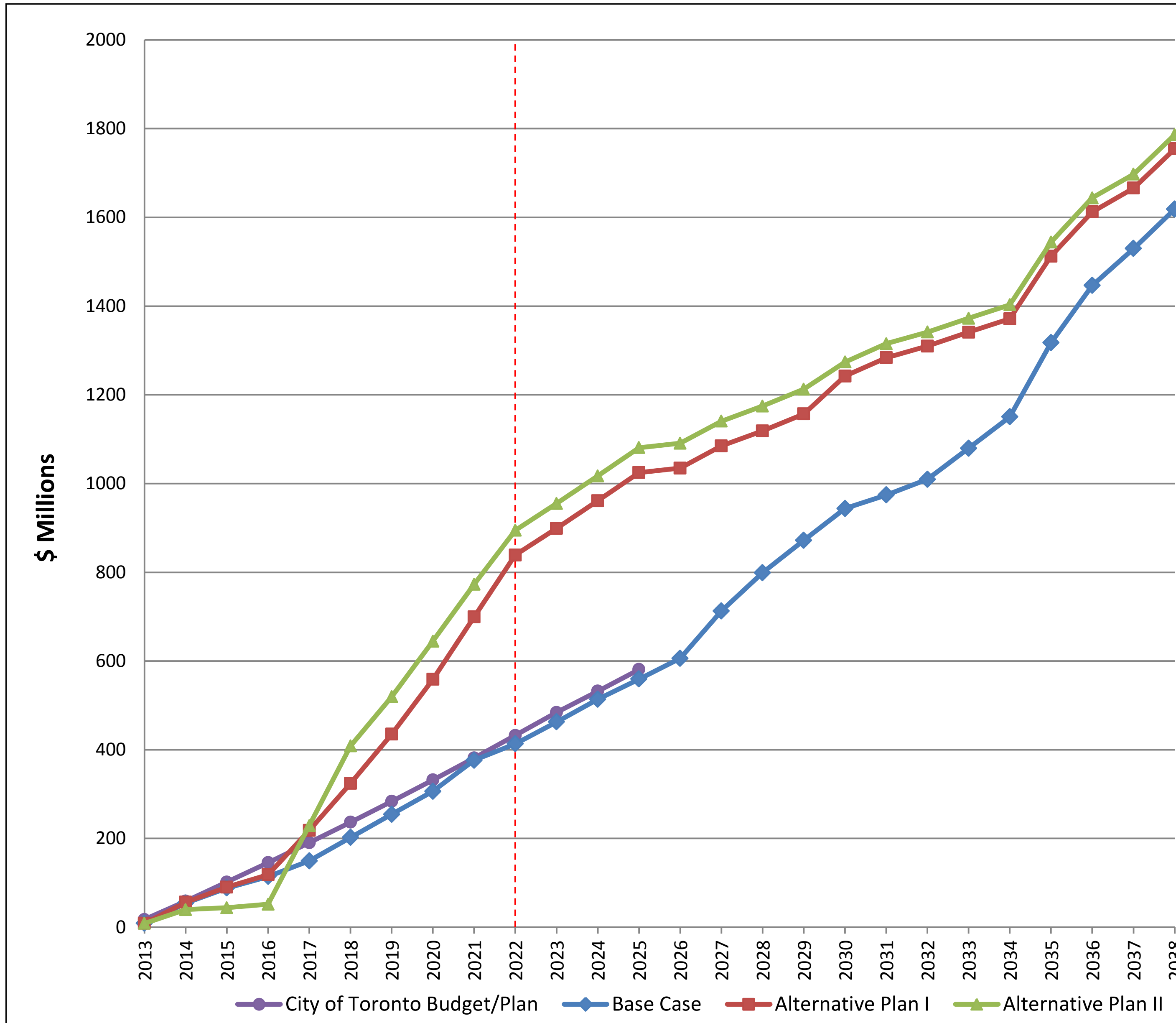


Figure 4.9 – Combined Elevated and At-Grade Section Accumulative Cash Flow Comparison

Table 4.27 – Year by Year Cash Flow ($ millions)

Year	City's Pre-Study Budget/Plan			Base Case			Alternative Plan I			Alternative Plan II		
	Elevated	At-Grade	Total	Elevated	At-Grade	Total	Elevated	At-Grade	Total	Elevated	At-Grade	Total
2013	11	6	17	9	0	9	9	0	9	9	0	9
2014	31	10	41	17	29	46	17	31	47	0	31	31
2015	34	9	43	34	0	34	34	0	34	4	0	4
2016	35	9	44	22	4	26	22	6	28	2	6	8
2017	36	9	45	31	4	35	94	6	100	156	22	177
2018	36	10	46	35	18	53	98	8	106	161	18	179
2019	37	10	47	33	19	52	98	13	111	98	13	111
2020	38	10	48	33	19	52	117	7	123	117	9	125
2021	39	10	50	60	9	70	119	22	141	119	9	128
2022	40	11	51	28	10	37	122	17	139	122	0	122
10 Year	**338**	**95**	**432**	**301**	**112**	**413**	**728**	**111**	**839**	**787**	**108**	**895**
2023	41	11	52	32	18	50	42	19	61	42	19	61
2024	37	11	48	32	18	51	43	19	62	43	19	62
2025	38	11	49	46		46	44	20	64	44	20	64
13 year	**453**	**128**	**581**	**411**	**149**	**559**	**856**	**169**	**1,025**	**915**	**166**	**1,081**
2026				47		47	10		10	10		10
2027				107		107	50		50	50		50
2028				86		86	34		34	34		34
2029				73		73	38		38	38		38
2030				48	23	72	62	23	85	38	23	61
2031				30		30	41		41	41		41
2032				35		35	26		26	26		26
2033				70		70	31		31	31		31
2034				71		71	30		30	30		30
2035				167		167	141		141	141		141
2036				129		129	100		100	100		100
2037				83		83	54		54	54		54
2038				89		89	89		89	89		89
Total				**1,446**	**172**	**1,619**	**1,563**	**192**	**1,755**	**1,597**	**189**	**1,786**

*Cash flow includes 2.5% per annum inflation and excludes engineering and contract administration fees

The present value of the capital construction cost for the base case using conventional construction method and the alternative using Accelerated Bridge Construction (ABC) method have been summarized in Table 4.28.

Table 4.28 – Capital Construction Cost Comparison

	Capital Construction Cost ($Million)		
	Base Case: Conventional Method	**Alternative Plan I: Conventional + ABC**	**Alternative Plan II: ABC**
Elevated Section	$ 988	$ 1,153	$ 1,186
At-Grade Section	$ 143	$ 157	$ 157
Total	**$ 1,131**	**$ 1,310**	**$ 1,343**
Cost Premium		**$ 179**	**$ 212**
*Cost Estimates in 2013 dollars			

The present value of the capital construction cost premium for Alternative Plan I is approximately $180 million and $210 million for Alternative Plan II. The capital construction cost for the base case includes coating of the existing girders which is recommended to be undertaken after the 2024 depending on the needs and the availability of funds as indicated in the previous sections of this study.

4.4 Traffic Impact and User Cost

A traffic impact assessment for the current submission has been carried out to identify the level of traffic impacts and delays that can be anticipated during the planned rehabilitation of the Gardiner Expressway from Highway 427 to the Don Valley Parkway under the base case alternative using conventional construction methods. The base case Strategic Plan consists of several contracts spanning a time period of 25 years (2014 to 2038). One Work Zone will be situated on the elevated section of the Gardiner and one Work Zone will be located on the at-grade section until year 2024 but starting 2025, only one (1) Work Zone will be located on the elevated section as the work on the at-grade section will complete by this time.

The traffic analysis for the strategic plan study is focused on an assessment of road capacity on parallel arterial routes, a review of planned lane closures on alternative routes, a theoretical delay, queuing assessment, and daily and weekly road user cost calculations for each of the proposed Work Zones.

Microsimulation Model of the Gardiner Expressway

A microsimulation model of the Gardiner Expressway was developed for the existing AM and PM peak hour to determine reasonable Work Zone capacities to be used in the delay analysis for each Work Zone and to assess the impact of one or more Work Zones being implemented simultaneously.

Assessment of Implementation of Multiple Work Zones

A review of the relative impact of having two Work Zones in place on the at-grade portion of the Gardiner and on the elevated section was carried out to assess the additional delay that may be attributed to maintaining two (2) Work Zones separated by a fixed distance compared to a single Work Zone. The following Work Zone analysis scenarios were modeled:

- Scenario 0 – Existing Conditions (no Work Zones in place)
- Scenario 1 – Theoretical Work Zone 1 in place between Kipling and Islington
- Scenario 2 – Theoretical Work Zone 2 in place between Spadina and Rees
- Scenario 3 – Theoretical Work Zones in place between Kipling and Islington (Work Zone 1) and between Spadina and Rees (Work Zone 2) with no traffic restrictions in both directions in between Work Zones
- Scenario 4 – Maintaining a Continuous Work Zone between Kipling and Rees

A review of the impact of implementing two Work Zones in close proximity to each other was also tested. For this analysis two (2) hypothetical Work Zones were tested between Dufferin and Strachan (Work Zone 3) and between Spadina and Rees (Work Zone 2). The following microsimulation scenarios ware carried out for these two Work Zones.

- Scenario 5 – Theoretical Work Zone 3 in place between Dufferin and Strachan
- Scenario 6 – Theoretical Work Zones in place between Dufferin and Strachan (Work Zone 3) and between Spadina Avenue and Rees (Work Zone 2) with 3 lanes open in both directions in between Work Zones
- Scenario 7 - Maintaining one 2 lane Work Zone between Dufferin and Rees

Microsimulation Analysis Findings

Scenario 1 - Theoretical Work Zone 1 (lane reduction between Kipling and Islington)

With the lane closure at Work Zone 1 in place (Scenario 1) a theoretical reduction in throughput of 10% was observed in the model. The capacity reduction at Work Zone 1 had a slight impact on the downstream location of Work Zone 2 causing a theoretical reduction in throughput of 4%.

Scenario 2 - Theoretical Work Zone 2 (lane reduction between Spadina and Rees)

In Scenario 2, where only Work Zone 2 experiences a lane reduction, a theoretical reduction in throughput of 19% was observed and no impact was observed at the Work Zone 1 location. This was expected since Work Zone 1 is significantly upstream of the lane closures at Work Zone 2 and is unaffected.

Scenario 3 - Theoretical Work Zone 1 and 2 (lane reduction at both Work Zones)

When lane reductions are implemented in Work Zones 1 and 2 simultaneously (Scenario 3), the greatest impact was observed downstream at Work Zone 2. As observed in Scenario 1, Work Zone 1 is expected to experience a theoretical reduction in throughput of 10%. Since this Work Zone is located upstream and is approximately 10.5 km to the west of Work Zone 2, it was not expected that the results from Work Zone 1 would differ too much from what was observed in Scenario 1. Work Zone 2 on the other hand, is expected to experience a greater theoretical reduction in throughput when compared to Scenario 2. This theoretical reduction of 34% is a result of a combination of the reduced capacity through the Work Zone and the metering of traffic resulting from Work Zone 1 lane closure.

Scenario 4 - Theoretical Continuous Lane Reduction between Work Zones 1 and 2

When one continuous 10.5 km Work Zone (1 continuous lane reduction) is put in place that spans from Work Zone 1 to Work Zone 2 (Scenario 4), a theoretical reduction of 20% was observed at Work Zone 1 and 33% at Work Zone 2. This scenario has the greatest impact on Work Zone 1. In previous scenarios, a theoretical reduction in throughput of 10% was typically observed at Work Zone 1; however, in this scenario the reduction has increased to 28%. The reason for the decreased capacity at both Work Zones under this scenario is attributable to the additional congestion that is created by the decreased capacity between the Work Zones coupled with the additional demand from by traffic entering and existing the freeway at the various on and off ramp locations.

Based on the results of Scenario 1 to 4, additional scenarios were developed to determine the impacts if the Work Zones were located closer. An additional theoretical Work Zone was tested (theoretical Work Zone 3) between Dufferin and Strachan, which is 1.5 km to the west of theoretical Work Zone 2.

Scenario 5 - Theoretical Work Zone 3 (lane reduction between Dufferin and Strachan)

When a lane reduction is implemented only at Work Zone 3 (Scenario 5) a theoretical reduction in throughput of 35% was observed at both Work Zone 3 and Work Zone 2.

Scenario 6 - Theoretical Work Zone 2 and 3 (lane reduction at both Work Zones)

This result is similar when both Work Zone 2 and Work Zone 3 are in place (Scenario 6). Since there are few ramps located between these two theoretical Work Zones, the throughput remains relatively constant and no significant impacts are observed at the downstream Work Zone as was observed in Scenario 3.

Scenario 7 - Theoretical Continuous Lane Reduction between Work Zones 2 and 3

Similarly, when a continuous Work Zone is put in place between Work Zone 2 and 3 (Scenario 7), very little difference is observed. Scenario 6 and Scenario 7 resulted in very similar operations due to the lack of ramps between the two Work Zones.

Based on this analysis, it was determined that the effect of implementing a long continuous Work Zone with a continuous lane reduction is comparable to implementing two separate Work Zones (with no lane reductions in between) if the Work Zones are closely spaced and have few ramp connections in between the Work Zones. However, if there is a significant distance between the Work Zones (i.e., 10 km) and there are on and off ramps located between the Work Zone then it is preferable to maintain the Work Zones as separate Work Zones and provide the maximum available capacity between the two Work Zones.

<u>Queueing, Delay, Road User Costs and Traffic Diversion Analysis</u>

A preliminary assessment of theoretical queues, delays, and road user costs was carried out for each of the planned construction stages on the Expressway. The analysis was undertaken based on the assumption that one (1) lane would be taken out of service in each direction at each Work Zone. The analysis was carried out using a typical 24-hour traffic profile that was developed from the AM peak, PM peak, and 24 hour traffic volume data that was provided by the City. The analysis not only addresses the traffic impact during each of the peak hours but actually takes into account the cumulative effects of queue building and queue discharging behaviours during successive hours when a traffic queue has formed. The results of the analysis are included in Appendix E.

The VISSIM microsimulation analysis that was undertaken for this project identified a maximum Work Zone capacity of up to 2,000 vehicles per hour per lane (vphpl). This service flow rate could potentially be achieved during stable free flow conditions; however, when the traffic demands reach and/or exceed this capacity, the stop and go conditions result in unstable constrained traffic flows of closer to 1,500-1,600 vphpl. As a result, a conservatively low Work Zone capacity of 1,500 vphpl was used in the analysis of each proposed rehabilitation stage.

Based on previous experience, the Work Zones that are in place long term on urban freeways tend to carry more than 1,500 vphpl with volumes being observed as high as 1800-2,000 vphpl. It should be noted that these high flow rates can only be achieved as long as the downstream conditions are not restricting free flow traffic movement. A supplementary complete queue and delay analysis was also carried out for higher Work Zone capacity of 1,800 vphpl and is included in Appendix E for comparison.

The queue and delay analysis was carried out for each contract based on the following assumptions:

- No Traffic Diversion (Existing Demand)
- 20% Diversion
- 40% Diversion

The ‘No Traffic Diversion’ scenario is intended to provide a baseline assessment to show the maximum theoretical delay that would be experienced if there was no traffic diversion, which is not a realistic situation. Anytime there is an increased delay due to construction related impacts, motorists will actively look for a way to minimize the delay on future trips by choosing another vehicular route, by switching modes to transit (given a viable alternative exists based on the person’s trip origin and destination), or by carpooling. In addition, those who have flexible work hours may elect to make their trips to and from work either before or after the AM and PM peak periods or even avoid traveling at all, if that option is available.

When construction related activities result in delays and queuing, a 20% diversion rate is typically achievable when there are alternative travel routes and/or modes of travel (i.e., local and regional transit) and the drivers are made aware of the upcoming construction activities in advance so they can plan how and when they will make their trips during construction. An effective public communication strategy is critical for achieving a target traffic diversion rate and to minimize delays during construction. A delay analysis was also undertaken based on a 40% diversion assumption for comparison purposes for all construction stages.

A review of the queue and delay analysis observed that queues and delays varied considerably between different construction Contracts. Since the Gardiner corridor is already experiencing some congestion during existing conditions, delays and queuing is expected for all proposed rehabilitation stages. For some contracts only a 20% diversion of from current traffic demand is required to achieve an average additional delays of approximately 30 minutes while for other contracts, the average delays with just a 20% diversion are considerably higher.

Since the queuing and delay results varied from contract to contract for a given % diversion assumption, it proved difficult to estimate delays and queues for all construction stages using a single system-wide diversion assumption. As a result, an alternate approach was used based on a system-wide additional delay of 30 minutes, which is the maximum delay that will need to occur before any significant diversion of traffic would occur. Therefore, the % diversion for each construction stage was established based on the amount of diverted traffic that is needed to achieve an average delay of 30 minutes. This approach acknowledges that there will be delays as a result of the planned lane closures on the Expressway and that the road users will endure some additional delay before a major diversion of traffic occurs.

The estimated queuing, delays and the rates of diversion that are required to achieve the target average delays of 30 minutes for the proposed Gardiner Rehabilitation Contracts up to year 2024 excluding the work on the ramps are presented in Table 4.29 and 4.30.

Table 4.29 – Eastbound Traffic Impact

CONTRACT	Required Diversion	Diverted Vehicles	Diverted Vehicle Delay (veh-hrs)	Max Delay (min)	Max Queue (km)	Avg. Delay (min)	Avg. Queue (km)	Total Veh. Delay (veh-hrs)
CONTRACT G1	19%	9,841	4,921	62	8.3	29	2.9	26,090
CONTRACT G2	8%	3,691	1,846	61	8.3	29	2.6	23,284
CONTRACT G3	23%	12,507	6,254	64	8.7	30	3.2	28,452
CONTRACT G4	28%	16,125	8,063	63	8.5	29	3.3	29,071
CONTRACT G5	45%	38,478	19,239	96	13.0	31	5.0	44,785
CONTRACT E1	34%	24,408	12,204	89	12.0	31	4.2	37,519
CONTRACT E2 (1)	21%	11,141	5,571	63	8.5	29	3.1	27,210
CONTRACT E2 (2)	0%	-	-	6	0.8	4	0.1	818
CONTRACT E3	34%	24,408	12,204	89	12.0	31	4.2	37,519
CONTRACT E4/E5	8%	3,158	1,579	69	9.3	30	2.5	21,812
CONTRACT E6	0%	-	-	47	6.3	19	1.2	10,710

Table 4.30 – Westbound Traffic Impact

CONTRACT	Required Diversion	Diverted Vehicles	Diverted Vehicle Delay (veh-hrs)	Max Delay (min)	Max Queue (km)	Avg. Delay (min)	Avg. Queue (km)	Total Veh. Delay (veh-hrs)
CONTRACT G1	52%	48,871	24,436	96	12.9	29	5.3	47,163
CONTRACT G2	31%	20,702	10,351	82	11.1	27	3.5	31,155
CONTRACT G3	36%	25,984	12,992	90	12.2	29	4.1	36,861
CONTRACT G4	37%	26,975	13,488	86	11.7	28	4.0	35,331
CONTRACT G5	52%	48,871	24,436	96	12.9	29	5.3	47,163
CONTRACT E1	39%	29,278	14,639	86	11.7	28	4.1	36,119
CONTRACT E3	39%	29,278	14,639	86	11.7	28	4.1	36,119
CONTRACT E2 (1)	27%	17,258	8,629	89	12.0	30	3.8	33,437
CONTRACT E2 (2)	40%	30,501	15,251	87	11.7	28	4.1	36,813
CONTRACT E4/E5	18%	9,607	4,804	62	8.4	29	3.0	26,935
CONTRACT E6	0%	-	-	47	6.3	28	2.0	17,451

The traffic impact on the Expressway as indicated on the above tables illustrate that generally a diversion rate of 20% to 40% is required, with the exception of Contract G5 where approximately 50% diversion is required, to maintain the average delays in the 20-30 minutes range.

Construction Related Road User Costs

Construction related road user costs were estimated for both the vehicles queued on the Expressway and the vehicles that are assumed to be diverted since the diverted vehicles are expected to experience a similar level of delay even though a different route is chosen. The delay calculation does not assess the level of additional delay experience by the existing users of the adjacent parallel arterial roads caused by the diverted traffic which means the road user costs are a conservatively low estimate of the total additional delay that is likely to occur during implementation of this Strategic Plan. Daily and Weekly road user costs were estimated based on a 24 hour time period for each Contract. Where simultaneous Work Zones are proposed (i.e. one Work Zone on the at-grade section and another on the elevated section), only one (1) contract with the higher user cost has been considered and disregarded the 2nd Work Zone to avoid over-estimation. The Weekly road user cost is estimated based on the assumption that weekend delays will be approximately 80% of the average weekday delays.

The user costs due to traffic delays caused by the reduction in the number of lanes of traffic during construction for the two alternative plans is summarized in Table 4.31.

Table 4.31 – User Cost Comparison

Year	User Cost ($M)		
	Base Case: Conventional Method	**Alternative Plan I: Conventional + ABC**	**Alternative Plan II: ABC**
2014	$ 550	$ 550	$ 470
2015	$ 460	$ 460	-
2016	$ 460	$ 460	-
2017	$ 390	-	-
2018	$ 390	-	$ 460
2019	$ 390	$ 460	$ 620
2020	$ 460	-	-
2021	$ 460	-	-
2022	$ 390	$ 620	$ 250
2023	$ 620	$ 460	$ 460
2024	$ 620	$ 460	$ 460
2025	$ 130	$ 460	$ 460
2026	$ 130	-	-
2027	$ 460	-	-
2028	$ 460	-	-
2029	$ 460	-	-
Total	**$ 6,830**	**$ 3,930**	**$ 3,180**
User Cost Savings from Alternative Plan		**$ 2,900**	**$ 3,650**
*User Cost Estimates in 2013 dollars			

The anticipated user cost savings from using the ABC alternative is approximately $2.90 billion for Alternative Plan I and $3.65 billion for Alternative Plan II.

4.5 Conclusion/Discussion

This strategic study presents three (3) alternatives of comprehensive strategic plans to undertake the rehabilitation of the Expressway. The base case alternative uses conventional construction methods on the elevated and at-grade sections of the Expressway. The combined work on the elevated and at-grade section is prioritized and scheduled to incur the lowest capital construction cost that follows very closely with the City's preliminary 13 Year Plan and the 10 Year Budget, which were established prior to this study. The proposed base case plan will enable the City to accomplish the goal of rehabilitating the Expressway to a 'state of good repair' within the available funding constraints. However, due to the existing traffic conditions, the anticipated user costs from construction related traffic restrictions is expected to be extreme over the course of implementing this Plan, which lead to the development of the alternative Accelerated Bridge Construction (ABC) Plans.

The alternative ABC Plans propose to use Accelerated Bridge Construction (ABC) method to streamline the construction schedule on the elevated Expressway and to reduce the total duration of traffic restrictions due to construction. The work on the at-grade section has been scheduled to maximize the user cost savings by limiting the traffic restrictions on the at-grade section to the periods of traffic restriction for construction on the elevated section of the Expressway. As indicated in the preceding sections of this report, Alternative Plans I and II will incur a cost premium of approximately $180 million and $210 million respectively over the course of the Plan, but will result in a user cost saving of approximately $2.90 billion and $3.65 billion respectively. A summary of the capital construction cost and user cost of the strategic plan alternatives is shown in table 4.32.

Table 4.32 – Strategic Plan Alternatives Cost Comparison (Present Value – 2013 $)

	Base Case: Conventional Method	Alternative Plan I: Conventional + ABC	Alternative Plan II: ABC
Capital Construction	$ 1,131 M	$ 1,310 M	$ 1,343 M
User Cost	$ 6,830 M	$ 3,930 M	$ 3,180 M
Total	**$ 8.0 B**	**$ 5.2 B**	**$ 4.5 B**

Additional benefits of the ABC method over the conventional deck replacement using cast-in-place construction include the following:

- mitigates noise, vibration, and dust;
- less weather dependent;
- highest quality achievable by fabricating the structural elements in a more controlled environment;
- reduction in 'interim' repair requirements;
- new steel girders will be incorporated instead of salvaging the existing girders; and
- mitigates cost impacts from future steel coating requirement.

The Alternative Plans, however, exceed the City's established financial constraints and require additional funding to be secured by the City. In addition, due to the more complex and unconventional construction procedures, this method presents additional risks which need to be addressed during design and construction as discussed previously.

5. OTHER CONSIDERATIONS TO ACCELERATE CONSTRUCTION

There are methods used by other owners to expedite construction. Given the significant impact this project will have on users and the City economy, these should be further explored on a Contract specific basis. They are identified and described in the following:

Simultaneous Contracts: As the name implies, Simultaneous Contracts refers to the delivery of two or more contracts at the same time with a physical separation of space between them. Traffic impact analysis has indicated that adjacent contracts with similar lane restrictions do not result in any significant increase in delay or user costs. Undertaking two or more contracts at the same time would reduce the overall traffic delay and user cost of implementing the Strategic Plan.

There are some challenges to deliver more than two contracts at the same time. These include:

1. Physical separation of the Contracts Work Zones to satisfy the requirements of the Ministry of Labour (Ontario) to avoid the City becoming the 'Constructor'. Alternatively, the City could become the 'Constructor' and accept this Ministry requirement. The City assuming the role of the "Constructor" results in a significant cost impact and risk to the City and is not recommended;
2. Both budget and cash flow must be available to undertake simultaneous Contracts; and
3. Availability of Contractors. Contractors within the GTA must have the available equipment and labour to undertake higher volume of work in any selected period.

We believe this method has merit and the current Strategic Plan utilizes this approach somewhat (separate and simultaneous Contracts for elevated and at-grade sections), additional opportunities should be explored during detailed design.

Incentive / Bonus Clauses: This method is widely used by many States in the United States. There are numerous details to implement such incentive payments to Contractors for early completion. In general, most consist of a maximum lump sum payment for completion and a stipulate number of days ahead of the scheduled completion date to zero incentive payment, if it is only delivered by the Contract specific date.

This daily dollar amount is often applied as a disincentive as well, so that for each day the Contractor extends completion beyond the Contract specified completion date, the same amount is subtracted from future payments to the Contractor as "a penalty" or disincentive. The maximum value of the disincentive is sometimes limited by an "upset" limit.

While effectively used in some jurisdictions, the Contract specifications need to be well structured to avoid administration issues during construction. Some of the issues include:

1. Dollar value for the incentive needs to be significant enough to provide the Contractor with compensation and profit to accelerate the Contract. This could be by compensating payment of overtime or shift premium, development/fabrication of new equipment to speed the work or the use of the materials or methods that may speed the completion of construction.
2. Specific work in the Contract must identify what factors are considered as delays beyond the Contractor's control (for which he/she is granted extensions). Strikes/labour disruptions, rain days (and what constitutes rain days) and other delays must be identified; and
3. When Contract completion is achieved must be defined. We believe this approach has considerable merit given the high user costs associated with lane restrictions. The daily bonus will need to be significant to be an incentive to any successful bidder.

Lane Rental Cost: In this method, the owner assigns a cost to each day one or more lanes of traffic are closed for construction. The contract "bid" or tender is evaluated as two parts. Part A is the price for the various tender items of construction (materials, labour). Part B of the tender is completed by the Contractor and consists of a base number of days of required lane closures (duration of traffic staging) as provided by the Owner. To this number of days, the Contractor may add or subtract days he believes his methodology will reduce or extend that number. The land rental cost then becomes the Owner's estimate of days plus or minus the Contractor's reduction or extension multiplied by the daily 'rental' cost established by the Owner.

Part A and B of the tender are then combined and used to award the Contract with the lowest overall price being the successful bidder. If the Contractor reduces the overall number of lane reduction days, then number of days of reduction multiplied by the determined rental rate can become the incentive the Contractor receives. Should the Contractor go beyond the total number of days that was identified at the time of bidding, then the daily rate becomes a 'disincentive' that is subtracted from monies owed to the Contractor.

The issues associated with this approach are similar to those that relate to the general bonus/incentive clauses noted above.

We believe this method has merit as an alternative to the bonus/incentive clause. The advantage is that this method focuses only on the duration of time traffic is impacted and not the overall construction duration. Time for the Contractor to complete work with the Contract, which does not impact traffic, does not count toward the incentive/disincentive in the lane rental approach.

Contract Innovation: Several jurisdictions financially compensate Contractors for time and cost saving innovations which either accelerate construction and/or reduce costs. This is done through sharing of any cost saving resulting from the Contractor's new approach.

This method is more applicable to realizing cost savings and usually does not relate to time saving. To include compensation for saving in construction duration may 'double reward' a Contractor for time savings, if an incentive or lane rental approach also exists in the Contract.

We would suggest the inclusion of Contractor Innovation (with a City agreed to formula for sharing such savings clause in all Contracts, we would suggest this relate only to cost saving and not acceleration of the work. Work acceleration can best be addressed with other previously discussed mechanisms.

Winter Construction: To reduce the overall duration of construction, some suggest the use of construction throughout the winter months. The effectiveness of this approach is literally "weather dependent" and can vary from one winter to the next depending on the prevailing temperature and snowfall.

Certain activities can be undertaken in the winter months. These include steel work/repairs, demolition, and localized concrete repairs and new concrete construction of components where it is feasible to maintain the concrete temperature of poured concrete during curing.

In general, winter work proceeds at a reduced rate of production. As such, while work is being completed earlier, it is taking a greater duration of time and may be prolonging traffic impact longer than would be required if the work was only performed in the non-winter months.

In addition, winter construction has greater probability of delivering a less durable repair as a result of winter construction conditions. Concrete cured in the winter months may be exposed to salt spray from adjacent traffic making it more susceptible to scaling and deterioration. There are many other examples of the negative impact winter construction can have on the durability/quality of construction. (We note that it may not reduce the quality/durability if stringent controls are enforced and/or the weather is not extreme).

In addition, snow removal in restricted lanes (reduced lanes) are further restricted for snow removal or simply by snow maintenance operations.

In conclusion, the effectiveness of undertaking construction in the winter months relates to what specific activities are occurring. In general, we do not believe that activities which require the restriction of traffic during the winter months are advisable, if there are other options. Some site activities may be highly effective in advancing a Contract during the winter depending on the work being performed.

6. STRATEGIC PLAN RISKS AND POSSIBLE MITIGATION MEASURES

As with all large infrastructure projects, there are a number of identifiable risks that could impact either or both the cost and construction schedule. The following identifies some of the major risks to the implementation of the Strategic Plan for the Expressway. We also provide possible mitigation measures as follows:

1. *Utilities*: Utility impacts are an often cited reason for delay of the construction of a project. Sometimes utilities are found to be in the way of the proposed construction and relocation can result in a long period of delay. This is typically a minor issue on the elevated portion of the Expressway (where most active utilities are surface mounted and highly visible). Work on the at-grade portion as well as the design and implementation of some of the previously approved Environmental Assessment components of the work may be impacted more by utilities.

   The best mitigation method is typically undertaking a thorough field review of the Work Zone, including "in field" investigation methods such as (but not limited to) test pits.

2. *World commodity prices:* Some materials required to implement the Strategic Plan, such as steel, asphalt and fuel are commodities where either they, or their constituent components, are traded on world markets. Fluctuations in pricing for these products tend to be more volatile and prone to world demands.

   While it is possible to "hedge" prices for these materials on futures markets", such "future trading" is also a risk (volatising of the futures market) and beyond what is normal for an Owner.

   Purchasing of materials by the Owner for supply to the Contractor at a latter date is possible as well. This may afford the Owner the ability to take advantage of lower prices; however, the risk in ordering materials, storage costs, and possible handling costs, usually exceed any savings.

   The only mitigation measure that might be considered by the City, in MRC's opinion, is possibly time of tendering and awarding of Contracts to take advantage of lower work commodity costs. Once tendered and awarded, the Contractor would assume the risk. The prevailing level of risk will be priced into the Contractor's bid price.

3. *Prevailing Market Prices*: As there is more construction activity in the GTA, market prices tend to escalate. All segments of the construction process see prices escalate in times of higher activity. Rental companies can increase rates; material supplies and labour rates all increase; Contractor's mark-up and profit margin increase as well.

   There are a number of on-going and planned projects that will impact current market prices during the implementation of the Strategic Plan for the F.G. Gardiner Expressway. These include Metrolinx initiatives and TTC projects on public transit initiatives; Highway 407 East Design Build, MTO increased spending on structure rehabilitations within the province as well as a current high level of high-rise residential/office construction. There are no mitigation measures which can reduce increased market prices.

4. *Labour Agreements*: Labour disruptions can be a risk to projects. Strikes by any Union during construction will directly impact the schedule for any Contracts implementing the Strategic Plan.

It is possible to obtain agreements with local Unions to ensure “labour peace”. This is generally done by the Contractor and results in increased costs to the Contract.

We would recommend that the City and their Consultant for the implementation of the Strategic Plan to be knowledgeable on which agreements for Unions are coming open for re-negotiation during any individual Contract. The timing of the possible labour disruption and it’s occurrence within the timing of the individual contract should be assessed prior to each Contract being tendered. A decision on requesting a Contract period without labour disruption can be made on that basis.

5. *Weather*: The weather can also represent a risk to construction. Wet or cold weather can disrupt construction activities and delay construction.

   While it is not possible to control the weather, the use of pre-fabricated or pre-manufactured components to the maximum extent possible will mitigate weather impacts by reducing the dependence on the weather to the ability to advance construction.

   Accelerated Bridge Construction methods take maximum advantage of the use of pre-fabricated components and reduce the dependence of construction on the prevailing weather.

6. *Nuisance Impacts*: The noise or dust will be two of the major environmental impacts resulting from construction to implement the Expressway Strategic Plan. If either of these issues cannot be managed to the satisfaction of the public, pressure may develop to limit the Contractor’s activities (restrict hours of work or methodology). Much of the elevated Expressway is in close proximity to numerous residential and office buildings. Mechanical breaking of concrete and other noise generating activities that may take place may generate numerous complaints.

   Adopting construction methodologies, such as accelerating construction techniques, which tend to have reduced noise generation activities, will result in reduced complaints from residents. This will result in the least risk permitting the Contractor to work two (2) shifts per day using extended working hours.

7. RECOMMENDED SCHEDULE FOR DESIGN SERVICES / APPROVALS TO IMPLEMENT STRATEGIC PLAN

To effectively implement Contracts under the Strategic Plan, where the timing of construction start in the field and the duration of construction may be tied to specific ‘windows of opportunity’, it is important to establish milestone dates.

In this Section, we have identified times for various ‘steps’ within the tender and procurement process as well as some commended review periods. These have been reviewed by the City and should be reconfirmed at the outset of each design assignments between the City and the Designer when the Design Schedule is prepared:

FROM/TO	DURATION
• Pre-Design/Survey	16 weeks
• Detailed Design	30 weeks
• 90% Design Package to City for review	6 weeks
• Documents/Drawings submitted to City (Procurement)	6 weeks
• Tender Document available, Bid Period	6 weeks
• Tender Period	8 weeks
• Award	12 weeks
• Construction Start from Award	2 weeks

From the commencement of pre-Design to the start of construction is estimated to require 80 weeks.

In addition to the above design and tender/award process, the additional time required by the Contractor to prepare for an accelerated design contract has been estimated in the event that process is selected, by the City.

FROM/TO	DURATION
• Contract Award	-
• Shop Drawing Preparation and Review for new girders	15 weeks
• Order Structural Steel	15 weeks
• Fabricate Steel Girders	15 weeks
• Fabricate “bridge panels”	30 weeks
• Implementation of “lane restrictions”	-

The above indicates that to use an accelerated construction methodology, upwards of 75 weeks of time will be required from Contract Award to the implementation of lane restrictions. This time frame should be fully developed by the Designer during the pre-design stage considering many factors. Successful estimation of this ‘lead time’ will enable the overall design and construction schedule to be established to maximize the use of a set ‘window’ for field construction.

8. ALTERNATIVE “PROJECT DELIVERY” METHODS

All of the forgoing discussions have considered only the Design – Bid – Build (DBB) method of implementing the Strategic Plan for the Rehabilitation of the F.G. Gardiner Expressway. DBB is one of the oldest and most familiar methodologies for contracting between and Owner and a Contractor.

In the DBB approach:

- The Owner provides a detailed design, and contract drawings and specifications to complete an undertaking (the “works”);
- A Tender is let by the Owner for completion of the “works” by bidders;
- Upon Tender close, and assuming the conditions of the bid are acceptable to the Owner, a Contract is entered into between the Owner and the Bidder (the Contractor), who will complete the works; and
- The works are completed to the requirements of the drawings and specifications.

Several alternate methods exist which could be used to implement the Strategic Plan. Among others, these include:

- Design-Build (DB)
- Design-Build-Operate-Transfer (DBOT); and
- Public-Private Partnership (P3).

The DB alternative is similar to the DBB method with the exception that the successful Bidder for the “works” is also responsible for the design/engineering to complete the “works”. DBOT and P3 methods generally entail operation of the facility by the Contractor for some predetermined time (typically for a fee or based on the collection of a toll in the case of a transportation facility). In a P3 arrangement, the successful Bidder (Contractor) arranges some or all of the project financing in exchange for future payments by the Owner (or tolls) to repay the capital and financing costs over an agreed period of time.

The above is not intended to cover all possible methods to deliver projects. The reader is directed elsewhere for a more extensive treatment of these and other project delivery methods.

The DB methodology was considered to warrant further discussion in the Report as a possible methodology, meeting the City’s requirements, for the possible implementation of the Strategic Plan for the Rehabilitation of the F.G. Gardiner Expressway. This method is similar to the DBB approach except the Owner received proposals/bids from DB bidders on the basis of the completion of a “bid package” based on preliminary design and end result specifications provided by the Owner.

The proposal package for a DBB project for the implementation of the Strategic Plan would typically outline such major factors as the following:

- Overview of the Owner’s approach to complete the work (developed to an extent to confirm the feasibility of the method);
- Timeline for completion of the work including duration of permitted lane restrictions;

- Expected durability and other requirements for various components to be designed by the Contractor;
- End result specifications to cover all components of the work; and
- The required quality control to be completed by the DB Contractor.

The major advantages of a design build (DB) Contract is that it is often possible to accelerate the overall project as engineering, shop drawing preparation/review and procurement of materials are generally completed earlier and faster than in a DBB process. The DB Contractor can also select construction means and methods to suit previous experience or available equipment. Innovation by the Contractor is believed to be maximized in this project delivery process as innovations and cost savings go directly to the DB Contractor.

Cost for DB projects are usually nominally more than those for DBB projects to reflect the greater risk assumed by the DB Contractor and cost of Engineering for the detail design. This may be somewhat offset by reduced financing costs and/or user costs due to a reduction in construction duration.

Control of the final product, by the Owner, during a DB Contract must be entirely defined in the Proposal documents prepared at the bid stage. In the Owner’s proposal (on which the DB Contractor based their bid), any alternative approach to design, traffic restrictions, or minimum acceptable quality will inflate the contract cost and may delay the completion of the project.

MRC believes the implementation of the F.G. Gardiner Strategic Plan using the DB methodology is a viable alternative to the DBB approach assumed in this Report. We would recommend that the City review the advantages and disadvantages of the DB methodology further to determine if the DB approach meets with the City’s needs.