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Canada-United States-Ontario-Michigan
Border Transportation Partnership

Detroit River International Crossing Environmental Assessment Study

Practical Alternatives Evaluation

Constructability Report for Access Road Alternatives

Draft

May 2007

URS

Preface

The Detroit River International Crossing (DRIC) Environmental Assessment Study is being conducted by a partnership of the federal, state and provincial governments in Canada and the United States in accordance with the requirements of the Canadian Environmental Assessment Act (CEAA), the Ontario Environmental Assessment Act (OEAA), and the U.S. National Environmental Policy Act (NEPA). In 2006, the Canadian and U.S. Study Teams completed an assessment of illustrative crossing, plaza and access road alternatives. This assessment is documented in two reports: Generation and Assessment of Illustrative Alternatives Report - Draft November 2006) (Canadian side) and Evaluation of Illustrative Alternatives Report (December 2006) (U.S. side). The results of this assessment led to the identification of an Area of Continued Analysis (ACA) as shown in Figure 1.

Within the ACA, practical alternatives were developed for the crossings, plazas and access routes alternatives. The evaluation of practical crossing, plaza and access road alternatives is based on the following seven factors:

- Changes to Air Quality
- Protection of Community and Neighbourhood Characteristics
- Consistency with Existing and Planned Land Use
- Protection of Cultural Resources
- Protection of the Natural Environment
- Improvements to Regional Mobility
- Cost and Constructability

This report pertains to the Constructability portion of the Cost and Constructability factor and is one of several reports that will be used in support of the evaluation of practical alternatives and the selection of the technically and environmentally preferred alternative. This report will form a part of the environmental assessment documentation for this study.

Additional documentation pertaining to the evaluation of practical alternatives is available for viewing/downloading at the study website (www.partnershipborderstudy.com).

Constructability Report

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1. Summary

Overall, the construction staging and constructability reviews to date confirm that all the alternatives are constructible. Factors influencing constructability include traffic, poor soil conditions, municipal drains and utilities.

Construction staging for the new access road will include a requirement to maintain existing traffic on the Highway 3 and Huron Church Road corridors during construction. Four lanes of traffic will be maintained along Highway 3, and a minimum of four lanes of traffic will be maintained along Huron Church Road during construction. All access road alternatives can accommodate existing Highway 3 / Huron Church Road traffic during construction.

It is clear that access road construction will be complicated by the high water table and relatively poor ground conditions, particularly towards the north and west ends of the project. The construction of below grade sections should be feasible up to a depth of 10 m without undertaking additional measures to control soil. Below grade sections and cut and cover tunnels, which would require excavation to a depth of 15m below existing ground, would require complex construction techniques such as incorporating temporary ground improvement measures or other temporary wall and base stability enhancements during construction. The tunnel alternative is more complex and time consuming than other alternatives due to the necessity to build the tunnel box, ventilation, electrical communication systems and safety systems.

Complex construction staging will also be required to accommodate municipal drain crossings. Replacing the existing bridge over Grand Marais Drain/Turkey Creek with a concrete box culvert will allow for the construction of a below grade freeway cross-section passing over the drain. Construction of a tunnel cross-section under Grand Marais Drain/Turkey Creek would require complex construction techniques as described above. Inverted syphons for Cahill Drain and Lennon Drain crossings are considered to be feasible.

Utility crossings will need special consideration for below grade and tunnel alternatives. Existing utilities crossing the corridor could be incorporated into overpasses or could be provided in separate structures. Additional work would be required to bury utilities under the below grade or tunnel cross-sections.

With respect to the plaza locations, the major differences in constructability are associated with Plaza C. Construction of Plaza C would require the relocation of the Keith Transformer Station, which would add considerable time and cost to the project.

Construction staging and constructability issues for the international bridge alternatives related directly to the main span and inspection plazas are addressed in the *Bridge Type Study Report (July, 2007)* being prepared by URS and Parsons.

2. Background

2.1. Project Overview

The Detroit River International Crossing (DRIC) Study is an Environmental Assessment Study undertaken by a joint partnership between the Ministry of Transportation Ontario (MTO), Transport Canada (TC), the Michigan Department of Transportation (MDOT) and the U.S. Federal Highway Administration (FHWA). This Report has been prepared to document constructability associated with implementing five practical highway access road alternatives and four practical plaza alternatives which were developed for this project in 2006. Documentation of the construction costs is provided in the *Practical Alternatives Evaluation Construction Cost Report, August 2007.*

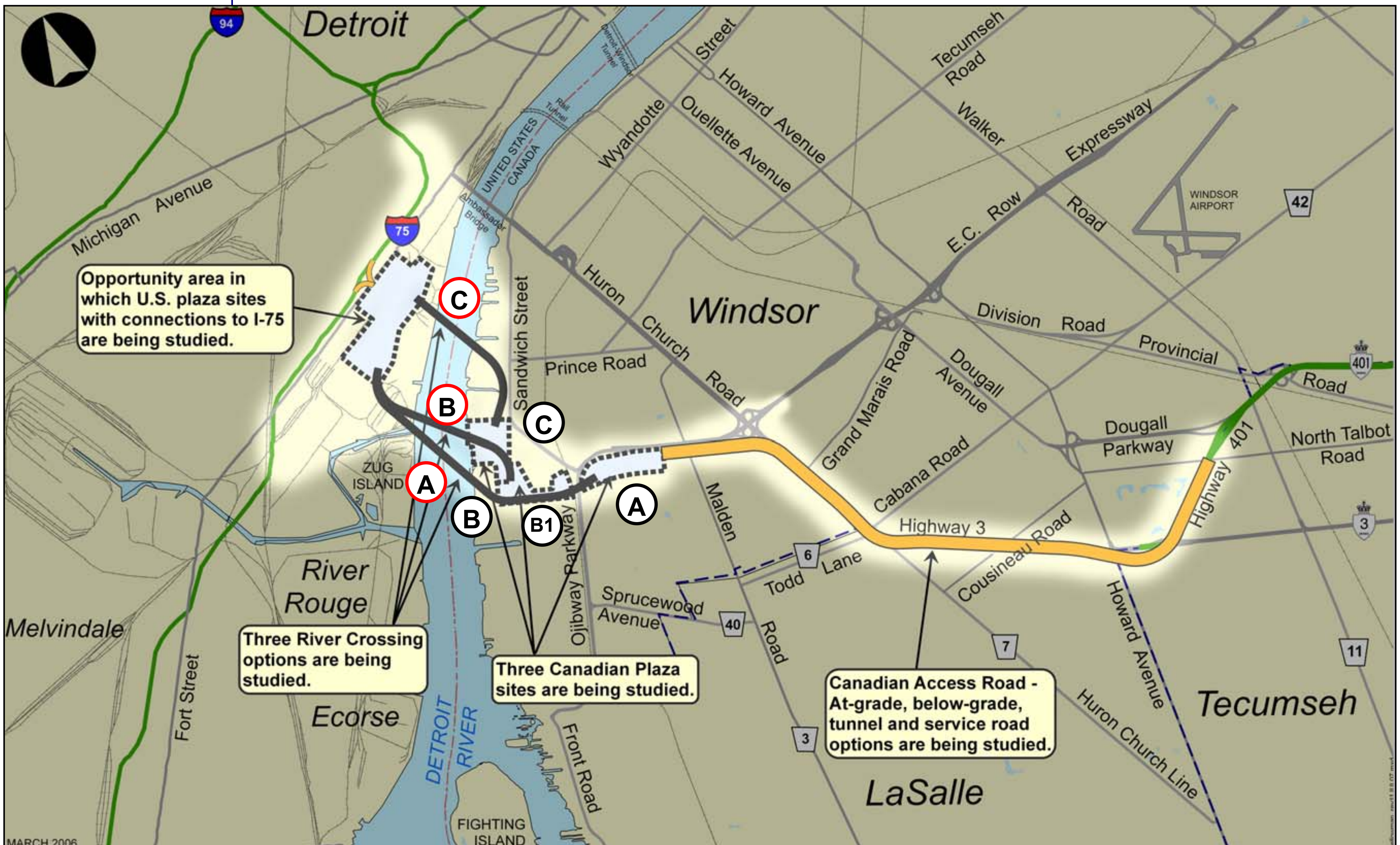
2.2. Project Limits

The project limits for this phase of the study are defined by the Area of Continued Analysis (ACA), which begins near the western terminus of Highway 401, and generally follows the alignments of Highway 3, Huron Church Road, E.C. Row Expressway. Approaching the Detroit River, the ACA includes area for four border plaza and three international bridge crossing alternatives. The ACA traverses through the Town of Tecumseh, Town of LaSalle and the City of Windsor. A key plan which identifies the ACA is presented in **Figure 1**.

2.3. Project Schedule

The partnership has an objective of completing the DRIC project by 2013. Given the importance of this corridor and the projected traffic, the completion of construction by 2013 is highly desirable. The complexity of construction of the access road, plaza and crossing will influence the assessment of risk to completing the project within the target timeframe.

FIGURE 1 – AREA OF CONTINUED ANALYSIS - PRACTICAL CROSSING, PLAZA AND ROUTE ALTERNATIVES



3. Existing Conditions

The following sections outline those aspects of existing conditions which are relevant to constructability.

3.1. Existing Land Use

Land use along Highway 3 and Huron Church Road is generally a mixture of residential and commercial, with some institutional and open space. Commercial land use along Huron Church Road is Highway Commercial. Between Huron Church Road and Ojibway Parkway, there are some residential areas, but mostly open areas, most of which covered by low vegetation and trees. This area includes an Area of Natural and Scientific Interest (ANSI). Between Ojibway Parkway and the river is a mixture of industrial uses ranging from light to heavy industrial. More information on land use can be found in the technical report entitled *Draft Existing and Planned Land Use, June 2007*.

3.2. Soil Conditions and Groundwater

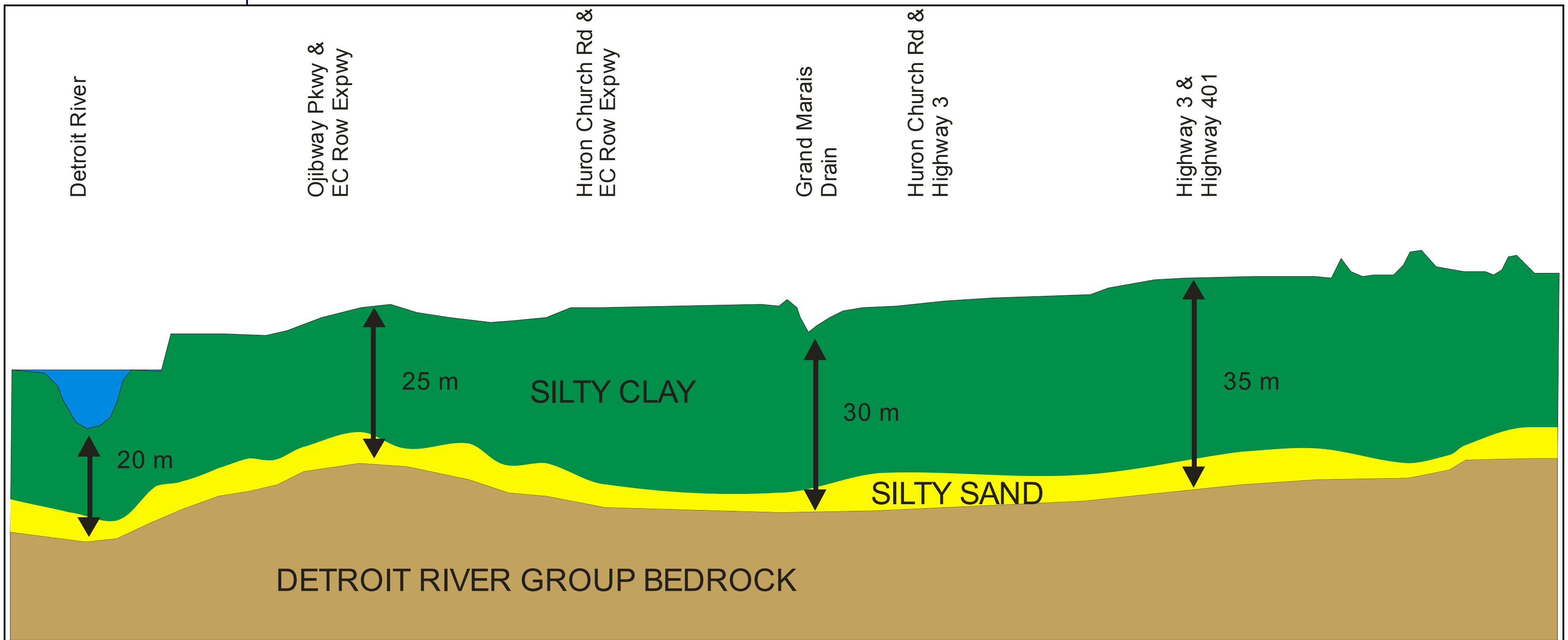
As noted in the *Interim Foundations and Geotechnical Engineering Report*, *July 2005* prepared by *Golder Associates Ltd*., the existing soils within the ACA generally consist of soft silty clay. West of the Huron Church Road and E.C. Row Expressway interchange, the soil conditions become progressively softer, and less favourable for conventional construction methods. A majority of the bedrock is comprised of limestone, ranging in depths of 20 m (65 ft) below ground surface at the Detroit River, to 25 m (82 ft) at Ojibway Parkway and E.C. Row Expressway to 35 m (114 ft) at the existing terminus of Highway 401. The existing topography is flat, with a gradual decline in elevation towards the Detroit River. The profile of soil conditions between the Detroit River and the existing terminus of Highway 401 is presented in **Figure 2**.

Soil conditions become less conducive to construction with deeper excavation. The construction of below grade or tunnel facilities should be feasible up to a depth of 10m. Construction activities beyond this depth would require either temporary ground improvement measures or other temporary wall and base stability enhancements during construction. Cut depths greater than 10m will require further evaluation, and it is anticipated that additional stability enhancement measures may be required.

High groundwater conditions exist within the study limits, particularly near the Detroit River. Groundwater elevations range between 0.5 m to 6.0 m (1.6 to 19 ft) below the ground surface. Groundwater within the study limits contains dissolved hydrogen sulphide gas. The gas is released when groundwater is exposed to atmospheric pressure. Strategies for groundwater control will be required for all methods of construction.

For additional information regarding existing soil and groundwater conditions, please refer to the *Preliminary Foundation Investigation and Design Report Bridge Approach Corridor, June 2007 by Golder Associates Ltd.*

FIGURE 2 – PROFILE OF SOIL CONDITIONS WITHIN ACA



3.3. Municipal Drains

Within the Highway 3 / Huron Church Road section of the ACA, there are multiple municipal drain crossings. All of the drainage systems within the ACA are part of the Turkey Creek watershed, which outlet to the Detroit River. All of the drainage systems have been impacted by urbanization. A plan showing the locations of municipal drain crossings is shown in Figure 3. Major Municipal Drains which will affect constructability include the Grand Marais Drain/Turkey Creek, Cahill Drain, Lennon Drain and Wolfe Drain.

Grand Marais Drain/Turkey Creek

Grand Marais Drain/Turkey Creek is the most significant watercourse in the study area, as it drains a large section of southwest Windsor. Grand Marais Drain/Turkey Creek has been significantly altered as a result of urbanization. Grand Marais Drain/Turkey Creek under the Huron Church Road Bridge has a trapezoidal concrete lined open channel with widths of 10 m at the bottom and 25 m at the top of the channel. The clearance to the bottom of the low flow channel under the Huron Church Road bridge is 6 m. There is a pedestrian pathway / bikeway located to the north side of the low flow channel. The pathway / bikeway is closed during storm events due to flooding. Warm water sport fish have been confirmed in this creek.

Cahill Drain

The Cahill Drain is the second largest drainage system that crosses the ACA. The Cahill drain and one tributary crosses the ACA south of Cabana Road, and outlets to the Grand Marais Drain / Turkey Creek. The Cahill Drain supports warmwater sport fish communities.

Lennon Drain

The Lennon Drain is a trapezoidal open channel which is located south of Cabana Road, and outlets into the Cahill Drain. The Lennon Drain supports warmwater sport fish communities.

Wolfe Drain

The Wolfe Drain runs parallel to Highway 3 on the east side of Highway 3 between Highway 401 and Cousineau Road. The Wolfe Drain is a trapezoidal open channel, with multiple bridges constructed over the drain to accommodate driveways to residential homes on the east side of Highway 3. The Wolfe Drain outlets to Cahill Drain and ultimately to Grand Marais Drain / Turkey Creek. The Wolfe Drain supports warmwater sport fish communities.

Other Municipal Drains

Other Municipal Drains within the ACA which are not expected to materially affect constructability but still receive runoff from the proposed freeway corridor include Titicombe Drain, Basin Drain, Marentette Mangin Drain, and McKee Drain.

For additional information regarding municipal drains within the ACA, please refer to *Stormwater Management Plan, Highway 401 from Ojibway Parkway to North Talbot Road City of Windsor, July 2007* by *URS Canada*.

FIGURE 3 – MUNICIPAL DRAINS

3.4. Utilities

There are numerous utilities located within the ACA. These include communications (Bell Canada and MaXess Networks), gas (Union Gas), hydro (Hydro One, Essex Power and EnWin) and Municipal (Storm Sewer, Sanitary Sewer, Watermain). Communications and hydro are predominantly overhead with some underground sections.

Major utilities crossing the Highway 3/Huron Church Road Corridor include:

- 600 mm watermain (100 m north of Howard Avenue);
- 250 mm watermain & 375 mm sanitary (300 m north of Cabana Road/Todd Lane);
- 375 mm sanitary (north side of Pulford Street);
- 300 mm sanitary (at Norfolk Street);
- 300 mm watermain, intermediate pressure pipe (natural gas), 300 mm and 225 mm sanitary (at Grand Marais Road West);
- 1050 mm storm sewer & 200 mm watermain (at Labelle Street); and
- 200 mm watermain (225 m north of Labelle Street).

A detailed listing of utilities within the Highway 3/Huron Church Road corridor is presented in **Appendix A.**

4. Practical Alternatives

Five access road alternatives including a freeway extension of Highway 401 to a new plaza and international bridge have been carried forward for evaluation. All alternatives follow the existing Highway 3 and Huron Church Road corridor, and run parallel (south) of E.C. Row Expressway to the plaza locations. Four plaza locations and three international bridge locations were also evaluated. The location of the connecting route alternatives, plazas and international bridge crossing is shown on the key map in **Figure 1**.

4.1. Access Road Alternatives

The proposed typical section for the Highway 401 extension is a six-lane freeway (3 lanes at 3.75m width in each direction), with a 6.8 m median. The median will include a tall wall concrete median barrier with 3.0 m shoulders. The outside shoulders will also be 3.0 m. Interchanges will be provided at Highway 3 and Huron Church Road (south of EC Row) for all alternatives. Depending on which access road alternative is selected, additional access will be provided at either St. Clair College or Todd Lane/Cabana Road. Access road alternatives which connect to either Plaza B or C will include an interchange at Ojibway Parkway. Plaza A cannot accommodate an interchange at Ojibway Parkway. Alternatives considered for the freeway include at-grade freeway, a below grade freeway and a tunnel.

Two configurations for service roads paralleling the new freeway are proposed. One configuration includes a one-way service road system on each side of the freeway. Each one-way service road includes two lanes at 3.5 m, a left shoulder width of 2.5 m and a right shoulder width of 3.0 m. Another configuration includes a four-lane service road (two lanes in each direction) from Howard to south of the E.C. Row Expressway. Under this configuration, the freeway will be constructed along side existing Highway 3 and Huron Church Road, leaving them virtually unchanged.

Access road geometrics were developed based on MTO design guidelines and consultation with design specialists, agencies and stakeholders. The following is a summary of the 5 access road alternatives:

Alternative 1A includes an at-grade freeway with below grade sections and one-way service roads on each side of the freeway. Interchanges are proposed at Highway 3, St. Clair College and Huron Church Road.

Alternative 1B includes a below grade freeway with one-way service roads on each side of the freeway. Interchanges are proposed at Highway 3, St. Clair College, and Huron Church Road.

Alternative 2A includes an at-grade freeway with below grade sections which is predominantly aligned west of the existing Highway 3 and Huron Church Road. This section of Highway 3 and Huron Church Road would function as a service road to the freeway. Interchanges are proposed at Howard Avenue, Todd Lane/Cabana and Huron Church Road.

Alternative 2B includes a below grade freeway which is predominantly aligned west of the existing Highway 3 and Huron Church Road. This section of Highway 3 and Huron Church Road would function as a service road to the freeway. Interchanges are proposed at Howard Avenue, Todd Lane/Cabana and Huron Church Road.

Alternative 3 is a cut and cover tunnelled freeway with service roads (Highway 3 and Huron Church) constructed on top of the tunnel box. Interchanges are proposed at Highway 3, St. Clair College and Huron Church Road.

Conceptual renderings of the Access Road Alternatives are presented in **Figure 4**. Typical Engineering cross-sections for each alternative are presented in **Appendix B.**

At-grade freeway Alternatives 1A and 2A include localized cross-sections which are below grade. The below grade cross-sections are primarily located at major crossing roads such as Howard Avenue, Cousineau Road/Sandwich Parkway, Cabana Road/Todd Lane and Spring Garden Road. These locations include the section between North Talbot Road to south of Howard Avenue, and from Spring Garden Road westerly to the international crossing. In addition, Alternative 3 (tunnel) includes localized below grade cross-sections which function as a transition between the at-grade and tunnel cross-sections.

4.2. Plaza Alternatives

Four locations for a new inspection plaza have been developed. Plaza A is located south of EC Row Expressway, east of Ojibway Parkway. Plazas B and B1 are located in the Brighton Beach Industrial Park between Broadway Street and McKee Street. Plaza C is located adjacent to the Detroit River, west of Sandwich Street and South of Prospect Avenue. All plaza locations are approximately 30-40 hectares (80 acres) in size, and have been designed to accommodate need to 2035 and beyond.

4.3. International Bridge Alternatives

Three locations for an international bridge crossing have also been developed. Bridge types investigated include Suspension and Cable Stay. Span arrangements which include piers in and out of the Detroit River have been considered. Details are being documented in a *Bridge Type Study Report (July, 2007)* prepared by URS and Parsons.

FIGURE 4 – ACCESS ROAD ALTERNATIVES

1A One-way service roads on either side of 6-lane freeway at grade.

1B One-way service roads either side of 6-lane freeway below-grade.

2A Six-lane freeway at grade, along side Huron Church/Highway 3.

2B Six-lane freeway below-grade, parallel to Huron Church/Highway 3.

3 Cut and cover tunnel below rebuilt Huron Church Road/Highway 3 Corridor.

5. Construction Methods

Additional property over and above what currently exists in the Highway 3/Huron Church Road Corridor will be required to accommodate construction of the Practical Access Road alternatives. Existing road allowances along Huron Church Road and Highway 3 range from 36 m to 55 m. The total road allowance required to construct the practical alternatives ranges from 80 m for a tunnel, to 90 m to 100 m for at grade or below grade alternatives.

The first phase of construction would focus on the relocation of utilities. There are numerous utilities located within the corridor, including Hydro, Bell, Union Gas and municipal utilities such as watermains, stormsewers and sanitary sewers. The next sequence of construction staging is dependent on which access road alternative is selected.

The Partnership is currently considering alternative methods of contracting to implement the new facility. These will range from conventional tendering through many variations that result in design-build construction.

5.1. At Grade Cross-Section (Alts. 1A and 2A)

At grade freeways will be constructed using conventional staging techniques implemented throughout the province. Following utility relocation, the next construction phase would focus on the construction of overpasses and underpasses, relocation of the existing roadway lanes as necessary, and any temporary staging. The final phase of construction would focus on completing the freeway itself.

The method of construction for Alternatives 1A and 2A is illustrated in **Appendix C**.

5.2. Below Grade Cross-Section (Alts. 1B and 2B)

The first sequence of below grade construction would focus on the construction of overpasses and underpasses, relocation of the existing roadway lanes as necessary, and any temporary staging. The following phase of construction would focus on completing the retaining walls and excavation for the below grade freeway.

There are three basic methods of constructing the below grade alternative:

Conventional (2:1 slopes). This alternative requires extensive excavation and backfill, and is not recommended where it would result in severe property impacts. This alternative will be considered in localized areas where vacant or surplus property is available and only if soil conditions permit.

Caisson Walls. This alternative utilizes drilling (auger) rigs to install caissons, which will form part of the retaining walls for the below grade cross-section. This alternative has reduced property requirements relative to the Conventional Method.

Diaphragm Wall. This method utilizes a trench cutter for installation of concrete walls using bentonite slurry to stabilize trench. This method can achieve higher production rates than caisson wall system, and also has reduced property requirements relative to the Conventional Method.

Once excavation has been completed and all required retaining walls are in place, the freeway itself will be constructed.

The method of construction for Alternatives 1B and 2B using a Diaphram Wall is illustrated in **Appendix C**.

5.3. Cut and Cover Tunnels (Alt. 3)

Cut and cover tunnels are constructed using excavation techniques and can include the initial construction of the side walls to minimize the overall width of the excavation. Although there is a high water table and generally poor soils, an assessment by the study team's geotechnical specialists has concluded that cut and cover tunnelling is a feasible construction method. Several cut and cover methods of construction are likely to be employed at various locations along the alignment. These include:

Conventional (2:1 slopes). This alternative requires extensive excavation and backfill, and is not generally being considered where it would result in severe property impacts. This alternative will be considered in areas where property is available.

Caisson Walls. This alternative utilizes drilling (auger) rigs to install caissons, which will form part of the tunnel walls. This alternative is typically constructed by the 'Bottom-Up' Method. Once the caissons are in place, the soil between the walls is excavated to a depth below the tunnel floor. The tunnel floor slab is poured, followed by the side walls of the tunnel, which are constructed from the 'bottom-up'. Once the tunnel walls have been completed, the roof of the tunnel is constructed, and the surface roadway on top of the tunnel is completed.

This method of construction has reduced property requirements relative to the Conventional Method. Caisson wall construction has been used as the primary method for similar projects in Ontario. It is noted that vibrations generated by the installation of caissons would need to be addressed, as there are numerous houses and businesses located in close proximity to the proposed construction zone.

Diaphragm Walls. This method utilizes a trench cutter for installation of concrete walls using bentonite slurry to stabilize the trench. Once the diaphragm walls are in place, the soil between the walls is excavated to a depth below the tunnel floor. The tunnel floor slab is poured. Once the tunnel walls have been completed, the roof of the tunnel is constructed, and the surface roadway on top of the tunnel is completed.

This method can achieve higher production rates than the caisson wall system, and also has reduced property requirements relative to the Conventional Method. The use of bentonite slurry is an environmental concern which would need to be addressed.

The method of construction for Alternative 3 using a Diaphram Wall is illustrated in **Appendix C**.

Mechanical ventilation of a long tunnel, such as the one being considered, is required to control air quality and visibility in the tunnel and at the portals. A mechanical ventilation system consisting of air flow ducts in the tunnel and one or more ventilation buildings with fans to force air in/out of the tunnel would be required. These ventilation systems would also be designed to control the direction of air flow and smoke in the case of an emergency. It is estimated that the ventilation building(s) would be about 18 m (59 ft) high (i.e. 4-5 storeys) plus the height of the stack. The total height including the stack could be up to 45 m (147 ft).

In addition to ventilation systems and buildings, numerous other safety features will need to be incorporated into the design of a tunnel. Some of the features unique to the tunnel design include emergency access between tunnels, emergency access and egress between the tunnel and the surface, ice prevention at portals and ramps, emergency telephone systems, containment of spills, flood prevention system, smoke detector, carbon monoxide and dioxide monitoring system, fire suppression systems, emergency power supply and storage for emergency supplies.

The cut and cover tunnel can be constructed in stages so that traffic can be maintained within the corridor throughout construction. Traffic staging is illustrated in Conceptual Construction Methods, **Appendix C**. Base stability conditions may require special construction techniques at deeper excavation depths, where the soils are poorest. Some surface settlement is anticipated adjacent to the excavation. The amount of settlement is dependent on both the total depth of excavation, and on the construction method used. Mitigation measures could be considered to reduce the risk of settlement during construction.

Integration of these systems will add to the time required to complete and/or increase effort/risks to complete the cut and cover tunnel alternative in the targeted timeframe.

6. Factors Influencing Constructability

6.1. Existing Traffic

Highway 3 / Huron Church Road provides primary access of local and international passenger and commercial traffic to and from the terminus of Highway 401 to the Ambassador Bridge. The Highway 3 / Huron Church Road corridor also provides movements for local and regional traffic through the City of Windsor and the Town of LaSalle. Construction staging for the new access road will include a requirement to maintain existing traffic on the Highway 3 and Huron Church Road corridors during construction. Four lanes of traffic will be maintained along Highway 3, and a minimum of four lanes of traffic will be maintained along Huron Church Road during construction. Access to and from all major crossing roads, commercial and residential entrances will be maintained during construction as required. Construction staging will need to be implemented to ensure safe and efficient construction operations as well as to minimize community impacts during construction.

For each Practical Alternative, the access road is comprised of a freeway section (the Highway 401 extension) and the future service roads (Highway 3 / Huron Church Road) and interchange ramps between the freeway and service road. The following sections present a typical sequence of construction for this type of infrastructure project. Detailed staging plans will be fully developed as part of the final design of the project.

A set of conceptual construction staging cross-sections for Alternatives 1A, 1B, 2A, 2B and 3 is presented in **Appendix D**.

6.2. Construction Staging

6.2.1. Practical Alternatives 1A and 1B (at-grade or below grade with one way service roads)

The first phase of construction will focus on the relocation of utilities and other municipal services. There are numerous utilities located within the corridor, including Hydro, Bell, Union Gas, cable television as well as municipal services such as watermains, storm sewers, municipal drains and sanitary sewers.

The next construction phase would focus on building the future service roads, the realignment of the existing municipal roadways (where necessary), construction of bridges and the construction of any temporary staging roads. During this phase, traffic will remain primarily on the existing Highway 3 / Huron Church Road with some routing onto localized temporary staging roads within the corridor.

The final phases of construction would focus on completing the new freeway itself. At-grade sections can be constructed using conventional freeway construction methods typically used on 400-series highways throughout the province. Below grade sections will be constructed by using excavation techniques suitable for urban areas. A variety of methods can be employed to minimize the overall property requirements of the project. During the final phases, traffic will be relocated onto the newly constructed service roads with some routing onto localized temporary staging roads within the corridor.

6.2.2. Alternatives 2A and 2B (at-grade or below grade with parallel service road)

The construction staging sequence and methods for these Practical Alternatives are similar to those for practical alternatives 1A and 1B. However, the alignment for Practical Alternatives 2A and 2B is, for the most part, beside the existing roadway so there will be less utility relocation and realignment of roadways required to construct these alternatives. During construction, traffic will remain primarily on the existing Highway 3 / Huron Church Road with some routing onto localized temporary staging roads within the corridor.

6.2.3. Alternative 3 (tunnel)

The first phase of construction will focus on the relocation of utilities and other municipal services. There are numerous utilities located within the corridor, including hydro, Bell, Union Gas, cable television as well as municipal services such as watermains, storm sewers, municipal drains and sanitary sewers.

The tunnel box itself would be constructed in two stages. In each stage, the first sequence of tunnel construction would focus on the realignment of the existing roadways (such as Highway 3/Huron Church Road) and temporary staging roads. During this phase traffic will remain primarily on the existing Highway 3/ Huron Church Road with some routing onto localized temporary staging roads within the corridor. The next phase of construction would focus on the construction of the tunnel structure itself using the cut and cover tunnel method. During this phase, traffic will be routed primarily onto temporary staging roads.

Once construction of the tunnel structure is in place, remaining features such as ventilation systems, pumping stations, power systems will be constructed, and the surface road network will be completed.

6.3. Soil Conditions

The construction of below grade cross-sections and cut and cover tunnels should be feasible up to a depth of 10m without undertaking additional measures to stabilize the excavation. It is noted that the construction of a tunnel section below existing Grand Marais Drain/Turkey Creek would require an excavation depth of approximately 15m below existing ground. This would require either temporary ground improvement measures or other temporary wall and base stability enhancements during construction. Additional stability enhancement measures may be required in this area. For additional information regarding soil conditions, refer to *Foundation Investigation and Design Report Detroit River International Crossing Bridge Approach Corridor*, *April 2007 by Golder Associates Ltd.*

6.4. Watercourse Crossings and Storm Water Management Plan

6.4.1. Grand Marais Drain / Turkey Creek

At-grade access road Alternatives 1A and 2A would require the construction of new bridges over Grand Marais Drain / Turkey Creek. Sketches illustrating the new bridges are presented in **Sketch 1** and **Sketch 3** in **Appendix E**. Below grade Alternatives 1B and 2B could be constructed by either creating a short tunnel section under Grand Marais Drain / Turkey Creek, or by lowering the freeway 2 to 3 m below existing grades over Grand Marais Drain / Turkey Creek.

Tunnel Under Grand Marais Drain / Turkey Creek

Alternative 1B

The short tunnel section under Grand Marais Drain / Turkey Creek in Alternative 1B can be constructed by lowering the profile so that the tunnel is constructed under the existing creek using the cut and cover method. A sketch illustrating the tunnel concept under Grand Marais Drain / Turkey Creek is presented as **Sketch 2** in **Appendix E**.

The tunnel cross-section could be constructed under the following stages:

Stage 1 – Construct a temporary 6-lane detour bridge across Grand Marais Drain / Turkey Creek on the north side. Divert Huron Church Road to cross Grand Marais Drain / Turkey Creek over the temporary bridge. Remove the existing Huron Church Road bridge over Grand Marais Drain / Turkey Creek.

Stage 2 - Close the east half of the Grand Marais Drain / Turkey Creek channel by constructing a temporary bulkhead at the location of the proposed tunnel, and divert the flow of water through the west half of the Grand Marais Drain / Turkey Creek channel.

Stage 3 - Construct the eastern section of the tunnel box section by cut and cover method and temporary supports of excavations.

Stage 4 – Construct the Grand Marais Drain / Turkey Creek channel for the east half width and divert flow of the water through the east half width of the channel. Close the west half of the width of the Grand Marais Drain / Turkey Creek channel by temporary bulkhead at the location of the proposed freeway tunnel.

Stage 5 - Construct the western section of the tunnel box section by cut and cover method and temporary supports.

Stage 6 - Construct the west half of the Grand Marais Drain / Turkey Creek channel. Remove the temporary bulkhead and connect the eastern and western portions of the tunnel at the temporary bulkhead. Divert the flow of water through the full width of the Grand Marais Drain / Turkey Creek channel.

Stage 7 - Construct the new westbound and eastbound Huron Church Road bridge over Grand Marais Drain / Turkey Creek on the north and south sides respectively of the completed tunnel. Remove the temporary detour bridge over Grand Marais Drain / Turkey Creek.

Alternative 2B

The short tunnel section in Alternative 2B can be constructed in a similar sequence as identified above for Alternative 1B. The existing Huron Church bridge over Grand Marais Drain / Turkey Creek will be maintained during and after construction. No new bridges over Grand Marais Drain / Turkey Creek are required as part of Alternative 2B. The tunnel cross-section could be constructed following Stages 2 to 6 as presented under Alternative 3. A sketch illustrating the tunnel concept under Grand Marais Drain / Turkey Creek is presented as **Sketch 4** in **Appendix E**.

Alternative 3

The short tunnel section under Grand Marais Drain / Turkey Creek in Alternative 3 can be constructed in a similar sequence as identified above for Alternative 1B. Alternative 3 will require the construction of a temporary 6-lane detour bridge across Grand Marais Drain / Turkey Creek on the north side. Concrete caisson foundations to support the abutments of the new service roads over Grand Marais Drain / Turkey Creek will be staged with construction of the tunnel. A sketch illustrating the tunnel concept under Grand Marais Drain / Turkey Creek is presented as **Sketch 6** in **Appendix E**.

The tunnel cross-section could be constructed under the following stages:

Stage 1 – Construct a temporary 6-lane detour bridge across Grand Marais Drain / Turkey Creek on the north side. Divert Huron Church Road to cross Grand Marais Drain / Turkey Creek over the temporary bridge. Remove the existing Huron Church Road bridge over Grand Marais Drain / Turkey Creek.

Stage 2 – Close the east half of the Grand Marais Drain / Turkey Creek channel by constructing a temporary bulkhead at the location of the proposed tunnel, and divert the flow of water through the west half of the Grand Marais Drain / Turkey Creek channel. Construct concrete caisson foundations to support the east abutments of the new westbound and eastbound service roads over Grand Marais Drain / Turkey Creek.

Stage 3 – Construct the eastern section of the tunnel box section by cut and cover method and temporary supports of excavations.

Stage 4 – Construct the Grand Marais Drain / Turkey Creek channel for the east half width and divert flow of the water through the east half width of the channel. Close the west half of the width of the Grand Marais Drain / Turkey Creek channel by temporary bulkhead at the location of the proposed freeway tunnel. Construct concrete caisson foundations to support the west abutments of the new westbound and eastbound service roads over Grand Marais Drain / Turkey Creek.

Stage 5 – Construct the western section of the tunnel box section by cut and cover method and temporary supports.

Stage 6 – Construct the west half of the Grand Marais Drain / Turkey Creek channel. Remove the temporary bulkhead and connect the eastern and western portions of the tunnel at the temporary bulkhead. Divert the flow of water through the full width of the Grand Marais Drain / Turkey Creek channel.

Stage 7 – Construct the new superstructure and the abutments of the westbound and eastbound Service Road bridges over Grand Marais Drain / Turkey Creek. Remove the temporary detour bridge over Grand Marais Drain / Turkey Creek.

Below Grade Freeway Over Grand Marais Drain / Turkey Creek

Transport Canada has indicated that the Grand Marais Drain/Turkey Creek is classified as "not navigable". Therefore, construction of a below grade freeway over Grand Marais Drain / Turkey Creek can be achieved by replacing the existing bridge with a triple cell concrete culvert. Each cell would be 10 m in width, 2 m in height. This will permit a lowering of the freeway by approximately 2-3 m relative to the adjacent existing ground level. The triple cell concrete culvert can be incorporated into Alternatives 1B or 2B. A sketch illustrating this concept is presented as **Sketch 5** in **Appendix E**.

The tunnel cross-section could be constructed under the following stages:

Stage 1 - Close the east half of the Grand Marais Drain / Turkey Creek channel by constructing a temporary bulkhead and divert the flow of water through the west half of the Grand Marais Drain / Turkey Creek channel.

Stage 2 - Construct base and walls of the eastern section of the Grand Marais Drain / Turkey Creek three cell box culvert.

Stage 3 – Divert the flow of water through the completed eastern section of the box culvert, and close the west half of the Grand Mariais / Turkey Creek box culvert channel by temporary bulkhead. Construct the base and walls of the west half of the box culvert. Construct the top slab of the western most cell.

Stage 4 – Remove the temporary bulkhead and divert the flow of water through the east and west cells, and construct the top slab of the centre cell.

Stage 5 – Divert the flow of water through the west and centre cells, and construct the top slab of the east cell.

Stage 6 – Construct the freeway over the completed three cells.

Hydraulic Considerations During Construction

For both tunnel and culvert alternatives, a low flow channel for Grand Marais Drain / Turkey Creek will be provided during each stage of construction. For the tunnel alternative, the existing sideslope of Grand Marais Drain / Turkey Creek will be steepened to maximize capacity of the Creek. Additional hydraulic analysis will be undertaken to confirm if the resulting cross-sections during construction can accommodate the required design year storm event. A risk analysis will be undertaken if the required storm event cannot be provided during all stages of construction.

6.4.2. Municipal Drains

Cahill Drain, Lennon Drain

Construction of a below grade freeway over the Cahill Drain or Lennon Drain can be achieved by replacing the existing culverts by an inverted syphon. The inverted syphon would be 25 m in width, and approximately 2 m in height. The inverted syphon would permit a lowering of the freeway by approximately 2-3 m. A sketch illustrating a siphon concept is presented in **Appendix E**.

Constraints encountered in the design of solutions to accommodate an inverted syphon or culvert include the ability to accommodate fisheries.

Wolfe Drain

Alternatives for the Wolfe Drain are dependent on which connecting route cross-section and alignment is selected. Alternatives include maintaining the existing drain cross-section and alignment, or relocating the drain as an open channel.

All municipal drain drainage concepts identified above are feasible. Additional consultation with Agencies will be required to determine impacts to fisheries and associated compensation requirements. Additional analysis will be required to confirm sizes of realigned and/or combined drains, culverts and syphons. Additional hydraulic analysis will be required to confirm flow velocities resulting from the proposed drainage systems, and sedimentation (particularly with syphon alternative).

6.4.3. Storm Water Management Plan

The proposed stormwater management strategy developed for Alternatives 1A, 1B, 2A, 2B and 3 consists of utilizing oil/grit separators and stormwater management facilities consisting of wet ponds to provide quality and quantity control. Due to the terrain and the use of below grade cross-sections, pumping stations will be required in order to maintain drainage to the existing natural features.

For additional information regarding watercourse crossings and stormwater management plan, please consult the *Stormwater Management Plan, Highway 401 from Ojibway Parkway to North Talbot Road City of Windsor, November 22, 2006* by *URS Canada.*

6.5. Utilities

As identified in Section 2.4, there are 5 watermain, 5 sanitary, 1 storm sewer and 1 gas crossing the Highway 3/Huron Church Road corridor within the ACA. Utility crossings will need special consideration for below grade and tunnel alternatives. During construction, temporary supports for utilities may be required. For below grade cross-sections, utilities crossing the corridor could be strapped to overpasses, or could be provided in separate structures. It is noted that MTO policy does not allow utilities such as sanitary sewer, water mains and gas mains to be strapped to structures. If these types of solutions are not considered acceptable for any given utility crossing, additional work would be required to bury utilities under the below grade or tunnel cross-sections. Therefore, the degree of utility impacts is more for Alternatives 1B, 2B and 3.

For Alternatives 2A and 2B, most of the existing utilities which run parallel to Highway 3 / Huron Church Road can be retained since most of the existing road will be maintained in the current location. This will result in a slightly lower degree of utility impacts for Alternatives 2A and 2B.

6.6. Construction Resources and Duration

The mandate of this project is to have the entire facility constructed and operational by the end of 2013. Each practical alternative will require a different level of complexity and effort to construct within the targeted timeframe. The below grade and tunnel alternatives require significantly more complex construction than the at-grade alternatives. These alternatives, particularly the tunnel, will require a more intense construction period than the at-grade alternatives. The overall schedule will depend on equipment, labour and materials availability, and further details of staging which will be determined in later phases of design. Municipal noise by-law exemptions may be sought to facilitate more rapid construction.

For comparison purposes, URS has completed a preliminary 'order of magnitude' estimate of resource requirements for constructing a 6 km section of the access road alternatives from south of Howard Avenue to east of Malden Road. The overall construction schedules assume time for all civil works including roads, bridges, retaining walls and tunnels, as well as mechanical and electrical systems, and testing and commissioning. The timeline for utility relocation is not included in the construction duration. Utility relocation will require approximately **1 year** to complete in addition to the timelines specified below.

At Grade Cross-section

The at-grade cross-section (Alternatives 1A and 2A) can be constructed in approximately **3 years**. A typical 10-hour day shift during peak production periods would include the following resources:

- 14 Drill rigs;
- 16 Excavator CAT320 (front end loader/dozers);
- 20 Cranes (50 ton); and
- 60 Tri-axle trucks (20 Ton), 600 truck trips per day.

Below grade Cross-Section

The below grade cross-section (Alternatives 1B and 2B) would require **3.5 years** of construction. The method of construction assumed in our estimate is a Caisson Wall System (bottom-up construction). A typical 10-hour day shift during peak production periods would require the following resources:

- 36 Caisson drilling rigs (30 rigs for mainline, 6 for ramps);
- 10 Excavator CAT320 (front end loader/dozers);
- 10 Cranes (50 ton); and
- 50 Tri-axle trucks (20 Ton), 500 truck trips per day.

Tunnel Cross-Section

The tunnel cross-section (Alternative 3) would require between **4 and 4.7 years** of construction, depending on the construction method used. The construction timeline includes time to test and implement mechanical, ventilation and communications systems. Two estimates were completed, one assuming a Caisson Wall System and the other, a Diaphragm Wall System. A typical 10-hour day shift during peak production periods using a Caisson Wall System would require the following resources:

- 51 caisson drilling rigs (45 rigs for mainline, 6 for ramps);
- 30 Excavator CAT320 (front end loader/dozers);
- 15 Cranes (50 ton); and
- 120 Tri-axle trucks (20 Ton), 1200 truck trips per day.

A typical 10-hour day shift during peak production periods using a Diaphragm Wall System would require the following resources:

- 10 Trench Cutter Rigs (6 rigs for mainline, 4 for ramps);
- 25 Excavator CAT320 (front end loader/dozers);
- 15 Cranes (50 ton); and
- 110 Tri-axle trucks (20 Ton), 1100 truck trips per day.

Additional details regarding construction timelines and resources for at-grade, below grade and tunnel alternatives are presented in **Appendix F.**

Construction of the plaza (1.5 years) and international bridge (3.5 to 4.5 years) would be completed in parallel to the access road to meet the 2013 completion target.

We note that construction timelines are highly dependent on availability of resources (man power, equipment and materials). Higher construction complexity and resource requirements for constructing the tunnel results in a high risk that the tunnel will not be completed within the 2013 timeframe. Moderate to high resource requirements for at grade and below grade alternatives result in a moderate to high risk that the non-tunnel alternatives can be completed within the 2013 time frame.

7. Evaluation of Alternatives

Cost and Constructability is one of seven factors used to evaluate the practical access road alternatives. A summary of the assessment of constructability is presented in **Figure 5.** The construction costs included in this table were obtained from the '*Preliminary Construction Cost Estimate Report for Practical Alternatives (Access Road and Inspection Plaza)*' prepared by *URS Canada, August 2007*.

Construction staging and constructability reviews completed to date confirm that all alternatives are constructible. All alternatives can be constructed while maintaining 4-6 lanes for existing traffic within the corridor. Access to and from all major crossing roads and entrances can be maintained during construction. All alternatives will require a similar degree of utility relocation (approx. 1 year duration) prior to construction.

Soil conditions are not conducive to deep excavations. Complex staging including stability enhancement measures may be required during construction of excavations (for tunnel and below grade sections), particularly where excavations are deeper than 10 m, such as would be required for constructing a tunnel under Grand Marais Drain / Turkey Creek.

Construction of the tunnel would require significantly more materials for both civil components including concrete and aggregates, and safety support systems such as ventilation, lighting, CCTV and traffic control centre, when compared with non-tunnel alternatives. The additional materials would require significantly more resources (construction equipment, movement of materials and manpower). This, in turn, will require a longer duration to construct (4 to 4.7 years).

Extensive retaining wall systems are required for both at grade and below grade alternatives, with approximately 12 km of retaining walls required for the below grade alternatives. This results in moderate to high resource requirements for both non-tunnel alternatives.

The below-grade and tunnel alternatives pose the greatest risk to projected cost and schedule (with the tunnel posing the greatest risk) as they require significantly more complex construction than at-grade alternatives. These alternatives, particularly the tunnel, require a more intense construction period than the at-grade alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.

FIGURE 5 – PRELIMINARY ANALYSIS OF PRACTICAL ACCESS ROAD ALTERNATIVES

PRACTICAL ALTERNATIVE EVALUATION	Factor: Cost & Constructability

Performance Measure	Criteria/Indicator	Measurement/Units	Alternative 1A		Alternative 1B		Alternative 2A		Alternative 2B		Alternative 3
			Option 1	Option 2	Option 1	Option 2	Option 1	Option 2	Option 1	Option 2	
Preliminary Construction Costs, Assessment of Constructability	Length of Alternative (Hwy 401 to Malden)	Kilometres	9		9		9		9		9
	Preliminary Construction Costs (property costs not included)	$ millions CAD (2011)	920.0 (Plaza A) 750.0 (Plaza B and C)		1.360 (Plaza A) 1.190 (Plaza B and C)		790.0 (Plaza A) 620.0 (Plaza B and C)		1.200 (Plaza A) 1.030 (Plaza B and C)		3.780 (Plaza A) 3.610 (Plaza B and C)
	Life Cycle Cost	Qualitative	The life cycle cost for Alternative 1A is approximately 14% higher than Alternative 2A.		The life cycle cost for Alternative 1B is approximately 58% higher than Alternative 2A.		Alternative 2A has the lowest life cycle cost.		The life cycle cost for Alternative 2B is approximately 41% higher than Alternative 2A.		The life cycle cost for Alternative 3 is approximately 306% (i.e.three times) higher than Alternative 2A. This is primarily due to higher maintenance costs associated with safety support systems.
	Site constraints (eg. utilities, watercourse crossings)	Qualitiative	All alternatives will require a similar degree of utility relocation prior to construction. Watercourses can be crossed by constructing a bridge at Grand Marais Drain / Turkey Creek, and culverts at Cahill and Lennon drains. 4 Pumping Stations & 10 SWM Ponds required		All alternatives will require a similar degree of utility relocation prior to construction. Relocation of utilities for below grade alternatives such as Alternative 1B may be slightly more complex as additional excavation may be required. Watercourses will be crossed by constructing a short tunnel section under Grand Marais Drain/Turkey Creek and syphons at Cahill and Lennon drain. 5 Pumping Stations & 8 SWM Ponds required		All alternatives will require a similar degree of utility relocation prior to construction. Alternative 2A will have a slightly less impact on utilities since some utilities parallel to Highway 3/Huron Church Road can be retained, since most of the existing road will be maintained at the current location. Watercourses can be crossed by constructing a small bridge at Grand Marais Drain/Turkey Creek, and culverts at Cahill and Lennon drains. 4 Pumping Stations & 8 SWM Ponds required		All alternatives will require a similar degree of utility relocation prior to construction. Alternative 2B will have a slightly less impact on utilities since some utilities parallel to Highway 3/Huron Church Road can be retained, since most of the existing road will be maintained at the current location. However, relocation of utilities for below grade roadways may be slightly more complex as additional excavation may be required. Watercourses will be crossed by constructing a short tunnel section under Grand Marais Drain/Turkey Creek, and syphons at Cahill and Lennon drains. 5 Pumping Stations & 7 SWM Ponds required		All alternatives will require a similar degree of utility relocation prior to construction. Relocation of utilities for below grade alternatives such as Alternative 3 may be slightly more complex as additional excavation may be required. Watercourses will be crossed by constructing a tunnel under Grand Marais Drain/Turkey Creek, Cahill and Lennon drain. 4 Pumping Stations & 3 SWM Ponds required
	Geotechnical considerations	Qualitative and quantitative assessment of subsurface conditions	Due to the depth of excavation at certain locations, special construction measures are required for an approx. 250 m section to enhance stability of soils.		Due to the depth of excavation at certain locations, special construction measures are required at 4 areas totalling approx. 3600 m to enhance stability of soils.		Due to the depth of excavation at certain locations, special construction measures are required for an approx. 250 m section to enhance stability of soils.		Due to the depth of excavation at certain locations, special construction measures are required at 4 areas totalling approx. 3600 m to enhance stability of soils.		Due to the depth of excavation for tunnel alternative, special construction measures are required for entire section between Highway 3 and Malden Road (approx. 7500 m) to enhance stability of soils.
		Lengths of above grade, at grade, depressed and tunnel sections	0.6 km above grade, 3.8 km at grade, 4.6 km below grade, 0 km tunnel.		0.6 km above grade, 1.5 km at grade, 6.8 km below grade, 0.1 km tunnel.		0.6 km above grade, 4.1 km at grade, 4.3 km below grade, 0 km tunnel.		0.6 km above grade, 1.3 km at grade, 7.0 km below grade, 0.1 km tunnel.		0.6 km above grade, 1.9 km at grade, 0.5 km below grade, 6.0 km tunnel.
	Construction staging/duration	Qualitative assessment of construction duration for access road	The at-grade alternatives pose a smaller risk to schedule relative to below-grade and tunnel alternatives as they require less complex construction. These alternatives will require a less intense construction period than the below-grade or tunnel alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.		The below-grade and tunnel alternatives pose the greatest risk to schedule (with the tunnel posing the greatest risk) as they require significantly more complex construction than the at-grade alternatives. These alternatives, particularly the tunnel, will require a more intense construction period than the at-grade alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.		The at-grade alternatives pose a smaller risk to schedule relative to below-grade and tunnel alternatives as they require less complex construction. These alternatives will require a less intense construction period than the below-grade or tunnel alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.		The below-grade and tunnel alternatives pose the greatest risk to schedule (with the tunnel posing the greatest risk) as they require significantly more complex construction than the at-grade alternatives. These alternatives, particularly the tunnel, will require a more intense construction period than the at-grade alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.		The below-grade and tunnel alternatives pose the greatest risk to schedule (with the tunnel posing the greatest risk) as they require significantly more complex construction than the at-grade alternatives. These alternatives, particularly the tunnel, will require a more intense construction period than the at-grade alternatives. The overall schedule depends on equipment and labour availability, and further details of staging which would be determined in later phases of design.
	Assessment of construction risks	Qualitative assessment of effects of traffic management, utility relocations, subsurface conditions on completion of construction within project timeframe (2013)	Construction duration and costs will be highly influenced by property acquisition, utility relocation, availability of adequate resources (labour, equipment and materials) for duration of project, as well as soil stability and risks associated with deep excavations (250 m).		Construction duration and costs will be highly influenced by property acquisition, utility relocation, availability of adequate resources (labour, equipment and materials) for duration of project, as well as soil stability and risks associated with deep excavations (3600 m). The risks associated with utility relocation, resources and exavation are greater with below grade alternatives than at grade alternatives.		Construction duration and costs will be highly influenced by property acquisition, utility relocation, availability of adequate resources (labour, equipment and materials) for duration of project, as well as soil stability and risks associated with deep excavations (250 m).		Construction duration and costs will be highly influenced by property acquisition, utility relocation, availability of adequate resources (labour, equipment and materials) for duration of project, as well as soil stability and risks associated with deep excavations (3600 m). The risks associated with utility relocation, resources and exavation are greater with below grade alternatives than at grade alternatives.		Construction duration and costs will be highly influenced by property acquisition, utility relocation and availability of adequate resources (labour, equipment and materials) for the duration of project, as well as soil stability and risks associated with deep excavations (7200 m). The risks associated with utility relocation, resources and exavation are greatest with tunnel alternative in comparison to at grade and below grade alternatives.
	Degree of impact on traffic during construction	Qualitative and quantitative assessment of ability to maintain access to existing crossings during construction	Access to and from existing crossing and local road network can be maintained during construction.				Access to and from existing crossing and local road network can be maintained during construction. Generally less disruption to Huron Church/Highway 3 traffic compared to other alternatives as new access road is built beside the existing roadway.				Access to and from existing crossing and local road network can be maintained during construction.
	Maintenance requirements	Qualitative assessment of costs and disruption due to maintenance operations	Yearly operation and maintenance requirements for at grade alternatives are lower than below grade and tunnel alternatives. Pumping stations require routine maintenance measures and monitoring to provide debris trapping removal and sediments handling and removal. Typical features for monitoring include: high water in the wet well, number of starts for each motor, leakage, sediments level, motor/engine failure, smoke, gases, etc.		Additional annual maintenance is required compared to at grade alternatives for syphons under Cahill and Lennon drains, but yearly operation and maintenance requirements for below grade alternatives are lower than tunnel alternative. Pumping stations require routine maintenance measures and monitoring to provide debris trapping removal and sediments handling and removal. Typical features for monitoring include: high water in the wet well, number of starts for each motor, leakage, sediments level, motor/engine failure, smoke, gases, etc.		Yearly operation and maintenance requirements for at grade alternatives are lower than below grade and tunnel alternatives. Pumping stations require routine maintenance measures and monitoring to provide debris trapping removal and sediments handling and removal. Typical features for monitoring include: high water in the wet well, number of starts for each motor, leakage, sediments level, motor/engine failure, smoke, gases, etc.		Additional annual maintenance is required compared to at grade alternatives for syphons under Cahill and Lennon drains, but yearly operation and maintenance requirements for below grade alternatives are lower than tunnel alternative. Pumping stations require routine maintenance measures and monitoring to provide debris trapping removal and sediments handling and removal. Typical features for monitoring include: high water in the wet well, number of starts for each motor, leakage, sediments level, motor/engine failure, smoke, gases, etc.		Yearly operation and maintenance requirements for the tunnel associated with watercourse siphons and safety support systems (ventilation, lighting, CCTV) are higher than at grade and below grade alternatives. Pumping stations require routine maintenance measures and monitoring to provide debris trapping removal and sediments handling and removal. Typical features for monitoring include: high water in the wet well, number of starts for each motor, leakage, sediments level, motor/engine failure, smoke, gases, etc.

Appendix A
Existing Utilities

Appendix B
Typical Cross-Sections

Appendix C
Conceptual Construction Methods

Appendix D

Conceptual Construction Staging Cross-Sections

Appendix E

Concepts at Municipal Drain Crossings

Appendix F

Construction Duration and Resource Requirements