UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING
Department of Civil and Environmental Engineering

High iQ Consulting Consultants

# BURYING THE GARDINER

## Gardiner Expressway Replacement Tunnel


GEOE 401 – HIQCC (Team #G5)
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## Background

The Gardiner Expressway is an 18-km major access route in Toronto, ON that connects users all over the GTA. In 1965, the expressway was constructed adjacent to Lake Ontario. Cutting across downtown core, a considerable length of the highway is an elevated section on waterfront property. However in recent years, maintenance to the road have been more frequent and extensive, causing them to become unfeasible (City of Toronto, 2019).

Gardiner Expressway maintenance → becoming unfeasible

*(Richard Eriksson, 2005)*    *(The Toronto Star, 2012)*

## Problems

### Deteriorating Roadway

The Gardiner Expressway is coming to the end of its lifespan; it's not economically feasible to maintain.

### Waterfront Property

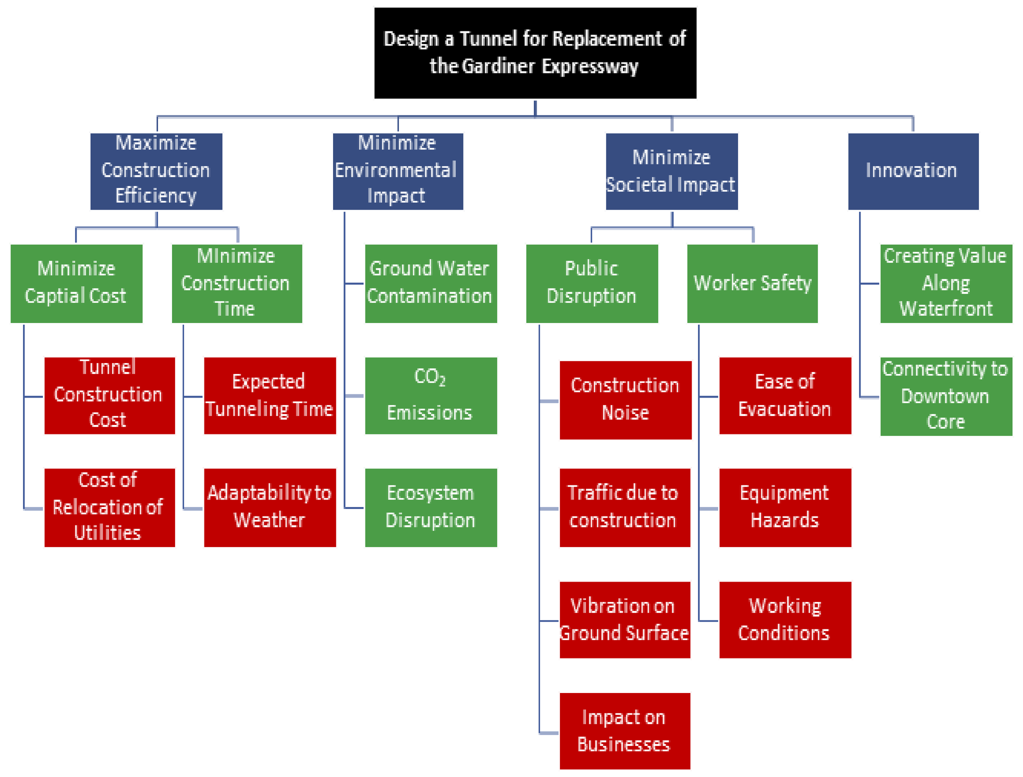
The Gardiner's elevated section is a raised obstruction and occupies valuable waterfront property.

### Innovative Design

A roadway concept needs to replace the Gardiner yet improve on its design, utility, and usage of space.

## Solution

Underground Highway Tunnel Bypassing and Providing Access to Downtown Toronto




**Design criteria used to select a project alternative**

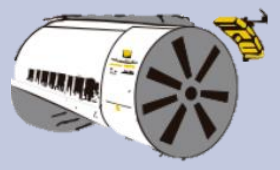
## Project Alternatives

Design alternatives for this project are a combination of three tunneling methods and three potential tunnel alignments. A total of 9 alternatives were considered.

### Tunneling Methods


Cut and Cover

Drill and Blast


Tunnel Boring Machine (TBM)

### Alignments


## Selected Alternative

### TBM + Alignment A (on Queen St)

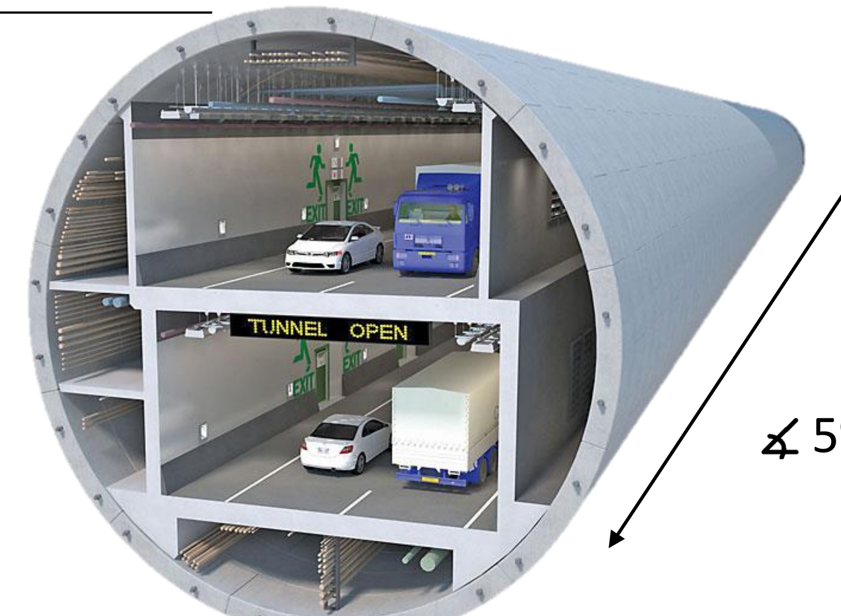
The alternative incorporating the TBM methodology and Alignment A (segment on Queen St) was found to be the optimal design choice as it yielded the highest average score in design criteria selection .


**Finalized Alignment**

## Tunnel Geometry and Specifications

### Dimensions

Twin tunnels are required and sized appropriately to allow for 4 lanes of traffic in each direction and 5% downward slope; adequate for 100km/hr speed limits. (Transport Association of Canada, 2017)




Ø 18m circular diameter

Max depth at 35m

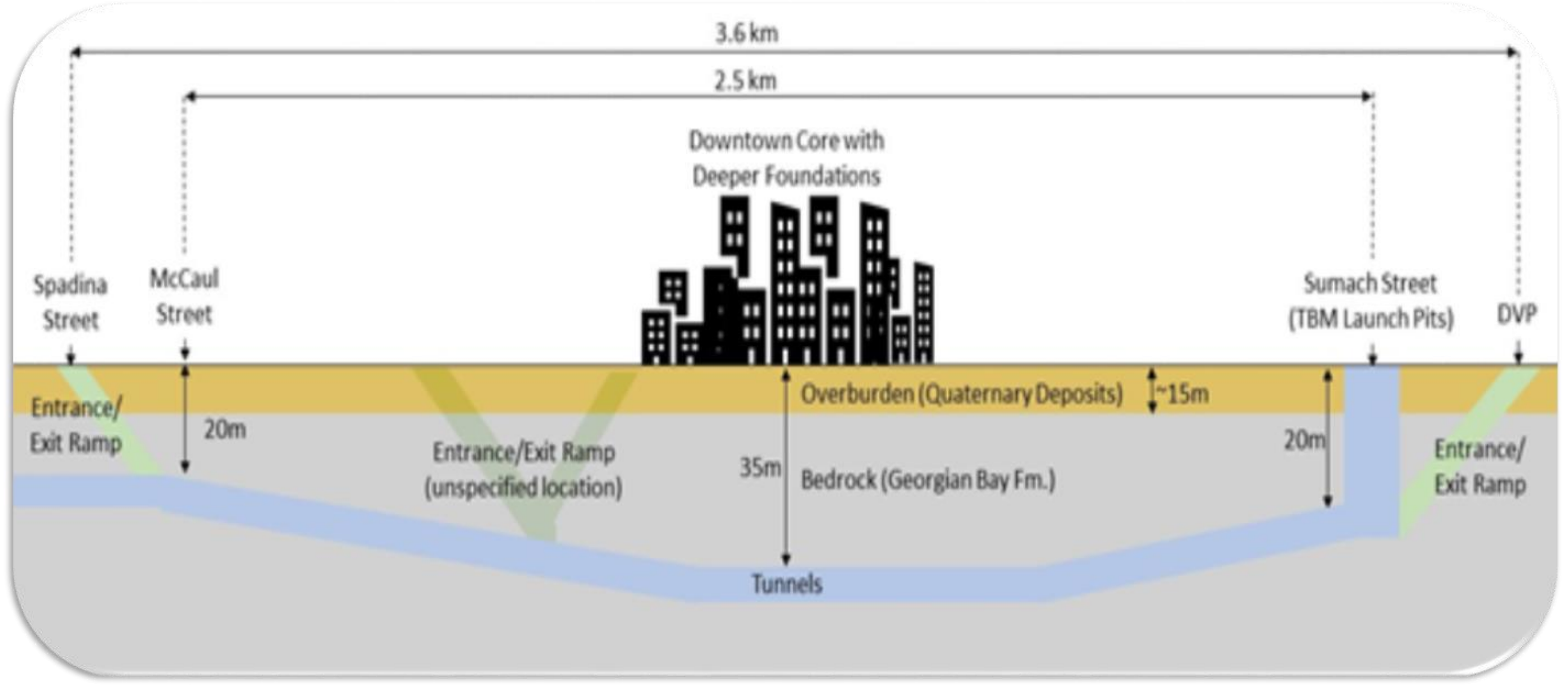
Total length of 11,300m

5% slope on the ramp

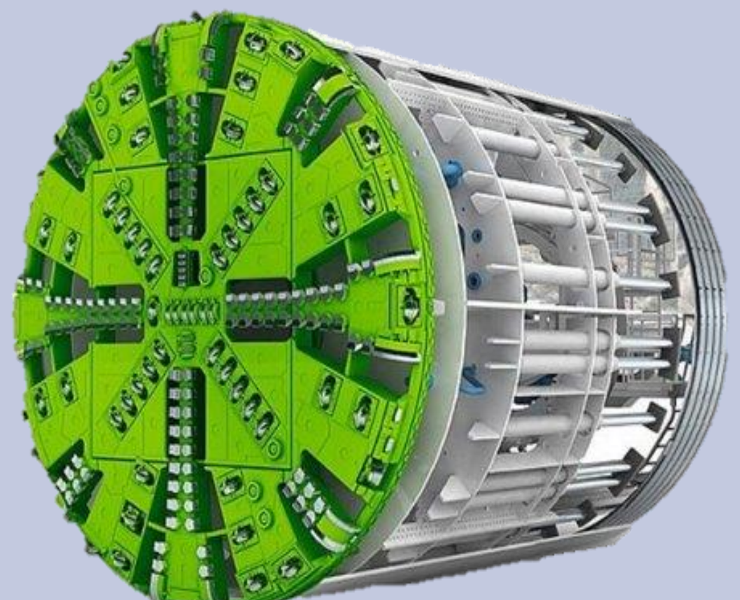
*(WSDOT, 2018)*

### First section of alignment to be designed on Queen Street

The TBM will drill from a depth of 20m below grade at the proposed launch pits to 35m, avoiding underground obstructions along the alignment.




## TBM Type



*(Herrenknecht, 2020)*

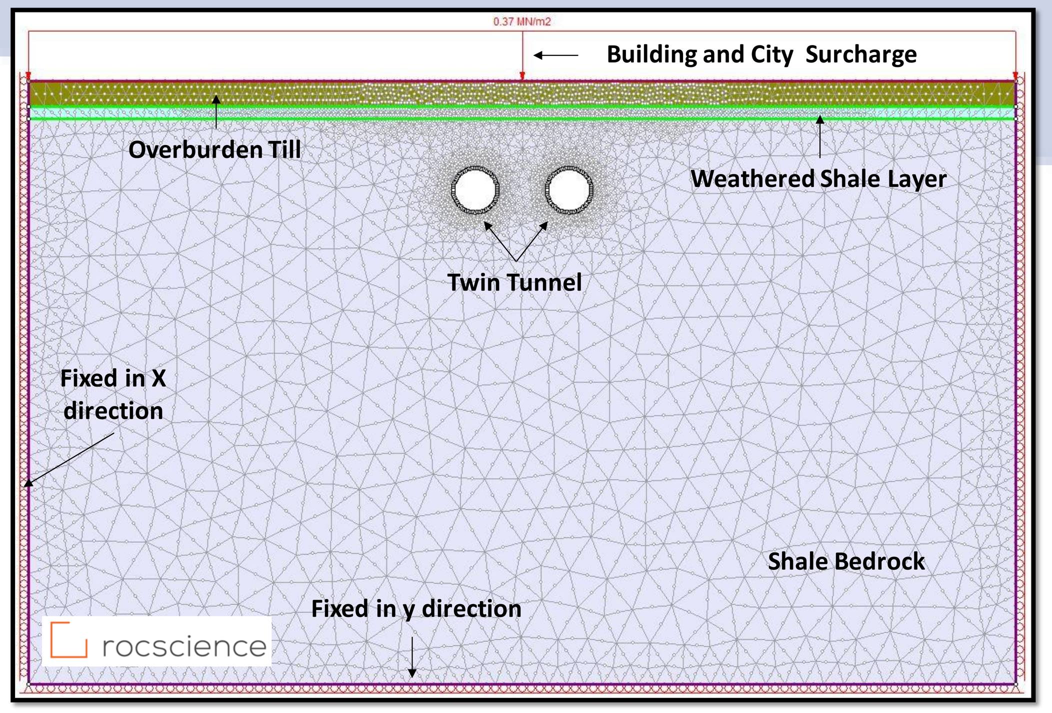
### Mix-shield/Crossover

Hybrid technology allows advancement within Toronto's specific geological conditions and pore pressures. Also feasible to be manufactured for specified tunnel size. (Herrenknecht, 2020)

### Geological Conditions

- 15m overburden till
- 5m weathered shale (soft sediments)
- Thin interbedded limestone (hard rock)
- High water table

## Geotechnical Modeling in RS2




### Parameters Considered

- Mohr-Coulomb Properties
  - Peak & Residual Strength
  - Stiffness

  (Ha, 2017)
- Distance Between Tunnels
- City Surcharge
- Stress Ratio
- Seismic Loads
- Modelled using Elastic-Brittle-Plastic Behavior

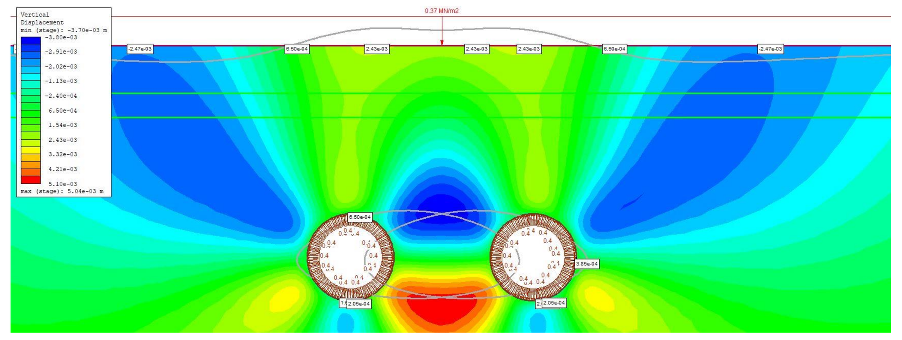
### Sensitivity Analysis

Parametric analysis done to determine which parameters affect the model the most. Those parameters that were sensitive were taken to be more conservative. Finalized parameters are listed below:

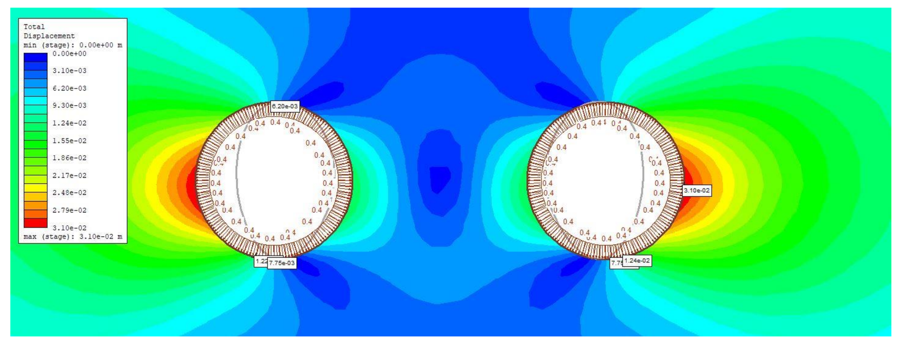
| Material Name | Material Color | Initial Element Loading | Unit Weight (MN/m3) | Elastic Type | Poisson's Ratio | Young's Modulus (MPa) | Use Residual Young's Modulus | Failure Criterion | Material Type | Peak Tensile Strength (MPa) | Peak Friction Angle (degrees) | Peak Cohesion (MPa) | Residual Tensile Strength (MPa) | Residual Friction Angle (degrees) | Residual Cohesion (MPa) | Dilation Angle (degrees) | Material Behaviour | Porosity Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Georgian Bay Shale | | Field Stress and Body Force | 0.0256 | Isotropic | 0.3 | 2340 | No | Jointed Mohr Coulomb | Plastic | 0 | 40.89 | 3.45 | 0 | 33 | 0.11 | 0 | Drained | 0.08 |
| Overburden | | Field Stress and Body Force | 0.02 | Isotropic | 0.35 | 1000 | No | Mohr-Coulomb | Plastic | 0 | 30 | 1 | 0 | 30 | 0 | 0 | Drained | 0.2 |
| Weathered | | Field Stress and Body Force | 0.0256 | Isotropic | 0.3 | 1170 | No | Mohr-Coulomb | Plastic | 0 | 33 | 0.11 | 0 | 33 | 0.11 | 0 | Drained | 0.08 |

### Results & Final Design Criteria

- Vertical surface deformation < 2.5mm to minimize disturbance to above buildings while allowing the typical tunnel wall deformation of 35-45%
- Required tunnel liner pressure to be 7.7MPa to withstand a seismic event



Vertical displacement contours & exaggerated deformation profile of the ground surface and tunnel after placement of tunnel liner.



Rock-support interaction method was implemented and an allowable tunnel deformation of approximately 31mm, 4.5m behind the tunnel face

## Implementation

### Benefits

- ✓ 150-year design life
- ✓ Accessible downtown bypass
- ✓ Efficient use of space
- ✓ Social advantages

### Things to Consider

- × Financial costs upwards of CAD $7.5 billion
- × Urban interruptions
- × Project magnitude

### References

City of Toronto. (2019). About the Gardiner Expressway. Retrieved March 23, 2020 from: https://www.toronto.ca/services-payments/streets-parking-transportation/road-maintenance/bridges-and-expressways/expressways/gardiner- expressway/about-the-gardiner-expressway/
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