IEEE – 18-May-2011

Niagara Tunnel Project Overview

- Hydroelectric diversion tunnel, 10.2 km long and 12.7 m in diameter, within the urban and tourist area of Niagara Falls, Ontario, Canada
- Increase water diversion capacity at the Sir Adam Beck complex by 500 m^3/s (+27%)
- Increase average annual energy output at the Sir Adam Beck complex by 1.6 billion kWh (+14%)
- Design Build Contract awarded to Strabag AG (Austria) in August 2005
- Owner's Representative is Hatch Mott MacDonald with Hatch Acres
- Project budget is $1.6 billion
- In-Service by December 2013

Progress at 10-May-2011

- TBM excavation completed
- Invert concrete @ 7.2 km
- Profile restoration @ 3.8 km
- Arch concrete @ 2.6 km

Preliminary Engineering & Environmental Assessment Work

- Feasibility study to enhance Ontario's Niagara hydroelectric facilities from 1982 to 1988.
- Definition engineering and environment assessment (EA) from1988 to 1994 included extensive geotechnical investigations and engagement of domestic and international experts.
- EA submitted in 1991 for the preferred alternative with 2 new diversion tunnels each with nominal capacity of 500 m^3/s, an underground generating station with up to three 300 MW units and transmission improvements between Niagara Falls and Hamilton.
- EA Approval was received in 1998 for the full development with provisions for staging construction.

Key Commitments made during the EA process included:

- Avoid community disruption experienced during the 1950's tunnel construction and minimize impacts on residents and tourists.
- Tunnel excavation from the outlet near the Sir Adam Beck PGS to the intake at the International Niagara Control Works.
- Use a Tunnel Boring Machine (TBM) to excavate the tunnel.
- Tunnel under the buried St. Davids Gorge and follow the corridor established for the existing tunnels under the City of Niagara Falls.
- Re-use of excavated materials (particularly Queenston shale).

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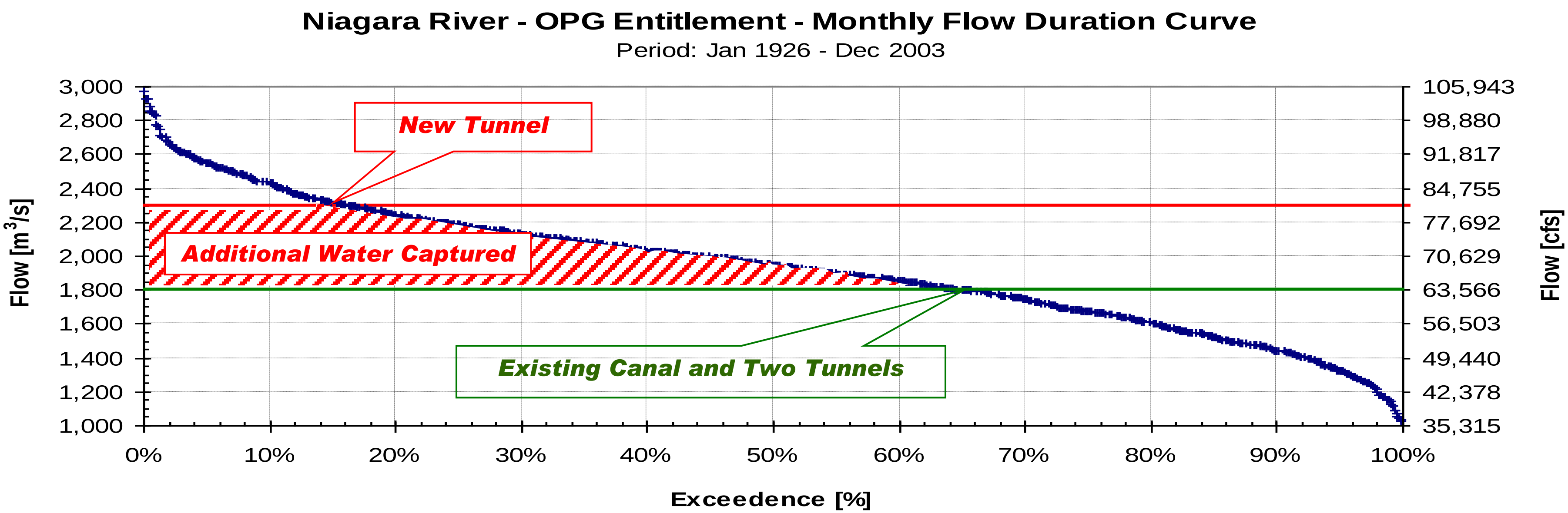
Water Availability & Utilization – The Opportunity



- **Under the terms of the 1950 Treaty between Canada and the United States, Niagara River flow available to Canada for power generation varies from about 1000 m³/s (35,000 cfs) to 3000 m³/s (106,000 cfs) and exceeds the existing Sir Adam Beck diversion capacity about 65% of the time.**
- **Available Niagara River flow will exceed OPG's diversion capability only about 15% of the time when the new tunnel is in operation.**

Niagara River Hydro Developments

	In-Service Year	Diversion Capacity m^3/s	Station Capacity MW	Annual Energy TWh	Annual Capacity Factor
Sir Adam Beck No.1 (3)	1922	600	417	2.1	
Sir Adam Beck No.2	1954	1,200	1,499	9.6	
Sir Adam Beck PGS	1958	-	174	- 0.1	
Current Totals		1,800	2,090	11.6	0.64
Niagara Tunnel	2013	500	-	1.6	
Totals (Canada)		2,300	2,090	13.2	0.72
Robert Moses	1964	3,000	2,400	14.2	
Lewiston PGS	1964	-	300	-0.5	
Totals (USA)		3,000	2,700	13.7	0.60

Outlet Area & Tunnel Construction

- **Blasting and rock excavation (300 m long, 23 m wide and 30-40 m deep) was completed in Apr-2006.**
- **A series of four conveyors transport the excavated rock from the TBM to the storage area between the existing canals**
  - **Queenston shale is segregated for re-use by Ontario's brick manufacturer's**
  - **Rock containing BTEX is initially stored on an impermeable pad.**
- **An enclosure was installed at the end of the overland conveyor to mitigate fugitive dust impacts in the area.**
- **Settling ponds and the on-site treatment plant clarify water pumped from the tunnel before discharge into the power canal.**
- **On-site batch plant produces shotcrete and concrete for the tunnel lining.**

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Intake Construction Progress

- **Mobilization of marine equipment (barges, tugs, cranes, etc) started in Apr-2006.**
- **Accelerating Wall replacement, Approach Wall installation and cellular cofferdam installation were completed in 2006.**
- **Cofferdam foundation grouting and dewatering were completed in Jul-2007.**

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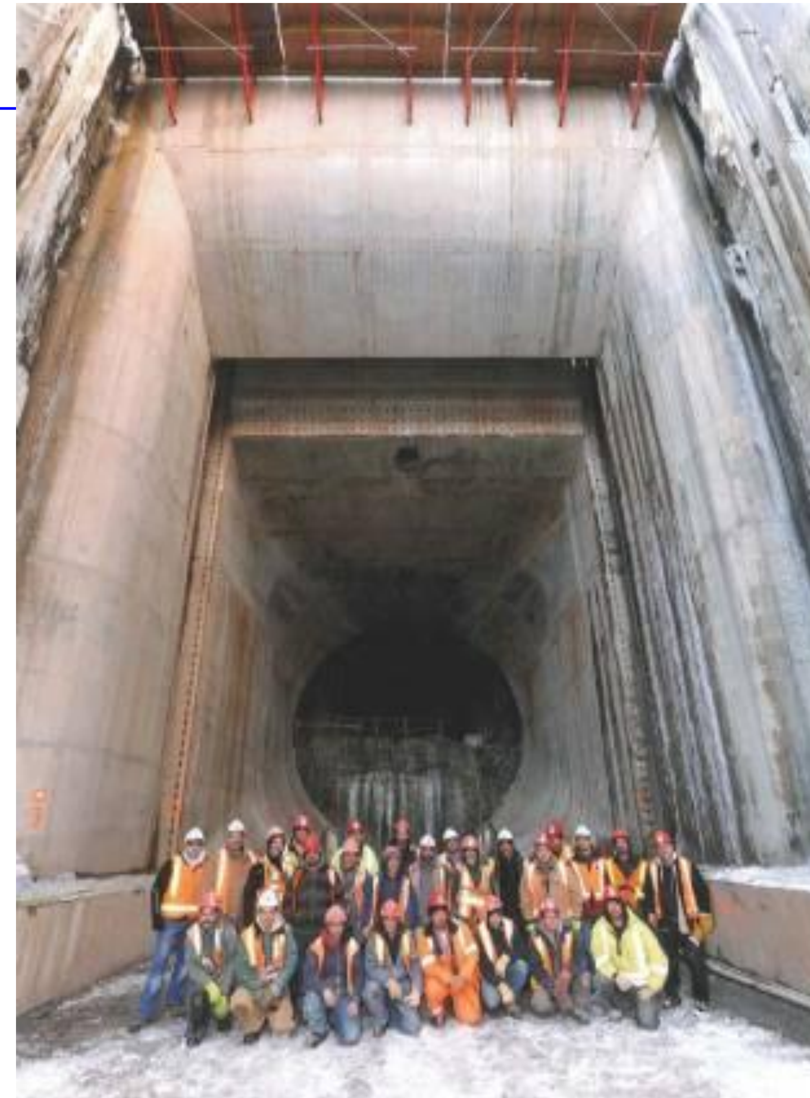
Intake Construction Progress

- **Intake channel excavation was completed in Jun-2008.**
- **Excavation of the 300m long grouting tunnel started in Jul-2008 and was completed in May-2009.**
- **Construction of the Intake Structure started in Sep-2009.**

Intake Construction Progress

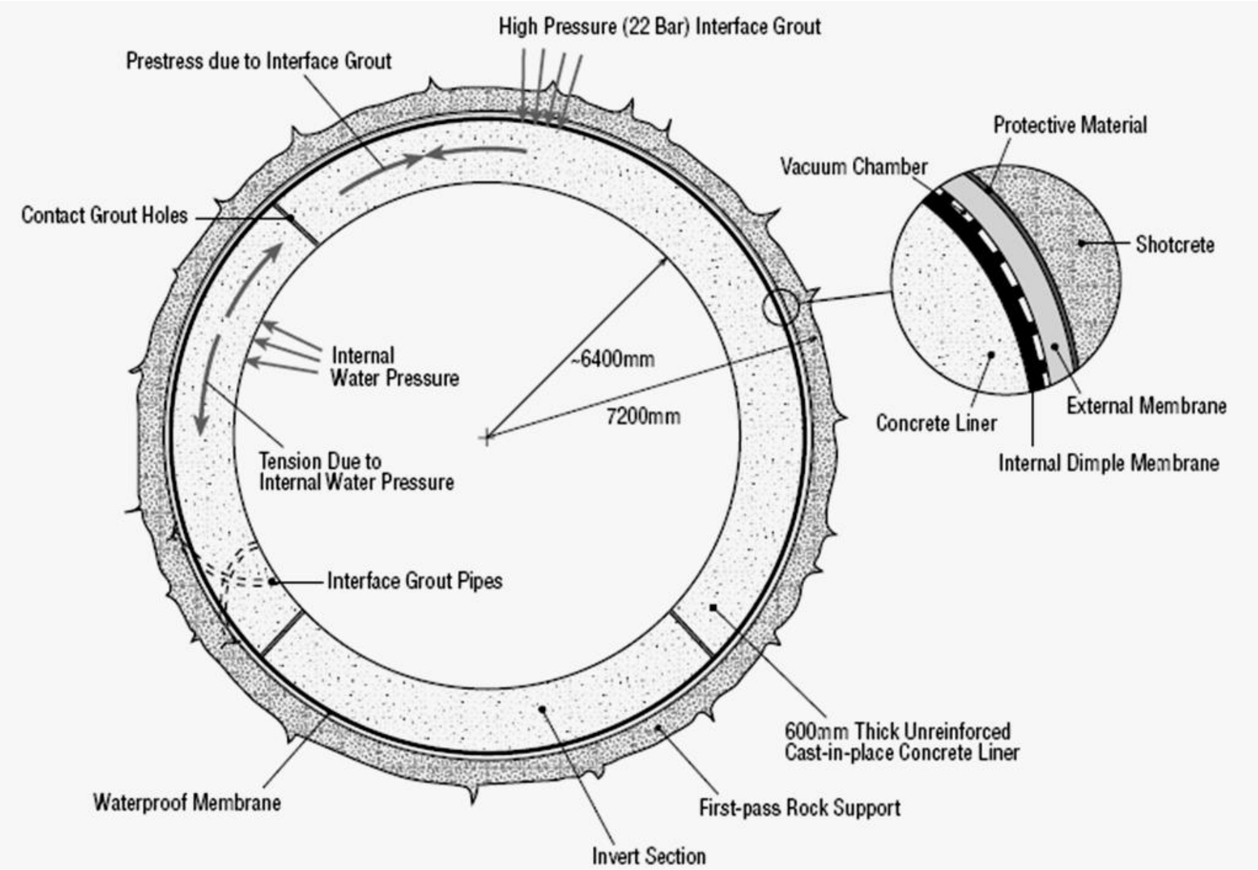
Concrete intake structure incorporates the rectangular to circular transition and sectional gates for tunnel dewatering

Construction of the Intake Structure started in Sep-2009 and primary concrete was completed in Jan-2011.



Key Elements of the Tunnel Design

- **Higher alignment with shallower slopes for decline and incline sections.**
- **Variable initial rock support dependent on host rock conditions includes rockbolts, wire mesh, steel ribs and shotcrete.**
- **Relatively simple open, hard rock TBM with sidewall grippers.**
- **Impermeable polyolefin membrane to prevent swelling of host shales.**
- **Unreinforced, cast-in-place, pre-stressed, permanent concrete liner, 600 mm thick.**



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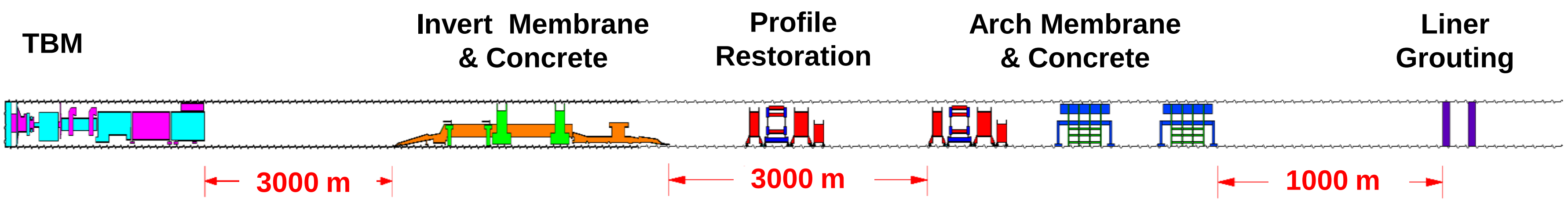
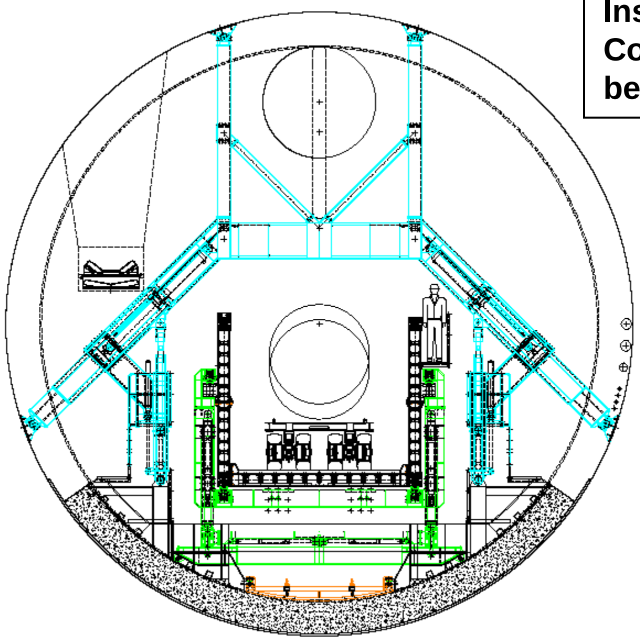
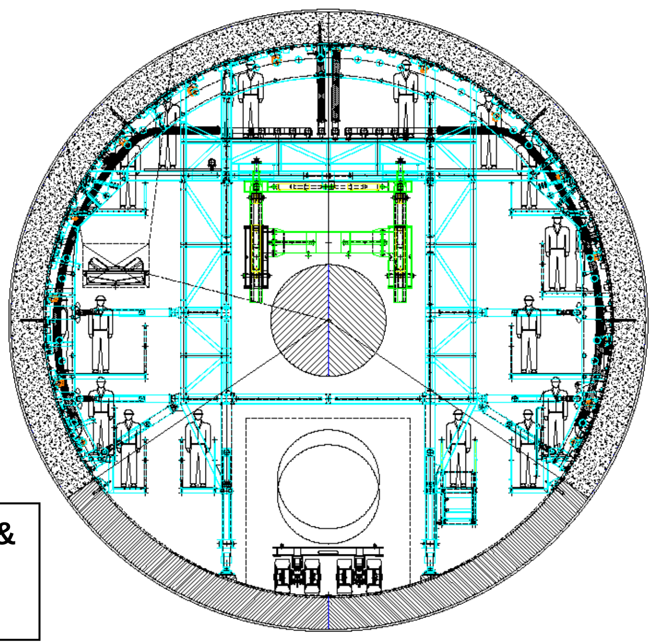
Tunnel Construction Sequence



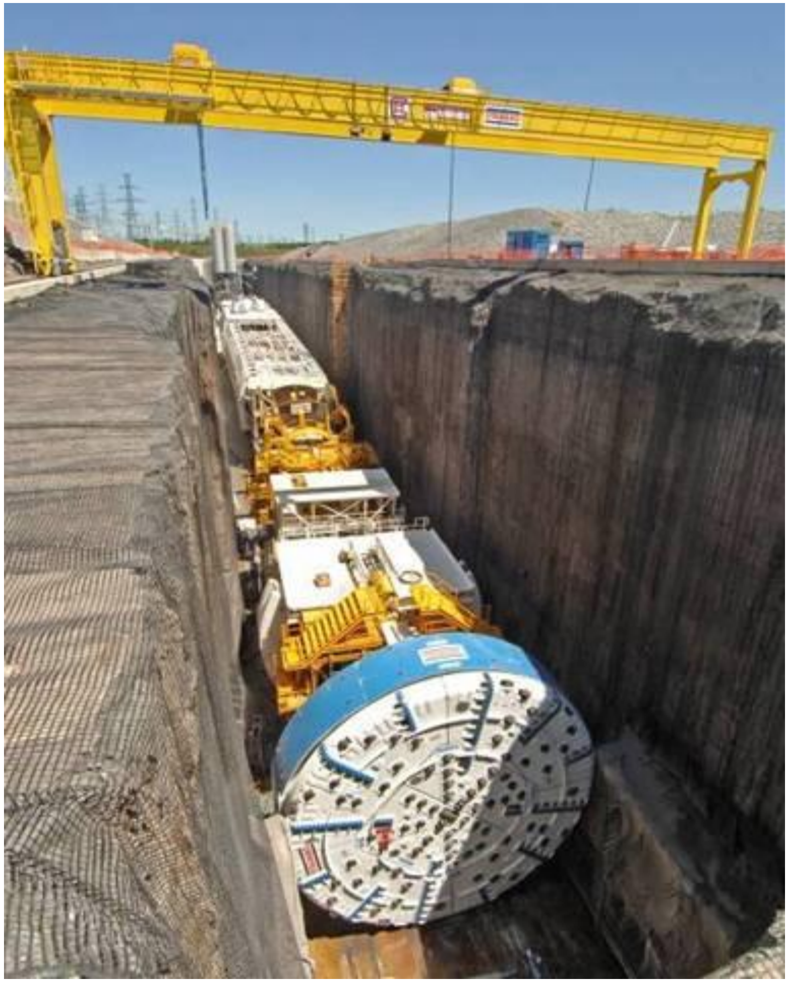


Install Invert Membrane & Concrete Liner 3000 m behind the TBM



Install Arch Membrane & Concrete Liner 3000 m behind the Invert Liner

Launching the TBM “Big Becky” on 08-Aug-2006



- **The largest open-gripper hard-rock tunnel boring machine in the world.**
- **Assembled for the first time on site in the outlet canal rock cut from May-Aug, 2006.**
- **“Big Becky” is 14.44 m high, 150 m long, weighs about 4,000 tonnes and has 85 x 500 mm cutters.**
- **Crew of 20 operates Big Becky 24 hours per day, 7 days per week to excavate the tunnel.**

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TBM Excavation Progress

TBM excavation started on 01-Sep-2006 and is expected to be completed in 2011Q2.

Challenges excavating and supporting the Queenston shale resulted in slow TBM progress and modifications to safely install initial support, change to the tunnel alignment, addition of the overbreak infill operation, concurrent TBM, infill & arch concrete operations and higher cost including more interest.

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Crown Overbreak During Tunnel Excavation

Challenges excavating and supporting the Queenston shale resulted in slow TBM progress and modifications to safely install initial support, change to the tunnel alignment, addition of the overbreak infill operation, concurrent TBM, infill & arch concrete operations and higher cost including more interest.

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TBM advanced into the Grout Tunnel on 01-Mar-2011

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Invert Membrane & Concrete started in December 2008

Invert Concrete is the bottom one-third of the permanent cast-in-place tunnel lining.

The Invert Concrete operation was launched in Dec-2008 and has now progressed about 70% of the way along the tunnel route.

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Invert Membrane & Concrete

Crown Profile Restoration started in September 2009

Work platforms required to infill zones with excess crown overbreak and restore the circular cross-section of the tunnel facilitate drilling, grouting, installation of rock bolts, forms, shotcrete & concrete.

Crown Profile Restoration in Progress

Applying shotcrete from Carrier 2

Installing steel forms from Carrier 1

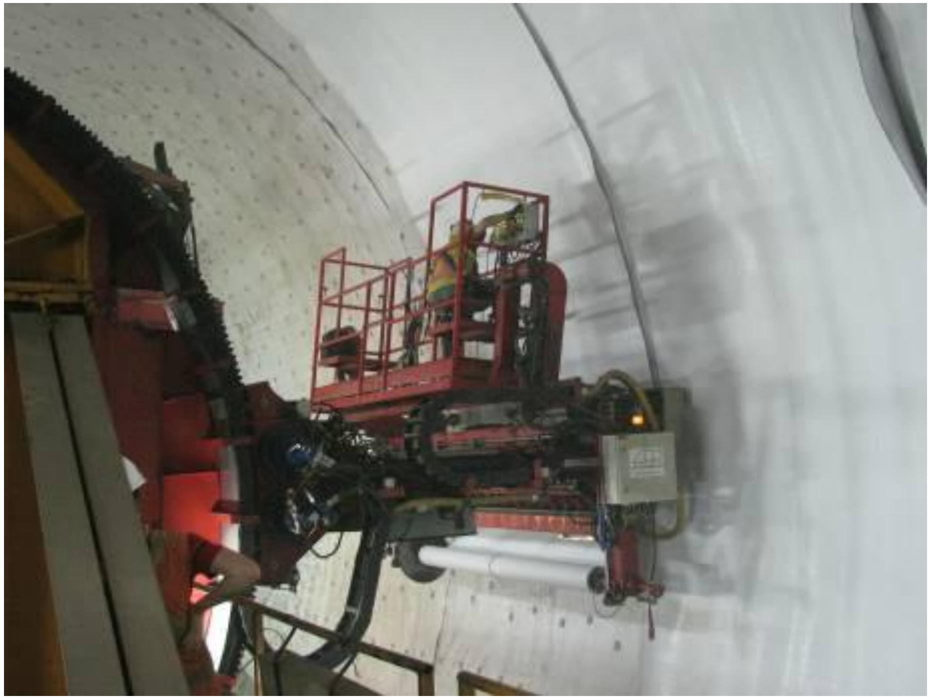
Arch Membrane & Concrete Carriers

- **The arch carrier assembly is about 450m long and includes platforms for handling the ventilation duct and conveyor, for installing the membrane and for concrete placement.**

Installing & Testing the Arch Membrane

HV testing to verify membrane integrity

Electrically testable polyolefin panels are attached by Velcro and seams are heat welded



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Arch Membrane & Concrete

Completed Arch Concrete at the Outlet portal

Impermeable membrane installed before the Arch Concrete at the dewatering shafts

Arch Concrete completed near the Outlet Portal

Break Through May 13, 2011

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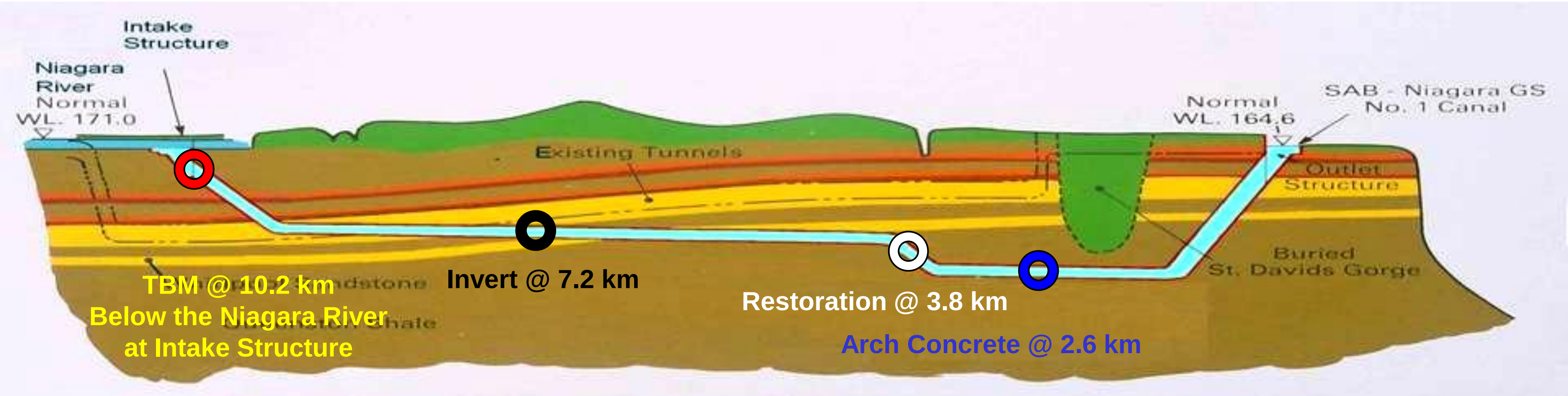
Current Status



On Schedule & Within Budget

for updates visit
www.opg.com/niagaratunnel

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