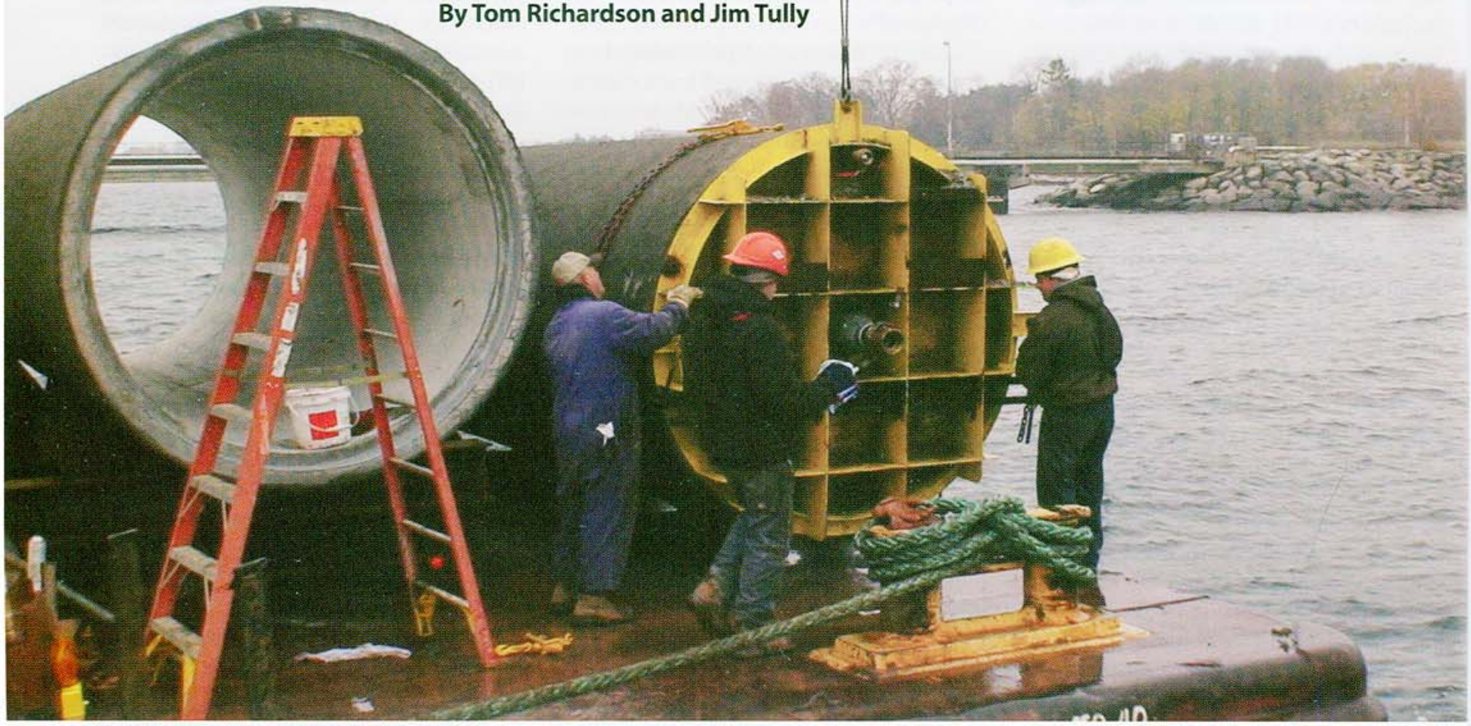
$ 22 Million contract for raw water intake incorporates innovation and new technology

By Tom Richardson and Jim Tully



Pumping unit designed in bulkhead to give the desired pressure differential between the pipeline interior and surrounding marine environment to pull pipe together. *Photo provided by Dean Construction Company Limited.*

When designers speak of raw water intakes for water purification plants, the Burloak intake tunnel may come to mind as a project characterized by innovative engineering and product applications that advanced the knowledge of marine pipeline construction.

Halton Region's $22 million design-build contract to draw water from Lake Ontario to the new 240 ML/d Burloak Water Purification Plant in Oakville, Ontario, differed from the conventional design and tender approach. The project was awarded to the design/build team of C&M McNally Engineering Corporation, marine contractor Dean Construction Company Limited, and consulting engineer R.V. Anderson Associates Limited for its innovative alternative that differed significantly from the initial design concept. Halton Region hired Associated Engineering (Ont.) Ltd. for the design review, but the design for the project was developed by the contractors and R.V. Anderson. The new plant will provide drinking water from Lake Ontario for the municipalities of Oakville, Burlington, and some areas of Milton.

The environmental assessment for the project determined that there was no acceptable location for a pumping station at the shoreline. The initial design concept envisioned a tunnel starting at the site of the treatment plant and ending at the intake. This concept required a very deep shaft at the plant, a second deep shaft at the lake, and construction of a riser shaft at the intake location that had to be bored under 17 metres of water. The tunnel would run for more than three kilometres from the plant to the intake and had to use gravity flow and allow for frictional losses. The depths of both the initial design concept and the final design eliminated the possibility of construction by open cut method on shore.

Redesign

A design change proposed by the C&M McNally team suggested constructing most of the intake's lakeside section as a trenched pipeline. This design would allow a shallower tunnel, reduced depth of the shafts at the plant and lakeshore sites, and a connecting vertical shaft to be drilled in much shallower water, thereby eliminating drilling a shaft in deep water at the inlet. This change resulted in significant construction cost savings and a shortened construction schedule. Despite the advantages of the pipeline option, proximity to Petro Canada's shipping pier required any marine pipeline to be buried below the lakebed so that it would not be damaged by ship anchors. Since the lakebed is exposed bedrock, blasting was required to prepare the trench.

Dean Construction was concerned about constructing and protecting the pipeline where it crossed the shoreline, and Conservation Halton had concerns about near shore spawning beds and the risk of erosion where the trench would cross the breaking wave zone. The contractors decided to tunnel the first 320 metres of the lake pipeline to avoid disturbing the shoreline or near shore lakebed. This decision also allowed construction of a riser shaft that connected the pipeline to the tunnel in five metres of water rather than the 17 metres proposed to connect the tunnel to an intake shaft in the preliminary concept.

The gravity flow-based intake is a combination of tunnel and concrete pressure pipe designed to last a hundred years. The tunnel extends for 1.7 kilometres from the lakeshore shaft to the plant, and the concrete pressure pipeline extends for 1.4 kilometres into the lake. The concept for the riser shaft was developed by Dean Construction, and R.V. Anderson worked with them to prepare its detailed design. The concrete cylinder pressure pipe used for the marine pipeline was produced by Munro Concrete Products Ltd. to American Water Works Association specification C301 *Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids.*

To produce concrete pressure pipe, a watertight steel cylinder with steel bell and spigot rings is fabricated, then concrete is cast on the inside and outside of the steel cylinder. Once cured, the concrete pipe surface is wrapped with prestressing wire and then coated with mortar. The marine pipe units were drawn together and joints tested using a technology application new to Canada called the H&R Hydro-Pull. Munro Concrete. supplied 1100 metres of six metre-long, 1800 mm diameter C301 concrete pressure pipe and fittings. They custom-designed the precast chamber at the top of the riser shaft with bell and spigot joints, in collaboration with R.V. Anderson.

Tunnel

Construction of the intake began with a 12-metre diameter by 15-metre deep entry shaft sited 30 metres north of the lakeshore in the Town of Oakville's South Shell Park. The shaft was sunk by breaking the Queenston shale with a hoe ram. The wall of the shaft was stabilized with 200 millimetres of pneumatically applied concrete, after each successive five-metre lift. The shaft was used to launch the tunnel-boring machine (TBM) for both the north and lakeside tunnel headings.

The first tunnel heading set off in a northward direction toward the site of the new plant. The diameter of the tunnel bore was 3 metres, and C & M McNally used their patented roof support system to ensure stability. Six temporary alignment holes (400 mm diameter) were drilled along the tunnel route to exhaust air, and to supply concrete for the tunnel lining. A Model 104121A Robbins main beam TBM was used to bore the northern tunnel in just over nine months. The tunnel reached depths of 23 metres along the route of the alignment.

A second shaft was excavated at the treatment plant site while tunneling was underway. The shaft was 23 metres in diameter for the first 6 metres of excavation and 20 metres in diameter for the next 19 metres. The shaft served as an exit shaft for the TBM, and will be used for the plant's low lift pumping station, awarded under separate contract.

When construction of the riser shaft was completed, the same tunnel boring machine was moved back to the South Shell Park shaft to bore a three-metre tunnel, 320 metres under the lakebed to the intermediate riser shaft. At the completion of boring, the TBM was backed out of the tunnel into the access shaft and removed from the site.

Intermediate riser shaft

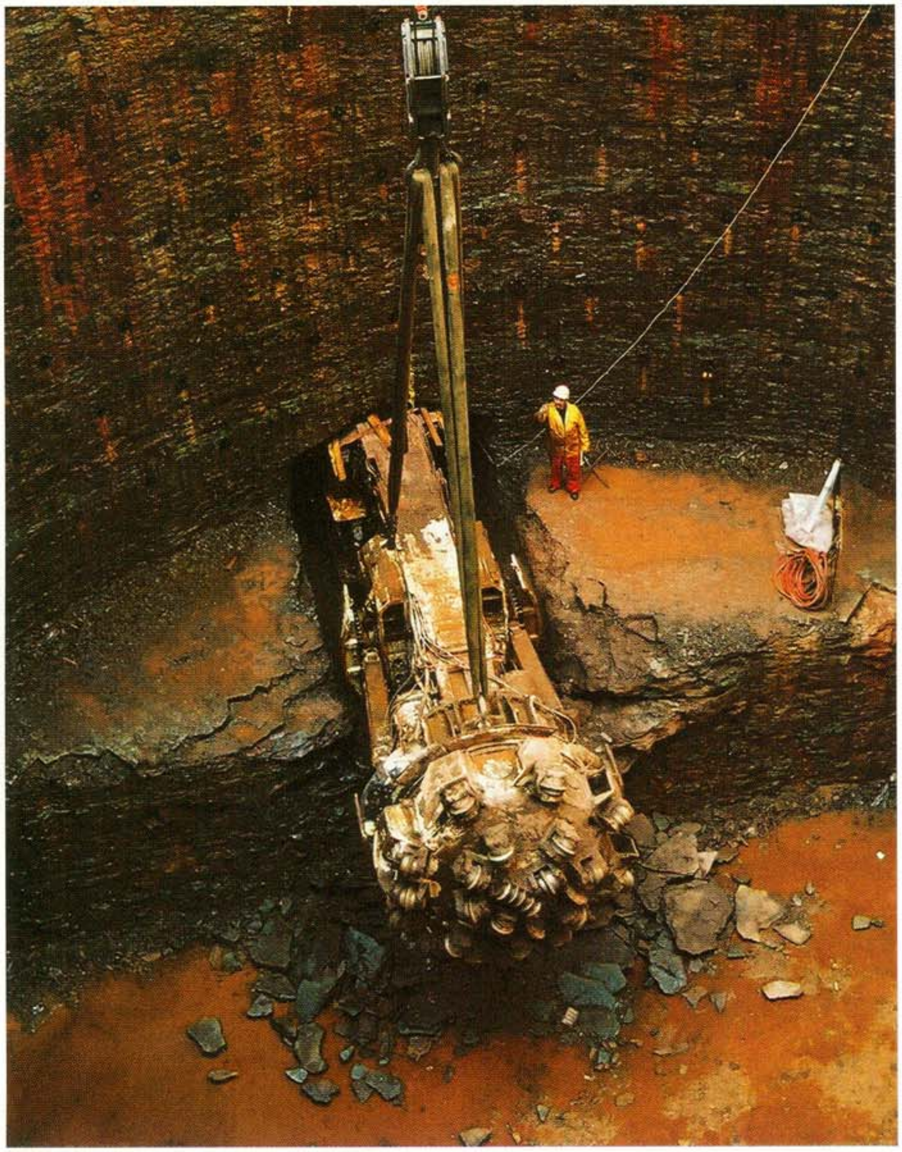
While C & M McNally was boring the tunnel to the north, Dean Construction began work on the riser shaft and marine pipeline. The first task was to drill a 3.5-metre diameter vertical shaft, 10 metres into the lakebed from the deck of the jack-up barge. Known as the *Intermediate Riser Shaft*, this structure would form the connection between the marine pipeline and the tunnel. Dean fabricated a custom core bit, complete with airlift and rock breakers to snap off sections of core, as the shaft was being drilled. The core bit was also used to excavate the first ten metres of the pipeline trench with overlapping bores to create a *secant* trench to avoid blasting directly beside the riser shaft.

The riser shaft consists of a section of 1800 mm diameter concrete pressure pipe installed vertically into the bored shaft. The bottom of the vertical pipe stopped above the elevation of the obvert of the tunnel that would be bored later. The annular space between the pipe and the drilled shaft was filled with *tremie* concrete. A custom precast chamber was required to house temporary shaft plugs and chamber cover, and connect the shaft to the marine pipeline. The precast chamber was connected to the vertical unit of concrete pressure pipe. This custom chamber piece uses concrete pressure pipe joints for sealing the plugs and cap and making the connection between the vertical shaft and marine pipeline.

Two levels of protection were provided in the design of the chamber piece to prevent the tunnel operation from being flooded. Two separate plugs were incorporated into the bottom of the precast chamber using two nested plugs of differing diameters that used the sealing bell and spigot rings of the concrete pressure pipe. Once the plugs were in place, the seals were tested for leakage with a temporary standpipe connection.

Within two metres of the riser shaft, the tunnel boring machine was halted and two small holes were drilled from the tunnel into the shaft to allow the

continued overleaf...



TBM removal after breakthrough at Burloak Shaft.
Photo by Tom Richardson, R.V. Anderson Associates Limited.

water to drain from the plugged shaft in a controlled manner and to check that the seals were holding. When the water had drained from the shaft, the TBM was advanced through the bottom of the shaft to connect it to the tunnel.

The precast chamber was finished slightly above the level of the lake bottom with a second, specially-designed cap that accommodated an access hole to the riser shaft. In addition, the design included duckbill checkvalves (one-way rubber valves) that allow trapped air in the riser to escape into the lake to avoid build up of an air pocket. Once the riser shaft was in place, installation of the pressure pipe began.

Marine pipeline

Dean Construction fabricated and installed a traveling twin tower drill platform on the jack-up barge to drill the holes for the explosive charges needed for excavating the trench for the pipeline. The position of each explosive hole was set using a GPS receiver mounted on top of each tower. Using a GPS, each drill hole was located within a 20 cm level of accuracy. The holes were drilled along each side of the trench at two-metre intervals over a length of 16 metres. Generally, one day of favourable weather conditions was required to drill, load and blast each 16-metre length.

Two barges are being used through 2007 for most of the installation of the pipeline. The drill barge precedes the excavation and pipe-laying barge by approximately 300 metres. Crushed stone is placed in the bed of the trench and the pipe lowered by cable. A diver guides the pipe home and completes the connection of the bell and spigot using a patented technology called *Hydro-Pull*. Once in place, the pipe is covered by crushed stone to the elevation of the lakebed.

The Hydro-Pull

Munro Concrete worked with Dane Hancock, of H&R Hydro-Pull in Fort Lauderdale, Florida, to introduce the technology to Canada for homing units of concrete pressure pipe in a marine environment. Hydro-Pull technology takes advantage of the incompressibility of water where an extremely small change in volume can create large pressure changes.

The pipe to be added to the pipeline has a sealed bulkhead attached on the opposite end of the joint to be made. Contained within this bulkhead is a pumping unit designed to give the desired pressure differential between the pipeline interior and surrounding marine environment. When the pipe is lowered into position and close to the existing pipe to which it would be connected, the special pumping unit is activated. This creates a hydrodynamic flow through the open end of the pipe and the attached bulkhead pumping unit, which reduces the pressure inside the pipe. As the pipe moves closer to the pipeline, the differential pressure continues to rise. The hydrodynamic flow through the open joint also helps to flush the bell and spigot and remove any debris from the fittings and gasket.

When 100 percent gasket contact is reached, the pressure differential between the inside of the pipe and the outside of the pipe rises to around 20 to 24 in/hg. To complete the insertion of the spigot into the bell, the only amount of water that needs to be removed is the cross sectional area times the depth of the joint. With the amount of water being pumped, jointing times are 4 to 6 seconds. Since jointing takes only a few seconds, considerable time can be saved over traditional methods of homing pipe in a marine environment. The diver needs only to direct the placement of the joint with the equipment supporting the pipe. Since the pressure differential can be monitored on deck, the joint integrity of the pipe added – and all previous joints installed – is known as soon as the joint is made.

Because the pressure outside of the pipe is greater than that inside, the gasket experiences a net force in the opposite direction of the frictional force during gasket compression. These opposing forces help to stabilize the gas-

continued overleaf...

Riser shaft chamber piece being prepared on deck for placement in lake.

Photo provided by Dean Construction Company Limited.

Dean fabricated a custom core bit to snap off sections of core, as the shaft was being drilled.

ket and reduce the possibility of a gasket being displaced from its seat. Once the pipe is properly supported on the bedding, the pumping unit is turned off which equalizes the pressure inside the pipe with the outside pressure. The bulkhead is then removed and placed on the next pipe to be installed.

Nothing needs to be added to any pipe before it arrives and any standard concrete pressure pipe joint can be used. Before the pipe is to be submerged, a chain binder is installed around the pipe. This chain has two chain tails at spring line on either side of the pipe to which the Hydro-Pull bulkhead is attached. The chain binders and bulkhead are removed by the diver, then used on the next pipes to be installed.

Raw water inlet

At the end of the pipeline, a precast concrete elbow will be attached to the last unit bending toward the surface. The 6.8 metre diameter x 3.5 metre tall precast concrete intake structure is being constructed in Hamilton Harbour by Dean Construction and will be transported to the end of the pipe where it will be lowered into position and joined at the elbow. The connection will be buried so that all that can be seen is the upright intake that looks somewhat like a mushroom cap. Water will be drawn into the pipe through stainless steel trash screens. Following the length of the pipeline will be four 75 mm diameter PVC pipes that will be used for chlorinating the intake to discourage zebra mussels and also enabling sampling of the quality of the raw water.

Environmental considerations and measures taken

Securing the necessary permits and approvals from the Department of Fisheries and Oceans, Ontario Ministry of Natural Resources and Conservation Halton to accommodate the need for blasting was a formidable task. Concerns of these agencies were settled with the application of a combination of technology, design of the project itself, and timing of construction of the pipeline and riser shaft.

The greatest concern was the extent of fish kill during blasting operations. Mitigating measures included placing a concrete vibrator inside a steel pipe to frighten fish from the blast area. Onboard scanners were used to time the blasts when no fish were detectable in the blast zone.

A unique air curtain was devised to enclose the blast zone in a wall of bubbles that reduced the overpressure shock waves from the blast, and at the same time reduced the amount of turbidity by up to 50 percent outside of the curtain, depending upon wind and wave conditions. The air curtain is expensive to operate and difficult to place. The contractor may attempt to lower its frequency of use, if it becomes apparent that very low numbers of fish are being killed by the blasts.

Construction of the raw water intake began in September 2005 and will end in December 2007 to coincide with completion of construction of the water purification plant that began in April 2006.

Tom Richardson, P.Eng. is with R.V. Anderson Associates Limited. Contact: trichardson@rvanderson.com

Jim Tully, P.Eng. is with Munro Concrete Products Ltd., Contact: jim.tully@munroconcrete.com