

Tunnel Water Inflow Recovery by Peter White, P.Eng.

Prime Minister Stephen Harper hopes to make Canada a 'clean energy superpower'. In 2009, the federal government announced a funding program that would provide \$1 billion towards green infrastructure. A portion of this money was committed to Yukon Energy for the upgrade and expansion of the Mayo hydroelectric dam¹.



Original water inflow

As part of this expansion project, a 6 m x 5 m hydro power tunnel was constructed to carry water to a new power house down stream. Tunnel excavation was through poor ground conditions below the water table towards a large headpond reservoir using drill and blast methods. Conventional grout curtains were installed prior to each blast using cement grout to fill water-bearing fissures and open fractures.



Water control gate fabrication

Grout curtain drill holes were hitting increasing water inflows as the tunnel approached the headpond reservoir. When blasting one of the final rounds in the tunnel, an open fracture was encountered that resulted in a water inflow of 1,500 GPM and flooding of the tunnel face. Tunneling operations were suspended until this water inflow could be stopped.

After the flooded tunnel was dewatered using large pumps, it was observed that the water inflow was entering at the top corner of the tunnel wall through an open fracture measuring approximately 30 cm wide x 60 cm high x 100 cm deep that was connected to the headpond reservoir through various water-bearing fissures.

The solution to this problem was a multi-staged approach that involved controlling, or diverting, the initial water inflows so that a water control gate could be installed before the open fracture could be secured and a permanent seal could be achieved.

A water control gate measuring 80 cm x 80 cm was fabricated using 1/2 inch steel plate. An opening measuring 30 cm x 30 cm was cut through the water control gate to allow



Water control gate and water diversion sluice

¹ <http://www.cbc.ca/news/canada/north/story/2009/08/21/harper-yukon.html>



Closing the water control gate

temporary passage of the 1,500 GPM water inflow.

A sliding door with door frame and closure bolts was fabricated on the outside face of the water control gate. A wooden frame consisting of 15 cm x 15 cm timbers was attached to the inside face of the water control gate.

Four 25 mm diameter grout hoses were installed into the opening and pushed as far as possible into the water-bearing fissures.

The steel water control gate assembly was positioned at the corner of the tunnel wall and was attached to the wall using conventional rock bolts so that the 30 cm x 30 cm opening was aligned directly with the water inflow fracture.

A wooden sluice measuring 2.4 m long was inserted through the opening in the water control gate and into the open fracture to divert the majority of the water inflow away from the water control gate.

Supplementary drainage hoses were installed between the water control gate and the irregular rock profile and enclosed using metal and wood construction materials that were sealed with fast-curing chemical grout.



Water control gate in closed position

After all of the water inflows had been diverted through the wooden sluice and supplementary drainage hoses, formwork was constructed and the water control gate was encapsulated with reinforced concrete.



Drilling probe holes

Two cement grout plants were setup adjacent to the water inflow site and a four-way header was assembled to allow all four of the grout hoses behind the water control gate to be grouted at the same time.

After all preparations had been made, the wooden sluice was removed from the opening and the water control gate was closed and secured in position by closing the tie-down bolts. When the gate was closed, the water inflow was stopped for the first time in over a month.

Grouting operations to fill the water flow pathways behind the water control gate commenced immediately using a thick cement grout with calcium chloride as an accelerator. Grouting pressures were monitored to avoid use of excessive grouting pressure acting on the water control gate.

After pumping 3,000 kg of cement behind the water control gate and into the water-bearing fissures, grouting operations were terminated. Cement grout was allowed to cure for 24 hours before opening the water control gate and removal of concrete formwork.



Dry tunnel excavation

After a month of difficult work to encapsulate the water inflow, a permanent seal was finally achieved. Subsequent probe hole drilling in the area of the original water inflow encountered minimal residual water inflows.

The understanding that a solution involved working with, not against, the environment and the natural water inflows and rock fractures was central to success. Tunnel construction continued without further complication. The power house from this expansion project started feeding power into the Yukon's transmission system at the end of 2011².

For innovative solutions, material selection advice and technical support – contact Peter White P.Eng, 416-919-1878, peter.white@groutingspecialist.com.

² <http://www.yukonenergy.ca/energy/projects/mayob/>