Canadian Fast-track Drill and Blast: Excavating the Rupert Transfer Tunnel at James Bay, Québec, Canada

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The Rupert Transfer Tunnel allows the transfer of a substantial portion of the Rupert River flow into the drainage basin of the Eastmain River, increasing the discharge of the Eastmain by nearly 100%. The increased flow will be turbined at five downstream hydroelectric powerhouses-Eastmain-1-A, then at Sarcelle, both new installations, followed by LG-2, LG-2A and LG-1, all existing powerhouses, all built in the 1970’s and 1980’s, before reaching the sea at James Bay.

The Rupert Transfer Tunnel is 2,908 meters long, with a height of 18.6 meters and a nominal width of 12.7 meters. It was excavated in 2007 and 2008, using the top heading and bench method. The heading was drilled and blasted from both ends, alternating rounds, while the bench was excavated from one end only. Modern computer-controlled data jumbos were used for the heading. The bench was excavated at 10 meter height, using crawler hydraulic drills. Large side-dump loaders and 50 tonne trucks were employed for mucking both the heading and bench. The excavation of 665,900 cubic meters of Canadian Shield granite took 13 months, working through a tough sub-Arctic winter, with temperatures reaching -40 Celsius.

To put this into a TBM-equivalent context, the excavated drill and blast volume equals 23.55 kilometers of 6 meter diameter TBM tunnel. The production rate required of that hypothetical 6 meter TBM would be an average of 1,812 meters per month, to excavate the same rock volume in 13 months..

1. The owner of the Rupert Tunnel is Hydro-Québec. Hydro-Québec is a Provincial Crown Corporation, owned by the people of Québec. It serves 3.6 million customers in the Province of Québec. H-Q exports energy to New England, New York State and the Province of Ontario, through 18 high voltage interconnections. It also imports energy from those same markets, buying somewhat more than it sells, using a concept it pioneered, that of ‘energy-banking’, which follows the old stock-market maxim of ‘buy low-sell high’. Low-cost night-time power purchased from nuclear and coal-fired must-run plants allows Hydro-Québec to conserve water in its reservoirs, then sell peak power back later in the day.

Hydro-Québec is the largest hydroelectric generator in the world. H-Q currently operates 59 hydroelectric powerhouses, equipped with 336 turbines, and producing 33,680MW. Three projects involving seven new powerhouses are under construction at this time, planned to come into service between 2011 and 2020, adding a further 2,468MW. They are: Eastmain-1-A, 768MW, in service by late 2011; La Sarcelle, 150MW, in service by late 2011; La Romaine, 1,550MW, in four power plants, the first to be in service by 2014, the second in 2016, the third by 2017 and the fourth plant in 2020.

Within the last decade, H-Q has brought on line seven new plants, totalling to 2,643MW, with 25 turbines. They are: Sainte-Marguerite-3, 884MW; Toulnustouc, 526MW; Eastmain-1,
480MW; Peribonca, 385MW; Grand-Mère, 230MW; Rapide-des-Coeurs, 76MW and Chute-Allard, 62MW.

Figure 1- Hydro-Québec’s Main Generation & Transmission Facilities (2008)

Hydro-Québec owns and operates the largest underground powerhouse complex in the world, at the Robert Bourassa (LG-2) and LG-2A site. The 22 units installed there have a total capacity of 7,722MW. A dozen H-Q powerhouses are each of over 1,000MW in their installed capacities. In addition to these large hydroelectric resources, Hydro-Québec operates the Gentilly-2 CANDU nuclear reactor- 675MW and the Tracy oil-fired thermal plant of 660MW, infrequently run, in addition to 3 gas turbine plants- Becancour, of 439MW; La Citière, 280MW and Cadillac,162MW , or, at 217,200 horsepower, by far the most powerful Cadillac ever built. All of these generating facilities- hydroelectric, both those built and those now under construction; nuclear; oil-fired and gas-fired total to over 38,000MW. Over 90% of Hydro-Québec’s energy is produced from falling water. H-Q also operates 23 diesel plants, serving off-grid island and northern communities.

During the 1970’s and 1980’s, Hydro-Québec, through its subsidiary, Société d’énergie de la Baie James (SEBJ), built seven hydroelectric generating stations in cascade on the La Grande River. These stations, with a total of 65 units, have an installed capacity of 16,020MW, with a replacement value in excess of $50 billion. Hydro-Québec has had, since 1971, a power purchase agreement for 5,429MW of power from Newfoundland and Labrador’s Churchill Falls plant, with the agreement running until 2041.

Hydro-Québec operates the largest electricity transmission network in North America. It was the first utility in the world to operate transmission lines at over 700,000 volts. The first 735KV line came into service in 1965. The H-Q high voltage (765-735KV) network now extends to 11,422 kilometres. The medium and low voltage distribution network now totals to 110,127 kilometres.
Residential customers of H-Q enjoy the lowest rates in North America- 6.87 cents per KWh. This compares to 7.13 cents in Vancouver, 11.01 cents in Portland, 15.05 cents in Chicago and 25.32 cents in New York City. About 95% of Hydro-Quebec's current production is hydroelectric, but 3,000MW of wind power is either online now or in the supply pipeline, with online dates to 2015.

2. The Rupert Transfer Tunnel will divert up to 800 cubic meters per second of water from the Rupert River watershed into the Eastmain River watershed, to provide additional hydroelectric generating capacity. This capacity will be realized at two new generating stations now under construction- the 768MW Eastmain-1-A powerhouse and the 150MW Sarcelle powerhouse. The total cost of the project is $5 billion. Further energy production from the existing facilities downstream will add substantially to the energy benefits.

In summary, and this by Terawatthours-

<table>
<thead>
<tr>
<th>Facility</th>
<th>Capacity (MW)</th>
<th>Service Year</th>
<th>Energy (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastmain-1-A</td>
<td>768</td>
<td>2011</td>
<td>2.3</td>
</tr>
<tr>
<td>Sarcelle</td>
<td>150</td>
<td>2011</td>
<td>1.1</td>
</tr>
<tr>
<td>Total from new facilities</td>
<td></td>
<td></td>
<td>3.4</td>
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</tbody>
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From the three existing downstream power plants-

<table>
<thead>
<tr>
<th>Facility</th>
<th>Capacity (MW)</th>
<th>Service Year</th>
<th>Energy (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert-Bourassa (LG-2), La Grande 2-A and La Grande-1</td>
<td>530</td>
<td>2011</td>
<td>1.1</td>
</tr>
<tr>
<td>Total energy attributable to the Eastmain-1-A Project</td>
<td>8.7</td>
<td></td>
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For comparison purposes, the 4 powerhouse La Romaine complex, now just starting into construction, will produce 8.0TWh, with a total installed capacity of 1,550MW, and a projected cost of $6.5 billion. In another comparison, the 935MW of new capacity added with the Rupert Transfer Tunnel will produce 9% more energy than the 1,550MW La Romaine project, and at lesser cost, due to greater utilization of the existing downstream plants.

(1TWh= 1,000GWh= 1,000,000MWh= 1 billion KWh)

To put these electrical terms into an urban context, the annual energy requirements of the Chicago metropolitan area could be met with 8.7TWh + 8.0TWh. (= Eastmain-1-A, Sarcelle and La Romaine)

A typical thermal plant of average efficiency, to generate 8.7TWh, would require over four million tons of coal. Visualize, if you will, a loaded train of 1,000 kilometres long, the distance from Vancouver to Calgary- that is four million tonnes of coal.

3. The Eastmain-1-A- Sarcelle- Rupert Project is comprised of these three principal elements-

- The construction of the 768MW Eastmain-1-A Powerhouse
- The construction of the 150MW Sarcelle Powerhouse
- The partial diversion of the Rupert River towards these two powerhouses, and onward, towards the existing Robert-Bourassa (LG-2), La Grande 2-A and La Grande-1 powerhouses.

4. The partial diversion of the Rupert River includes these works-

- Four dams.
- A spillway on the Rupert River, regulating the downstream flow into that river.
- 74 dikes around the perimeter of the reservoirs.
- 2 forebay lakes, totalling 346 square kilometres in area.
- A transfer tunnel of 2.9 kilometres in length.
- A network of canals totalling 12 kilometres, to facilitate the flow of water.
- Construction of a series of control weirs on the Rupert River, downstream of the spillway.
5. Description of the Rupert Transfer Tunnel Project - the tunnel is 2,908 meters long.

- Open cut rock excavation for the upstream and downstream portals - 467,000m³ Rock cuts to 60m depth, done with 10m benches.

- Underground rock excavation

  - Heading 296,600m³
  - Face area - 97m² pay (or 102m² excavated)

- Underground rock excavation

  - Benching 369,300m³
  - Face area - 127m²

- The heading was excavated with horizontal drilling, using 3 boom Sandvik (Tamrock) T11A data jumbos, with man-baskets. Drill length was 5.8m, while pull averaged 5.4m. For 15m at each end, the pilot & slash technique was used, with the pilot rounds limited to 2.5m pull, leaving at least 2m of rock to the 'A' line for the subsequent slash round.

  Number of pilot rounds required - 30m/2.5m = 12 rounds
  Number of slash rounds required - 30m/2.5m = 12 rounds
  Full face rounds required - 2,878m/5.4m = 533 rounds

- A typical 5.4m heading round broke 551Bm³ of rock, or about 1,500 tonnes of muck.

- For 300m, under Lake Sillimanite, probe drilling was required for 10m+ beyond the face.

- Benching was done using 4 to 5 hydraulic crawler drills working at one end only. Drill depth was generally 10.6m, with a section of 10-12m in length blasted on each shift. A 12m round broke 1,524Bm³ of rock, or about 4,100 tonnes of muck.

- Mucking for both the heading and the bench rounds was with Cat 988 side-dump loaders, into 4-6 Cat 773 trucks, of 50 tonne capacity. Power scaling was done with Cat 365 hoes.

- Each round was bolted and meshed, to the face, before drilling the next round. The mesh remains in place.

6. Schedule

- The job was bid on January 30th and was awarded in late March, 2007.
- Four new drill jumbos were conditionally ordered from Sandvik (Tamrock) in February of 2007 - before the contract award, to gain schedule advantage - two data T11’s, one non-data T11 and a 2 boom T8. The T8 was used for bolting.
- Mobilization, clearing of the portals and construction of temporary power lines and access roads started in April, 2007.
- Overburden excavation in the upstream and downstream portal areas started in May.
- Rock excavation in the portals started in July of 2007.
- In August, 2 of the 4 jumbos were delivered; the other 2 followed shortly thereafter.
- Pilot and slash work at the downstream portal started in September, 2007.
- Due to unforeseen rock excavation difficulties, the upstream portal work was finished later than planned, concluding in October, 2007.
- Tunnelling, on a sustained basis, working at both ends started in mid-October, 2007.
- The Christmas 2007/New Year 2008 holiday shutdown was of 2 weeks duration.
- Top heading work was finished in early June, 2008, for a heading duration of 8 months.
- Benching was completed by early November, 2008, for a benching duration of 5 months.
- Overall heading & benching duration was 13 months.
- The job was substantially de-mobilized by December, 2008, avoiding a second winter.
• The tunnel was finished 12 months ahead of the owner’s diversion schedule requirement.
• All the owner’s time-related objectives were met.
• Filling of the Rupert River forebay started on November 7th, 2009, a year after the tunnelling was completed.

7. General Observations

• Cost- The low bid submitted was $57 million. Some unforeseeable rock conditions were encountered, resulting in temporary losses in production, tunnelling delays and extra costs. These matters are currently under discussion.

• Camp- The camp is owned and operated by Hydro-Québec, without cost to the contractors or the employees- Yes, there IS a free lunch!

• The four Sandvik (Tamrock) jumbos were maintained by the contractor’s mechanics, working under the daily supervision of Tamrock’s onsite technician, supported by an adequate parts supply. There was never a round missed due to jumbo non-availability

Figure 2- The completed excavation of the Rupert Transfer Tunnel- note the horizontal ledge at the heading-bench line, 10m above the invert.
Figure 3- General layout of the Rupert Transfer Tunnel- Plan, Sections and Details

Figure 4- Loading a top heading round. A Sandvik T11A jumbo is in the foreground
Figure 5: Typical Top Heading Drill Round with 57mm diameter holes

Figure 6: Typical Drill Pattern Tunnel Bench 12.7m wide with 75mm diameter holes