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TREVI FONDATIONS CANADA

TECHNICAL REFERENCE

Dike A-418
Diavik Diamond Mine

Northwest Territories, Canada

Jet grouting

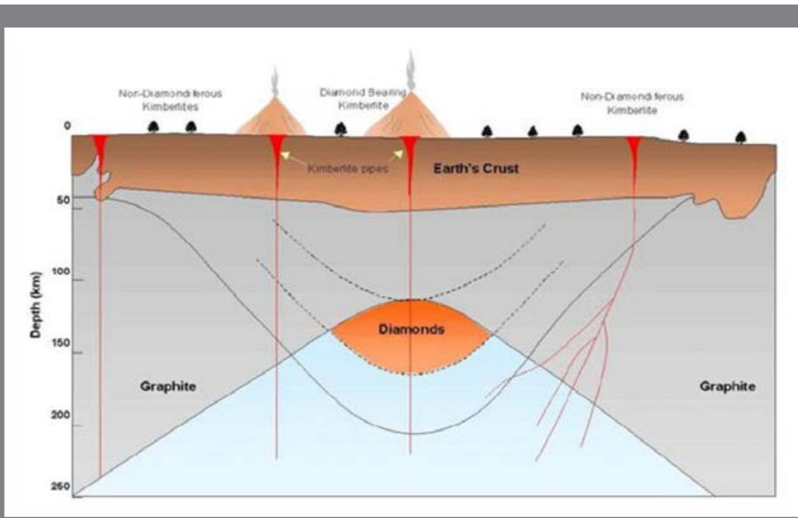
Owner:	DIAVIK DIAMOND MINE, INC.
Main Contractor:	**Lac De Gras Constructors - TREVI Foundations Canada, Inc**
Duration of works:	**May 2006 - September 2006**

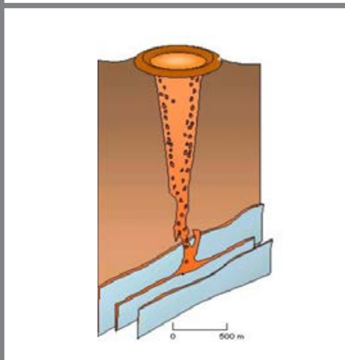
Introduction

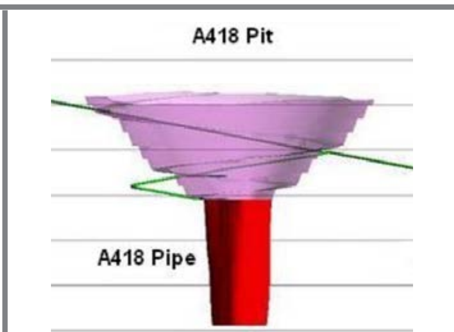
The Diavik Diamond Mine is located on a 20 square kilometre island, informally called East Island, in Lac de Gras, approximately 300 kilometres by air northeast of Yellowknife, capital of Canada's Northwest Territories. **The Arctic Circle lies 220 kilometres north of the mine.**

The lake averages 12 meters deep, and has a maximum depth of 56 metres. Water temperature ranges from 0°C to 4°C in winter and 4°C to 21°C in summer. Aboriginal people named the lake Ekati, as the veins of quartz found in local bedrock outcrops resembled caribou fat.

Lac de Gras has a 4,000 square kilometre drainage area. This lake, with Lac du Sauvage to the northeast, forms the headwaters of the Coppermine River flowing 520 kilometres from western Lac de Gras to the Arctic Ocean.







Kimberlite pipes

Project

A set of kimberlite pipes was discovered in this area, and further investigations led to the discovery of important diamond-field. Two kimberlite pipes were exploited by building a dike to allow dewatering and open pit mining of the rock (dike A154)

A new dike, the A418 dike was completed in 2006. It joins the existing A154 dike with East Island. Construction methods were the same as those used in A154 dike - various sizes of rockfill, a central concrete cut-off-wall, grout, and monitoring instrumentation.°

A smaller dike - only 1.3 kilometres long - the A418 dike required approximately 1.1 million tonnes of rockfill and is built in water up to 32 metres deep. A significant crushing facility prepared much of the rock before placement using rock from the A154 open pit. The rockfill portion of the A418 dike was completed in 2005, and the dike was made watertight in 2006. Like the A154 dike, fish within the embankment were returned to Lac de Gras and silty water was treated prior to its return to the lake.

The funnel shape of the Kimberlite pipes dictates the mode of extraction: open pit excavation down to a certain level, followed by underground mining through access galleries intercepting the pipes at depth. In order to start the open pit excavation, most of which lays under the lake level, it was necessary to construct a waterproof dike into the lake, encircling two known pipes, and dewater the area protected bywithin the dike alignment to begin the excavation.

This sequence was selected for the construction of the first pit containing the two A154 pipes, and was repeated in the development of the third pipe (A418), taking advantage of the lessons learned during the construction of the first dike. The original plan was to construct the A154 dike by placing selected material in the lake, compact it by vibroflottation and waterproof it by constructing a plastic cut-off by slurry wall method, through it and the underlying materials in situ, keying it into the bedrock. The underlying bedrock, in places highly fractured, was to be treated by an extensive rock program of grouting program.

Unfortunately, during the first phase of construction of the A154 dike, it became apparent that the geologic conditions at the site prevented the installation of the plastic cut-off down to the rock surface.

The presence of a layer of boulders in the till above the rock, coupled with the existence of permafrost in many areas, resulted in major over-excavations of the slurry wall panels and occasional collapses. The remedial action taken was to stop the plastic slurry wall at the interface of the bouldery till layer and the cutoff wall completed by jet grouting the gap between the revised bottom of the cut-off and the top of rock.

Since this modification to the original scheme resulted in the successful waterproofing of the dike, it was the basis for the design and construction of the second phasedike.

The positive experience of the first phase was incorporated in the design of the second phase, which specified the use of jet grouting as an integral part of the cut-off; as a matter of factit was the only form of cut-off wall in soil in the shallow portions of the dike, while being the connecting piece between the bottom of the slurry wall and the top of rock in the deeper sections. As in the first phase, the cut-off wall was continued into the fractured rock by an extensive program of pressure grouting.

Trevi's Canadian subsidiary was selected by Lac de Gras Constructors, a joint venture of Peter Kiewit Sons Co. and Nuna Engineering, to do the jet grouting work. Although the original schedule of work contemplated doing all construction during the summer months, the pressure to develop the third kimberlite pipe as soon as possible forced an acceleration of the schedule, requiring that a portion of the work be done during the 2005-2006 winter, to guarantee that dewatering could start at the beginning of September 2006 and be completed before the enclosed pond would freeze up.

Winter Ice Road

Working in the Arctic

Arctic work presents a series of challenges, logistics being one of the most important.

The remoteness of the location, the temporary nature of the mining activity and the fragile environment of the northern tundra demand that all heavy loads be transported on site via ice roads, which operate only for few months during the winter and are subject to the vagaries of the climate.

All major equipment and all construction materials are transported by trucks on the ice roads and when they close in the spring, any needed items can only be delivered by air, at a substantial premium. It is therefore critical the detail and accurate planning of all the required items to guarantee to plan accurately what˜s needed, to procure it and to schedule its transportation in a timely fashion.

The next challenge involves the people: Arctic work is typically done on a twenty-four hours a day, seven days a week basis, with either a two weeks on, one week off, or four weeks on, two weeks off basis.

Rotation of crews must be scheduled, transportation arranged and replacement found, often on a short notice.

Another difficulty that had to be faced was the presence underground of permafrost zones.Those areas required particular care, since there was a degree of uncertainty about the effectiveness of jet grouting in frozen soil and how to deal with it *(ultimately the jet grouting was successfully performed in accordance with the anticipated results).*

Lastly, **the winter. Working with temperatures dipping below - 40 degrees Celsius, with wind speed that reached 100 kilometers per hours, requires an extraordinary series of precautions to be productive and safe.**

During the winter phases, all drilling and grouting equipment works in heated, movable enclosures; all exposed water and grout lines must be insulated and heated with tape, all equipment operating outdoors is kept running at all times and special protective clothing must be worn by people working outside.

Trevi works

Jet grouted cut-off

The accelerated work schedule program required doing a test section and the cut-off at the four different Termosyphon areas between stations and during the winter months.
In those alignments the cut-off was done entirely by overlapping 1.3 meters diameter jet grout columns, from the surface to 1.5 meters into the rock, while the summer phase work was done with columns extending from one meter above the bottom of the slurry wall to 1.5 meters into rock.

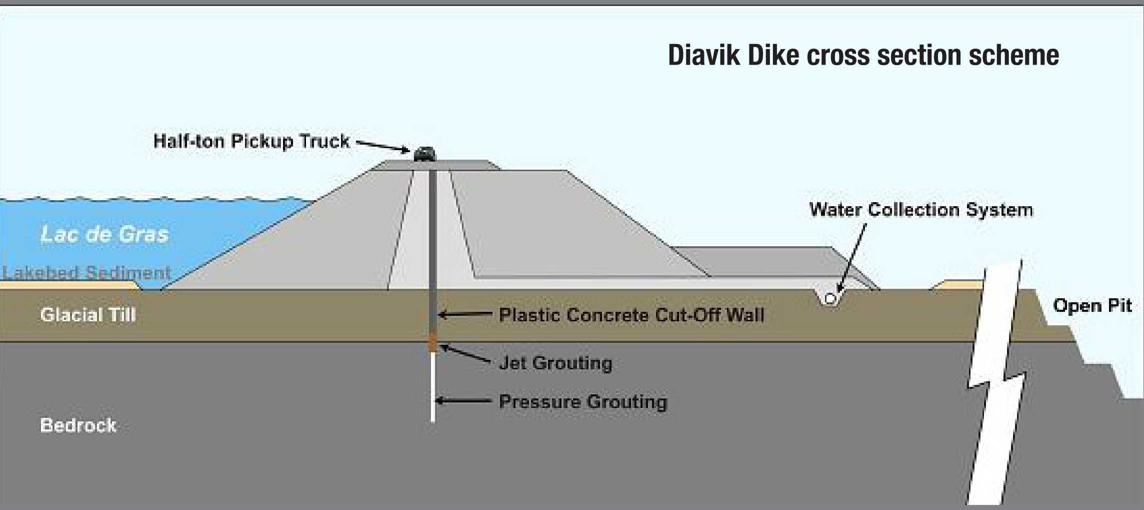
During the test program, 13 columns of 4 different target diameters were constructed, utilizing various grout mixes and withdrawal rates to establish the optimum working parameters as well as the maximum diameters obtainable in both the frozen and unfrozen zones. Those data would then be used in the production work as well as in the installation of any remedial columns which may be needed. The drilling alignment was recorded in every jet grouting column installed to determine the as-built location to ensure the continuity of the single line jet grouted cutoff. The actual deviation was measured by using a in-hole survey instrument which gave a survey position of the drilled bore-deviation of the hole location on two axis in a quick and reliable manner.

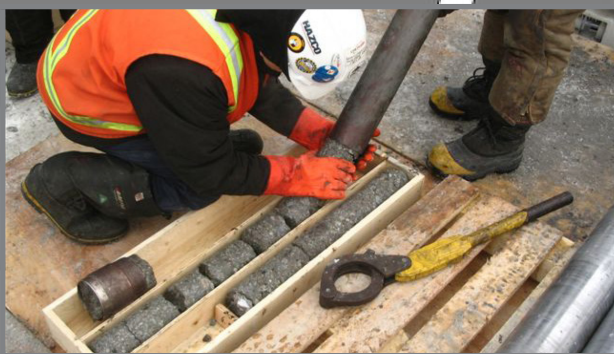
The jet grouting work was carried out using Soilmec rigs, expressly customized to meet the stringent requirements dictated by the demanding surroundings. During the winter the work was performed by a **Soilmec SM-405/8 rig**, supplemented during the summer by two **Soilmec R-312/200 MP** rigs with extended mast.
Ultimately the 826 meters long main cut-off was constructed by forming **1284 columns,with a diameter between 1.24 meters and 1.8 m, spaced 0.75 meters center to center in a single row, at depths exceeding 40 meters.** Over 27,000 meters of drilling were required to install approximately 7,500 linear meters of jet grouting.

Verification of the continuity of the cutoff was performed by coring with the use of a **Soilmec PSM-980 G** with a wireline core barrel system. The coring showed not only a good quality of the jet grouting installed but also a perfect contact at the interfaces with the cutoff wall and with the bedrock.

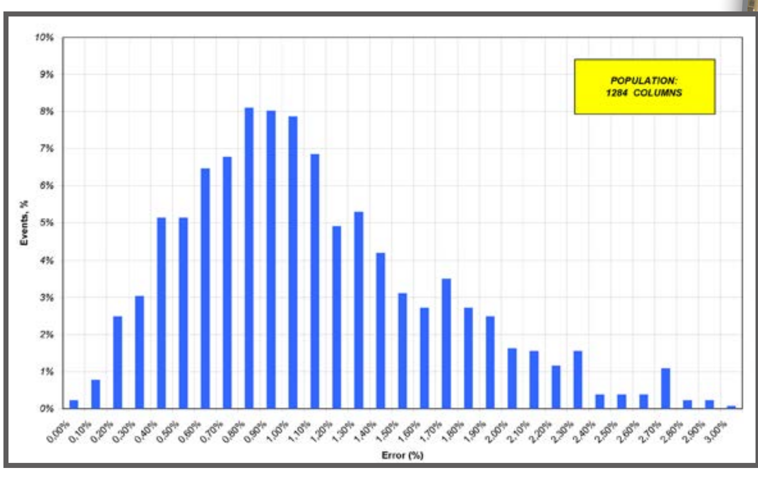
The installation of each jet grouting column was accurately monitored to minimize the potential requirements of additional closure columns. The bore deviation graph shows the accuracy of the drillings, with the majority of the columns deviated less than 1% from vertical.

The jet grouting technique was also successfully used to treat an unexpected ground condition at the South abutment of the A418 dike. At that location single fluid jet grouting was used to seal the unexpected fracture encountered at approximately 8





Drilling deviation distribution (Frequency vs. Deviation)

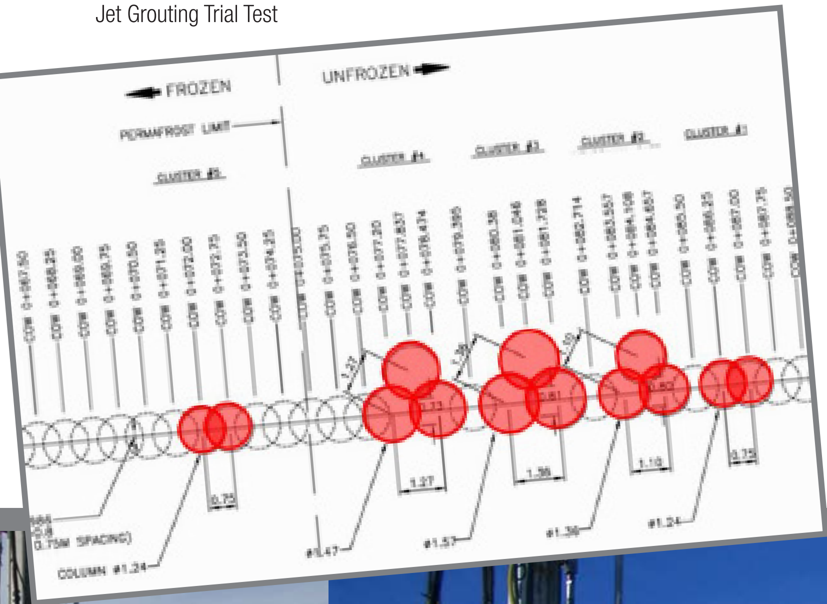


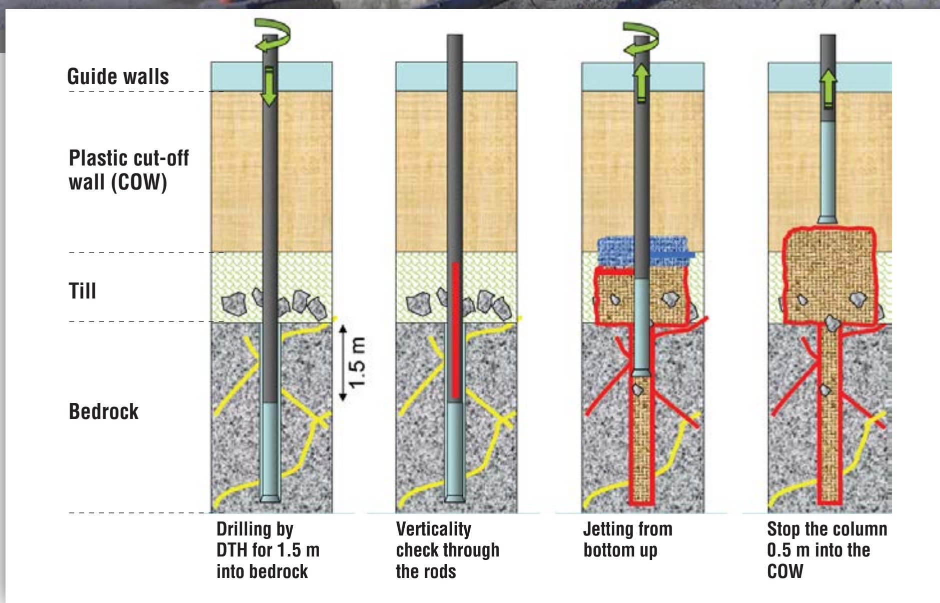
meters below the top of the bedrock, where the conventional rock grouting could not produce the required results.

The last challenge was the coordination among all the various contractors involved in the work. Daily coordination meetings were held between the jet grouting contractor, the pressure grouting contractor, the contractor performing ground-freezing at the termosyphon locations and the general contractor responsible for spoil removal, maintaining roads and providing logistical support to all those operations.

With a remarkable cooperative effort by all parties, the cut-off was finished on time and pumping of the impounded water began on September 4th 2006, allowing for the completion of dewatering ahead of the onset of the freezing weather.

Jet Grouting Trial Test






5,000 sq.m
of cutoff area
220 km
South of Artic Circle
24,100 m
drilling


- 50°C
minimum temperature
winds blowing up to
100 km/h
1,284 columns
jet grouting
(ø 1500 mm up to approx. 42 m depth)

TREVIFONDATIONS CANADA

1900A rue Cunard,
Laval (Quèbec)
Canada H7S 2B2
e-mail: **info@treviicos.com**
www.treviicos.com

TREVI
a TREVIGroup company

5819, via Dismano - 47522 **Cesena** (FC) - Italy
Tel. +39.0547.319311
Fax +39.0547.318542
e-mail: **intdept@trevispa.com**
www.trevispa.com