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Sent: Thursday, November 28, 2013 10:00 AM
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Subject: IE report comments - urgent

Robert/Ron and Scott

I am sending this email out and copying the SME's - hope you understand why .... I need some comments and suggested rewording of the attached section because it reads negative to me

It is urgent of course- pls send me the exact wording that we should send back to MWH

1.1 North Spur

1.1.1 General

The North Spur is a 1000 m long, 500 m wide and 45 m to 60 m high ridge that connects the Muskrat Falls rock knoll to the north bank of the river (Photograph 3). When the reservoir is impounded this feature will form a natural dam and become a major part of the river impoundment system. The feature is composed of unconsolidated mixed sand and marine silt/clay sediments. The depth to bedrock underneath the spur is in the range of 200 to 250 m. It contains a significant amount of glacio-marine silt/clay sediments, including horizons of highly sensitive clay strata, mixed with some sandy layers. The sensitive marine clays, which are similar to those found in Quebec and Norway, are susceptible to rapid strength loss, liquefaction and deep seated progressive rotational failures when overstressed.

The upstream and downstream slopes of this feature are subject to ongoing river erosion and mass wasting. This has contributed to local slope over-steepening of the slope, which triggers rotational sliding on both the downstream and upstream sides of the spur. Past studies indicate multiple small to large slide events have occurred during the recent centuries. A significant landslide took place on downstream slope of the North Spur in 1978 (Photographs 4 and 5). During 1980 it was determined that the natural mass wasting processes, could be arrested by controlling the water table with a pumped well system. A line of pumped wells was installed in the centre of the spur 1981 and continues to operate to present times.

1.1.2 Site Visit Observations

A brief site visit was made on September 24 to the plateau on top (Photograph 4) and the scarp of the 1978 slide (Photograph 5). The drilled wells were viewed and found to be in good condition. These are currently in operation. The slide is covered with vegetation indicating no significant activity for at least the past 25 years. As can be seen in photos, fine to medium sand is exposed in the crest of the slide scar. Large tilted and eroded blocks of cohesive soil could be seen at the toe (Photograph 6), adjacent to the river shoreline.

1.1.3 Stabilization Works

After reservoir impoundment, long term seepage and slope stability characteristics of the spur should be similar to a modern dam. Measures are needed to (a) control piezometric levels (b) control seepage across the weir and (c) stabilize the upstream and downstream slopes. The following measures are planned:

- Flatten both the upstream and downstream slopes to increase the overall safety factor against sliding failures.

- Rockfill and rip rap slope erosion protection will be placed on all areas of the upstream and downstream slopes. Stabilizing fill will be placed in selected areas of the downstream slope to improve local toe stability and reduce potential for retrogressive failures in sensitive marine clays of the Upper Clay unit.

- Construct an impervious fill blanket at the upstream slope and install a cut-off wall at the base of the blanket. This combined barrier will block water seepage into the spur from the reservoir. The cut-off wall (plastic cement slurry wall) will be connected to the impervious clay formation that extends beneath the river level.

- Construct a second cut-off wall across the north end of the spur to cut off seepage from the high ground north of the river. The upstream end of this wall will be connected to the cutoff wall of the upstream slope

- Construct toe relief drains and a major drainage trench for further lowering of the water table.

- Carry out long term monitoring of the piezometric conditions within the spur during operation of the reservoir. It is planned to augment the existing network of 29 piezometers with 15 additional ones. All piezometers will be instrumented with electronic sensors. Data will be recorded on a continuous basis and transmitted to NALCOR's headquarters in St John's.

Current plans are to continue operation of the dewatering wells for about two years after the reservoir is impounded. The situation will be studied during that time and, if warranted by piezometric conditions, the dewatering system may eventually be discontinued.

1.1.4 **Comments**

The stabilization works have been designed in accordance with currently accepted geotechnical design practices and will effectively stabilize the north spur when the reservoir is impounded. The upstream impervious blanket and the plastic cement slurry cut-off walls will control seepage and piezometric levels in the spur. Slope flattening excavations and the placement of lower slope weighting berms will enhance slope stability. Erosion control blankets of rockfill and rip rap will be placed on the upstream and downstream slopes to prevent natural erosion that would contribute to slope degradation and instability over time. The planned long term monitoring program is an important component of the works which will ensure safe operation of the reservoir and detect on a timely basis any anomalous behavior that may affect safe operations.

The IE has reviewed various aspects of the geotechnical designs and planned works. Detailed and rigorous investigations and laboratory testing of samples have provides accurate geotechnical and hydrogeological data. Equilibrium stability analyses have been carried out for the final slopes. Various materials assessments have been done to determine gradations of the various fill materials that will be used. These works have been augmented by a seismicity study, 2D seepage analysis and reservoir landslide generated wave height studies. All of this work has been carried out to a high standard.

Geotechnical design work continues at the time of writing and the final design report has not yet been issued. The recently issued "Cold Eye Review of Design and Technical Specifications, North Spur Stabilization Works" by Hatch has indicated that, among other things, additional work is recommended but is not essential to further enhance the design parameters for the sensitive clays and the overall seepage analysis assessment of the spur. MWH are advised that Nalcor is following the recommendations provided by the Cold Eye reviewers, which include the following:

- The review recommended that further work be done to assess cyclic softening of the geotechnically unique sensitive "upper clay" layers. Cyclic softening of the clay could reduce the shear

strength during an earthquake, resulting lower stability under seismic loadings. It could also trigger progressive overstressing in critical areas under static loading. It was noted that the previous soil testing gave contradictory data for the sensitive clay properties. Recommendations were made carry out undisturbed soil sampling and additional soil mechanics laboratory testing. The Hatch review also recommended that outside experts in sensitive clays be retained to contribute to this issue and that a literature review of sensitive clay data from other parts of Canada be carried out.

- The review recommended that a 2D FLAC finite difference dynamic analysis be done to determine the performance of the sensitive clay portions of the North Spur under earthquake loadings.

- It was recommended to carry out a 3D seepage analysis of the North Spur to augment the existing 2D assessment.

- Recommendations were made to install seepage measuring devices in some piezometer boreholes and to install borehole slope inclometers.

It is understood that proposals for the above works will be issued to Nalcor in the near future. The IE agrees with these recommendations and urges that work proceed on these items. The IE shares the opinion that more work is needed to confirm the properties and expected behavior of the sensitive clays in the North Spur. Data from the proposed work items will give more confidence in the current designs and should not result in any significant modifications to the planned works.

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