November 25, 2014

Imperial Metals Ltd.
580 Hornby Street
Vancouver, British Columbia
V6C 3B6

**Mr. Raj Anand, P.Eng.**
**Manager, Project Development**

Dear Mr. Anand:

**DSR - North Starter Dam**
**Independent Third Party Review**

## 1 INTRODUCTION

This is an independent third party review of the safety of the North Starter Dam (NSD) which is at the north end of the future tailings impoundment at the Red Chris mine (in development) about 18 km from Iskut, British Columbia. The location of the project is shown on Figure 1.1. This independent dam safety review is in response to the Chief Inspector's Orders on August 18, 2014. Those Orders were in response to the failure of the Mount Polley tailings dam on August 4, 2014. The Orders are attached as Appendix I. The Red Chris Development Corporation (RCDC) is the operator of the Red Chris mining project.

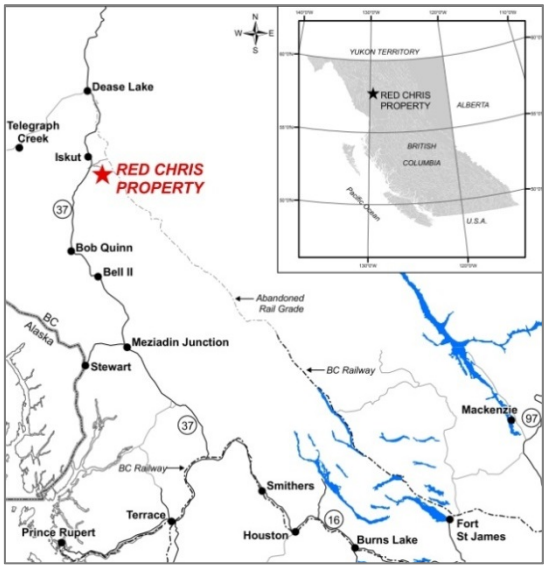


**Figure 1.1 Location Plan**

At the time of writing, the NSD does not retain tailings. The NSD Dam will become an integral part of the North Dam which will be built of compacted tailings using centreline construction techniques. The North Dam is one of three retention dams intended to store tailings for the projected mine life of 30 years. This dam safety report does not address the safety of the future tailings dam as that does not yet exist. All of the figures and data shown in this report are taken directly from reports by the designer.



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The purpose of this report is to confirm that the design of the NSD meets current good engineering practice, that the elements of a dam safety management system are in place, and that the dam is functioning safely according to its design intent. For the latter we rely on the Dam Safety Inspection report by BGC (2014). We inspected the dam at the same time as BGC staff on September 3rd and 4th, 2014. In this report, good engineering practice means that the design and operation of the dam meets the requirements of the Canadian Dam Association (2007)[1] Guidelines and the MAC (2013) TSM guideline for tailings.

The writer declares that he has the qualifications set out in "Professional Practice Guidelines - Legislated Dam Safety Reviews" by APEGBC to carry out Dam Safety Reviews in the province of British Columbia.

We also confirm that Mr. Todd Martin, P.Eng. has the qualifications set out in "Professional Practice Guidelines - Legislated Dam Safety Reviews" by APEGBC to carry out Dam Safety Reviews in the province of British Columbia. Mr. Todd Martin is the author of the BGC report "2014 Dam Safety Inspection Report" on which this report relies.

The following documents were relied on for this review:

- AMEC (2011) Red Chris Project, Tailings Storage Detailed Design Report, June 6;
- BGC Engineering Inc. (2014). Red Chris Tailings Facility, 2014 Dam Safety Inspection Report, Final Nov. 24;
- BGC Engineering Inc. (2014) Tailings Impoundment Area, Dam Breach and Inundation Study, Oct 31;
- BGC Engineering Inc. (2014). Tailings Impoundment Area, 2013 Construction Records Report, Draft, July 15; and
- BGC Engineering Inc. (2013). Stage 1 Tailings Impoundment Area Construction, July 23. (Construction Drawings)

## 2 PREVIOUS WORK BY REVIEWER AT RED CHRIS MINE SITE

The writer led and prepared a peer review report of the design of the tailings facility[2]in September 2014. As part of that review the writer read the extensive documentation for the design of the tailings facility. That report contains 22 recommendations some of which are adopted in the BGC Dam Safety Investigation where they apply to the NSD. As a result of that review we consider that:

- the design criteria for the static stability, seismic stability, and overtopping prevention meet current good practice; and
- the foundation characterization is adequate to design a dam to current good practice.

[1] Canadian Dam Association (2007). Dam Safety Guidelines with Mining Supplement (2014)
[2] Klohn Crippen Berger Ltd. (2104) Review of Tailings Impoundment Design, Red Chris Mine Site. Report to the Tahltan Central Council in October of 2014

This report only considers the safety of NSD at its most current reported crest elevation of El. 1097 m. The NSD will be raised to crest El. 1118 m and ultimately the North Dam will be raised to crest El. 1180 m and will envelope the NSD. Any conclusions in this report regarding the safety of the NSD to El. 1097 m do not apply to the future raises of the NSD and North Dam which must be evaluated independently with the operating and performance data at the time. The projected site in Year 3 is shown in Figure 2.1.

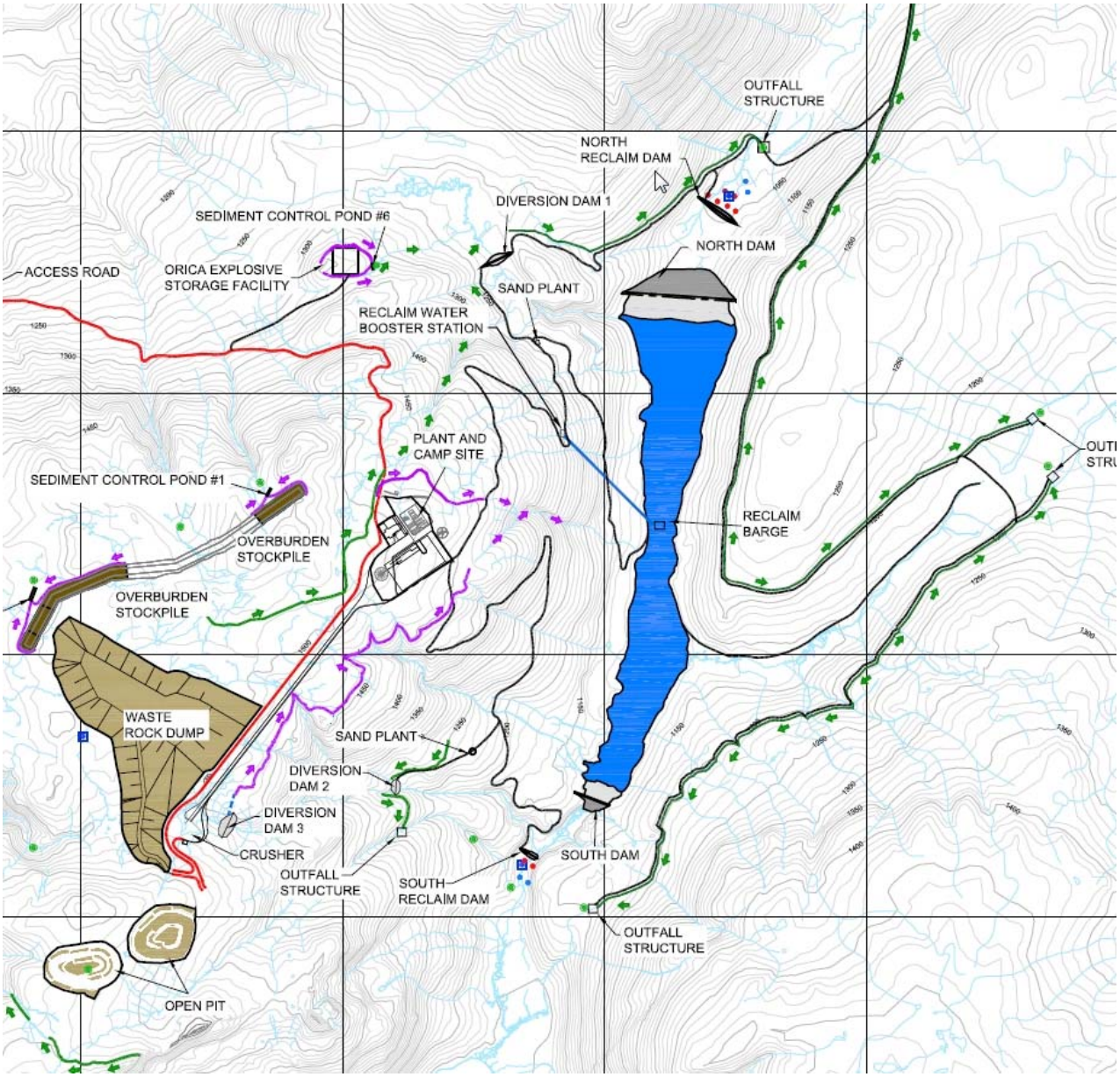


**Figure 2.1 Site Plan at Year 3. Grid is 1 km, north is up**

# 3 DESCRIPTION OF NSD

## 3.1 Introduction

A typical design section through the dam is shown in Figure 3.1. The NSD at a final crest elevation of 1118 m will be 43 m high with a 2.5H:1V downstream slope and the same upstream slope to El. 1097 m and 2H:1V above that. The dam was constructed to El. 1097 m in 2013. At the time of our site visit in September 3 and 4, 2014, the 2014 dam construction was just starting with the intention of raising the dam to at least 1104 m in 2014 and as high as 1109 m, weather permitting. We do not know the current height of the dam.

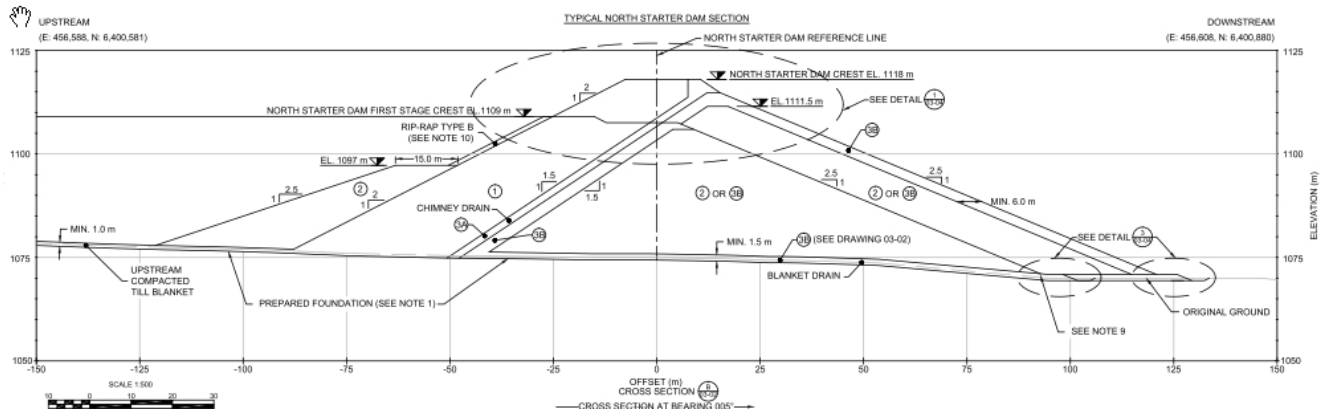


**Figure 3.1 Typical Section for NSD**

The dam section comprises an impervious sloping core (Zone 1), a filter (Zone 3A) and a drain (Zone 3B) with a supporting downstream granular shell. The filter/drain opposite the core is connected to finger drains which convey seepage to the toe of the dam. There will also be riprap on the upstream slope down to El. 1109 m.

The dam rests on dense, granular glacio-fluvial sediments to depth of 80 m. An impervious blanket extends from the core upstream to limit seepage gradients through the pervious foundation soils. As well as data from test hole logs the writer observed dense outcrops of sands and gravels upstream of the dam in exposed borrow areas. There were no indications of lacustrine deposits in the test hole logs or in the outcrops.

For this 2.5H:1V downstream slope with a dense granular foundation and properly functioning filter and drains, the Factor of Safety will be well in excess of 1.5. The static factor of safety for the existing condition, crest at El. 1097 m, was checked by the writer using Bishop and Morgenstern (1960)[3].

[3] Bishop, A.W. and Morgenstern, N. R. (1960) Stability Co-efficients for Earth Slopes, Geotechnique.

## 3.2 Design Criteria

In Canada, design criteria for dams are set based on the consequences of failure as estimated from an inundation study. Amec (2011) in their design report for the tailings facility assigned “Very High” consequence classifications to the North Dam and South Dam without an inundation study. At the same time, the designers assigned design criteria appropriate to an “Extreme” consequence of failure. The design criteria affected by consequence classification are seismic loading and flooding. The Maximum Credible Earthquake (MCE) was adopted and applied to the design as was the Probable Maximum Flood (PMF). The procedures used to estimate these design criteria were reviewed in our earlier report. The procedures meet acceptable standards although the rainfall records at site are sparse. Accordingly, we have recommended that at least one more climate station be installed in the valley which stores the tailings. In their DSI, BGC recommend that two more climate stations be installed. We agree with that recommendation.

Given that the design criteria for transient loads were assigned to the highest level of consequences, these criteria meet or exceed CDA Guidelines. Given the slopes of the NSD, the low seismic loading in the area, and the dense foundation soils and the compacted fills, the dam will not liquefy. The MCE (0.11 g) would only cause minor movements of the dam. Control of the PMF as recommended by BGC is described later.

## 3.3 North Reclaim Dam

The North Reclaim Dam downstream of the NSD was constructed to its target crest El. 1053 m in 2013. The maximum height of the dam is 7 m with a crest width of 11 m and crest length of about 330 m. The dam section is compacted glacial till upstream and sand and gravel downstream. The reservoir is partially lined with a glacial till blanket.

During the site visit of September 3 and 4 we noticed seepage discharge from the toe of the NRD. This seepage discharge was clear but represents an uplift force at the toe. As per our recommendation, the DSI recommends that an inverted filter be installed at the toe of the dam. The failure of the NRD would have little additional impact on the downstream environment relative to a moderate natural flood so is not evaluated further in this report.

## 3.4 2013 Construction

The construction of the North Starter Dam and the North Reclaim Dam are described in the BGC report by the same name. We inspected the dams in 2014 which included observations of preparation of the 2013 fill surface for 2014 fill placement. We have reviewed a sampling of available laboratory and field records and consider that the BGC report faithfully represents the dam as it exists now. The report documents changes to the specifications needed to adapt to borrow conditions in the field.

This dam will rely on the filter compatibility between the glacial till core and the downstream filter and drain. Filter compatibility is single most important aspect of the design and construction of these types of dams.

# 4 DAM PERFORMANCE

## 4.1 General

The primary failure modes for this type of dam are piping and overtopping. The dam instrumentation and inspection protocols need to be able to identify the development of these failure modes before they lead to failure. The piping failure mode can be monitored but only to detect, not prevent, piping. Prevention of overtopping can be done by ensuring that the impoundment has sufficient storage and release capacity for the anticipated design floods. This is discussed in the next section.

The instrumentation to monitor the behaviour of the dam consists of foundation piezometers and weirs. There are no inclinometers to measure displacements. The lack of inclinometers is entirely appropriate given that the foundation is dense, coarse fluvial sands and gravels interbedded with dense glacial tills and that the dam fills are compacted granular materials. Movements in these types of foundations are expected to be small and will not serve as a warning of the incipient piping or internal erosion.

There are three lines of piezometers at sections along the dam which are described in the DSI. The readings from these piezometers are plotted with time and against the rising reservoir level. As indicated in the DSI, these piezometers have not yet responded to the rising reservoir level even though the foundation is saturated. Some of the piezometers show a downward gradient even though a conventional seepage analysis would show an upward gradient at the toe. As stated in the DSI the foundation seepage is still dominated by the regional groundwater regime even though the pond is 16 m higher than the toe.

Piping or internal erosion is a process where seepage flow through incompatible materials leads to loss of fines from one material to another. This can manifest itself in cloudy seepage at the toe of dam and by sinkholes and depressions usually starting at the crest of the dam. In the DSI is reported a minor depression at the crest at Sta. 0+200 which is coincidentally over one of the finger drains. It is much too early to state that this depression is due to piping but seepage from this finger drain should be inspected for cloudiness and the size of the depression as the reservoir rises should be frequently and carefully monitored.

We understand that multiple weirs have been installed downstream of the dam to measure seepage flows. These were installed after our site visit of September 3rd and 4th, 2014. According to the DSI, additional weirs are also planned along the downstream toe of the NSD. Weirs along the toe of the dam should also be inspected for any accumulation of silt.

The addition of weirs to the monitoring program at the NSD is a welcome improvement. With other measurements in the list of recommendations in the DSI by BGC the water balance of the North Starter Dam and its associated North Reclaim Dam will lead to a better understanding of the seepage flows from the tailings dam during operation and closure.

## 4.2 Overtopping

In Section 8 of the DSI, BGC identified that the NSD does not have the capacity to store the 10 –day duration PMF coupled with a 1 in 100 year snowmelt in the spring of 2014 with the required freeboard. BGC state that RCDC is evaluating options for routing this flood so that it does not overtop the NSD. The options being considered are a spillway on the right abutment and additional pumping capacity. These options need to be resolved and implemented before the spring freshet in 2015. Since routing the PMF is part of the design criteria and is yet unresolved, it needs to be reported to the government when resolved.

# 5 DAM SAFETY MANAGEMENT

The Chief Inspector's Orders of August 18, 2014 require that the dam must have a Dam Break Inundation Study and an Emergency Preparedness and Response Plan (EPRP). Good practice in Canada, CDA (2007, 2014), also requires that the dam have an Operating, Maintenance, and Surveillance Manual.

A dam break inundation study has been prepared by BGC for this site which satisfies one of the above requirements. The inundation estimates were prepared for the full tailings dam height so meet all requirements for the existing NSD. That report recommends that the inundation report be used as a basis for an EPRP. We understand that an EPRP is being prepared but we have not seen that document. We also understand that an OMS manual is being prepared but have not seen that document.

# 6 RECOMMENDATIONS

The BGC DSI lists 15 recommendations. We agree with all 15 but stress that the last one, 2014-15, is required for the dam to meet the stated requirement to store and pass the PMF should it occur in 2015. Thus, currently the NSD does not meet design criteria so this deficiency must be corrected before the spring freshet in 2015.

Also, the crest depression at Sta. 0 +200 could be a sign of impending piping but it is much too early to make this judgment. Particular attention needs to be paid to the seepage emanating from the closest finger drain and any growth in the surface depression.

# 7 CLOSING

This letter report is an instrument of service of Klohn Crippen Berger Ltd. The letter report has been prepared for the exclusive use of Imperial Metals Ltd. for the specific application to the project "DSR - North Starter Dam – Independent Third Party Review". KCB has not been involved in the design, construction, operation or surveillance of this facility. KCB is not the Engineer of Record for this facility. The conclusions and recommendations contained in this report are KCB's opinion formed from review of limited information provided by the client as described in this report and a site visit. The letter report's contents may not be relied upon by any other party without the express written

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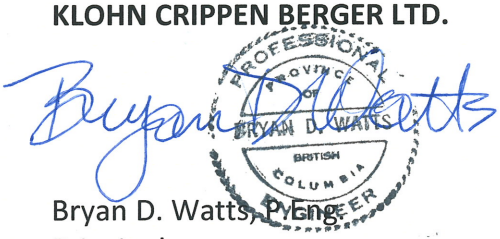
Yours truly,

**KLOHN CRIPPEN BERGER LTD.**




Bryan D. Watts, P.Eng.
Principal

BDW:dl

Attachment: BC Ministry of Energy and Mines – Notification of Chief Inspector's Orders

August 18, 2014

# Notification of Chief Inspector's Orders

## Tailings Dams – Independent Review of Dam Safety and Consequence Classification

As Chief Inspector of Mines, it is my responsibility to ensure that tailings dams in British Columbia are being designed, constructed, and operated in a safe manner. In light of the recent tailings dam failure at the Mount Polley mine on August 4, 2014, I am issuing the following orders for the purpose of reviewing the safety of tailings impoundment structures at mines throughout the province to establish where improvements may be required.

Owners, agents or managers responsible for tailings dams are being issued these orders pursuant to Section 18 of the *Mines Act*:

**Orders:**

*Dam Safety Inspection and Independent Third Party Review of Dam Safety Inspection*

1. You are required to conduct a Dam Safety Inspection (DSI) by December 1, 2014. The DSI must cover all dam structures for all tailings storage facilities on your mine site. The DSI must be conducted by a qualified professional engineer consistent with the BC Ministry of Energy and Mines Guidelines for Dam Safety Inspections.
   http://www.empr.gov.bc.ca/Mining/Permitting-Reclamation/Geotech/Documents/Guidelines_for_Annual_Dam_Safety_Inspections(RevisedAug2013).pdf

2. The mine manager must have the DSI reviewed by an independent qualified third party professional engineer from a firm that has not been associated with the tailings dam. The Independent Third Party Review of the DSI must also include a review of the dam consequence classification.

3. Both the DSI and the Independent Third Party Review of the DSI must be sealed by the qualified licensed professional engineers who conducted the work.

4. Any recommendations made in the DSI or the Independent Third Party Review of the DSI must be summarized in an accompanying letter from the Mine Manager to the Chief Inspector outlining the commitments for completing the recommended work along with a schedule for implementing the recommended work.

5. The DSI, Independent Review of the DSI, and the mine manager's letter to the Chief Inspector must be submitted to the Chief Inspector by December 1, 2014.

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**Ministry of Energy and Mines**

**Health, Safety and Permitting Branch**

**Mailing Address:**
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**Victoria, BC V8W 9N3**
**Ph: 250-952-0793**
**Facsimile: 250-952-0491**

**Location:**
**Sixth Floor**
**1810 Blanshard Street**
**Victoria, BC V8W 9N3**

*Emergency Preparedness and Response Plan and Dam Break Inundation Study*

6. All tailings dams that have a failure consequence classification of high, very high or extreme (and taking into account any change in dam classification resulting from the Independent Third Party Review of the DSI under Orders 1 through 5), must have an Emergency Preparedness and Response Plan (EPRP) and a Dam Break Inundation Study.

7. The EPRP and Dam Break Inundation Study must be completed and tested consistent with the Canadian Dam Association, Dam Safety Guidelines (CDA Guidelines). If the tailings facility already has an existing EPRP, it must be reviewed and updated for consistency with the CDA Guidelines and with current standards of engineering practice.

8. The Dam Break Inundation Study must be prepared by a qualified licensed professional engineer. The EPRP must be informed by the Dam Break Inundation Study with input from the qualified licensed professional engineer.

9. The Dam Break Inundation Study, the EPRP, and a summary of the EPRP test including any identified gaps and lessons learned from the EPRP test, must be submitted to the Chief Inspector by December 1, 2014.

The Ministry of Energy and Mines will be placing reliance on the seal of the qualified professionals undertaking the above work. In addition, all submitted reports and reviews that are submitted to satisfy these orders will be subject to additional review by Ministry of Energy and Mines geotechnical engineers and/or their consultants. As well, in the interest of transparency and the public interest, all submitted documents related to these orders will be made available to the public.

Sincerely,

Al Hoffman, P.Eng.
Chief Inspector of Mines