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NIRB file # - 08MN053
NRCan file # - NT- 098

September 23, 2019

Nunavut Impact Review Board
PO Box 1360
Cambridge Bay, NU, X0B 0C0

Via electronic mail to: info@nirb.ca
Dear Madams and Sirs,
Re: Natural Resources Canada's Final Written Submission for the NIRB's Review of Baffinland Iron Mines Corporation's "Phase 2 Development" Proposal

Natural Resources Canada (NRCan) is participating in the review of the "Phase 2 Development" Proposal for the Mary River Mine under the *Nunavut Planning and Project Assessment Act*. On November 23, 2018, NRCan submitted four information requests (IRs) on permafrost and terrain stability, primarily related to the Northern Railway Corridor, for the NIRB's consideration. NRCan received responses to these information requests on December 19, 2018. NRCan reviewed the Proponent's responses and submitted technical comments related to terrain and permafrost conditions as well as thermal modelling and analysis on March 7, 2019.

NRCan is submitting its final written submission summarizing its review of the proposal related to NRCan's areas of expertise. NRCan appreciates this opportunity to comment on the application. Should you have any questions related to NRCan's review, please do not hesitate to contact me at peter.unger@canada.ca.

Sincerely,

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Final Written Submission

Mary River Mine “Phase 2 Development” (NIRB File No. 08MN053)

Natural Resources Canada

Submission to the Nunavut Impact Review Board

September 23, 2019

Executive Summary

Natural Resources Canada (NRCan) participated in the assessment of Baffinland Iron Mines Corporation's (BIMC) proposed Phase 2 Development at the Mary River Mine as a federal department with expertise in permafrost and terrain stability. NRCan reviewed the Final Environmental Impact Statement (FEIS) Addendum and provided information requests and technical comments on terrain and permafrost conditions in the Northern Railway Corridor, and thermal modelling to support design of the railway embankment.

BIMC has agreed to conduct larger-scale detailed terrain analysis and to measure ground temperature to improve characterization of the ground thermal regime. NRCan's specific recommendations are that the mapping program be conducted in areas where the railway deviates from the road, that the winter 2019/20 drilling program be conducted to obtain additional subsurface data, and that the pre-drilling program be conducted to improve delineation of ice-rich areas, including thermistor installation.

NRCan also recommended thermal analysis and modelling, with ongoing measurement of ground temperatures and changes in surface elevation to support the detailed design of the railway embankments. After information on existing thermal analysis and modelling was provided by the Proponent, NRCan recommended continued refinement of the thermal, creep and stability analysis and development of monitoring programs through incorporation of new information collected. NRCan also recommended incorporating the effects of local factors into the 2D thermal modelling and the establishment of instrumented sites prior to construction. The Proponent responded that these recommendations will be incorporated into future thermal modelling and analysis and NRCan agrees with this approach. NRCan maintains its recommendations and also suggests that BIMC follow the recommendations made by the Proponent's geotechnical consultant, who prepared the design memo for the Northern Railway Corridor.

NRCan appreciates the opportunity provided by the Nunavut Impact Review Board to participate in this review. We would be pleased to answer any questions regarding our comments from the Board, its staff, the Proponent, or other Parties to this review.

Contents

1. Introduction

Natural Resources Canada (NRCan) has been participating in the environmental assessment of the proposed "Phase 2 Development" Project at the Mary River Mine in the context of its role as a federal department with expertise in permafrost and terrain stability. Below is a summary of NRCan's review of project information provided to date, and NRCan's final comments on the environmental assessment of the Phase 2 Development.

1.1. NRCan's Mandate

NRCan seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products. We are an established leader in science and technology in the fields of energy, forests, and minerals and metals and use our expertise in earth sciences to build and maintain an up-to-date knowledge base of our landmass. NRCan develops policies and programs that enhance the contribution of the natural resources sector to the economy and improve the quality of life for all Canadians. We conduct innovative science in facilities across Canada to generate ideas and transfer technologies. We also represent Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources.

1.2. NRCan's Participation in the Review of the Phase 2 Development Proposal

NRCan conducted a technical review to assess the technical merit of the information presented in Baffinland Iron Mines Corporation's (BIMC) Final Environmental Impact Statement Addendum (FEIS Addendum) for the Phase 2 Development submitted to the Nunavut Impact Review Board (NIRB) on October 5, 2018. NRCan provided four information requests for the NIRB's consideration on November 23, 2018. NRCan received responses to these information requests on December 19, 2019. NRCan reviewed the Proponent's responses and submitted technical comments related to terrain and permafrost conditions as well as thermal modelling and analysis on March 7, 2019. NRCan has also considered the additional information provided by the proponent on July 5 and 29, 2019.

1.3. NRCan's Role as a Regulator

NRCan issues licences for the storage and manufacturing of explosives under Section 7(1) of the *Explosives Act*. An emulsion plant currently operates at the Mary River mine site under a factory licence issued to the mine's explosives supplier. For the Phase 2 Development proposal, it is anticipated that licences will be required for explosives magazines situated at three storage areas along the Tote Road together with a new factory licence for a second emulsion plant to be constructed north of the waste rock pile.

2. Specific Comments

The Final Environmental Impact Statement (FEIS) Addendum was initially reviewed to determine if any additional information was required to complete the technical review. NRCan has reviewed BIMC's responses and commitments as well as new information provided in response to technical comments. A summary of NRCan's review is presented, as well as some additional comments with respect to the advanced design stages for the project.

2.1. Permafrost and Terrain Stability

NRCan's review focused on the terrain sensitivity and permafrost issues and design of project components for which these aspects of the physical environment are important. NRCan conducted a preliminary review of documentation submitted to NIRB by Baffinland Iron Mines Corp. (BIMC) in support of an Addendum to the Final Environmental Impact Statement for the Mary River Project. Phase 2 of the project includes construction and operation of a Northern Railway Corridor and modifications to the Milne Port area to accommodate additional volumes of iron ore. The objective of this preliminary review was to determine if the EIS and supporting documents contained adequate information for NRCan to conduct a technical review. The review focussed on terrain and permafrost aspects of the project and their relevance to project design, in particular the Northern Railway Corridor, and the assessment of environmental effects. NRCan submitted information requests to seek clarifications necessary to complete a technical review.

BIMC submitted an Information Request Response Package to NIRB in Dec. 2018. NRCan reviewed the responses to its information requests as well as responses to requests made by other parties (e.g. CIRNAC, QIA, GN) that were relevant to permafrost and terrain aspects of the project. These responses provide clarification regarding work conducted to determine baseline conditions in the Northern Railway Corridor and the analysis conducted (or planned) to support the project design and impact assessment. These clarifications allowed NRCan to proceed with its technical review. However, NRCan noted the responses to NRCan IR 2 and 3 (as well as similar ones submitted by other parties) indicated that the information requested would be provided in the Proponent's technical response and therefore after the submission of NRCan's technical review comments. For NRCan IR 2, BIMC indicated that ground thermal data have been collected at bridge locations and would be provided in the technical response. For NRCan IR 3, BIMC stated that thermal analysis had been conducted in support of the North Railway design and a report would be provided with technical responses. NRCan was therefore unable to fully evaluate the analysis conducted by the Proponent and the initial comments and recommendations submitted by NRCan in March 2019 reflected this.

The Proponent provided responses to technical comments submitted by NRCan and other parties in March 2019. Some of these responses referred to a report that was being prepared on Geotechnical Recommendations for the Northern Railway. This report was provided on April 26 2019. NRCan has reviewed the additional material and has provided its final technical comments (conclusions) and recommendations (June 5 2019). These are provided below NRCan's initial comments and recommendations submitted in March 2019.

NRCan received a response to its June 2019 comments from the Proponent in early July 2019. NRCan has provided further comments and recommendations considering these responses below its June 2019 comments and recommendations. Initial comments are in black text, comments from June 2019 are in blue, and NRCan's final comments are in red.

2.1.1. Documents Reviewed

Project Summary Baffinland Mary River Project Phase 2 Proposal
Addendum to the Baffinland Mary River Project Final Environmental Impact Statement – Phase 2 Proposal (submitted to NIRB Aug. 18, 2018) – Main EIS document +appendices
Technical Supporting Documents (TSD) Phase 2 Proposal: 1, 2, 6, 8, 28
Response to Information Requests Submitted by BIMC Dec. 2018

Additional documents reviewed that were provided in response to technical comments:
BIMC Response to Technical Comments of NRCan and other parties
Geotechnical Recommendations for Northern Railway, submitted April 26 2019

2.1.2 Issue 1: Terrain and permafrost conditions in the Northern Railway Corridor

Reference:
EIS Guidelines 6.2, 6.4.6.1, 8.1.4, 8.1.7
EIS: Main Document, TSD 2, 8

Additional documents reviewed following submission of technical comments
Response to NRCan-01(March 2019)
Geotechnical Recommendations Report (App. G, H)
Response to NRCan-01 (June 2019)

Issue
Permafrost is present throughout the proposed Northern Railway Corridor and will provide a foundation for the infrastructure. Information on terrain characteristics, including surficial geology and permafrost conditions (such as ground ice and thermal regime), is required to adequately design infrastructure and to determine impacts of the project on the environment and the environment on the project. Construction and operation of project infrastructure can result in changes to the ground thermal regime and subsequent warming and thawing of permafrost. This can have impacts on terrain stability (particularly where permafrost is ice-rich), infrastructure performance and ecosystems.

Proponent's Conclusion
The Proponent has utilized existing Geological Survey of Canada geology maps and interpretation of air photos to characterize terrain conditions in the Northern Railway Corridor (e.g. TSD 2, Att. 6.1, App. A, C). They have also conducted geotechnical investigations, including borehole drilling and geophysical surveys to further characterise the subsurface conditions (TSD 2, Att. 6.2, App. A,B,E,F,J; TSD 8). These investigations have facilitated delineation of areas along the corridor where ice-rich permafrost is likely to exist. They indicate (response to IR NRCan-1) that the terrain analysis is complete and therefore sufficient to support this stage of the design. Although information on ground thermal conditions has been collected elsewhere in the project area, the EIS did not present any information for the corridor. The Proponent indicated in response to IR NRCan-2 that ground thermal data have been collected at bridge locations and the information would be provided with the technical response.

NRCan's Initial Conclusion
NRCan agrees that for the most part, the terrain characterization follows a similar approach utilized for other projects. The Proponent has integrated information from the borehole logs and geophysical surveys with the air photo analysis to facilitate the terrain characterization. NRCan commented in IR NRCan-1 that the terrain maps presented are not at a scale that is normally provided for detailed terrain mapping along infrastructure corridors. The maps provided do show areas of potentially ice-rich terrain, such as areas where patterned ground is observed or surficial units where there is potential for segregated or massive ice (e.g. lacustrine or glaciofluvial sediments). They also highlight a few areas where small water bodies provide evidence of thermokarst. However, other information regarding terrain sensitivity or potential indicators of instability normally included on detailed terrain maps was not provided. This usually includes information on drainage, slope instability, erosion and areas of thermokarst. NRCan agrees that the Proponent may have provided this information separately in various formats including summary tables, maps and air photos (TSD 2). However, the Proponent may find it beneficial during the detailed design stage, to produce large scale alignment maps showing detailed terrain mapping along with characterization of terrain sensitivity including locations of terrain instability in addition to areas of ice-rich terrain. This would be useful in identifying problematic areas that may require attention in the design and for planning environmental monitoring and management programs.

NRCan understands that the Proponent has collected ground temperature information in parts of the project area such as the proposed southern railway corridor, the mine site and the Milne Port (TSD 8). However there was no ground temperature information provided for the Northern Railway Corridor. It appears, based on the response to IR NRCan-2, that some ground temperature information has been collected at bridge locations and will be provided later. Since ground temperatures are in part influenced by distance from water bodies, this information will be particularly important in informing the design of important infrastructure at water crossings. However information has not yet been provided for NRCan to understand the ground thermal conditions in these potentially sensitive areas of the corridor.

It is not clear whether instrumentation will be installed elsewhere in the corridor to support infrastructure design or as part of future monitoring programs. NRCan agrees that the ground temperature data collected in other parts of the project area or in the region (e.g. Smith et al. 2013; Ednie and Smith 2015) is sufficient to support feasibility assessments and initial design. However, it would be advantageous to acquire site specific information to characterize ground thermal conditions within the corridor to support decisions with respect to embankment design. This information is also useful to assess the impact of the presence of the embankment including the thermal effects that may result from snow accumulation or changes in drainage and subsequent effects on the ground thermal regime adjacent to the embankment and beneath the side slopes.

Initial Recommendations

NRCan recommends the following to support detailed design and environmental monitoring and management programs

- Conduct larger scale detailed terrain analysis including terrain sensitivity characterization and identification of problematic areas including areas of instability, potential erosion, drainage issues or thermokarst.
- Install instrumentation to measure ground temperature for characterization of ground thermal regime.

References

Ednie, M., Smith, S. L. (2015) Permafrost temperature data 2008-2014 from community based monitoring sites in Nunavut. Geological Survey of Canada Open File, 7784. doi:10.4095/296705

Smith, S. L., Riseborough, D. W., Ednie, M., Chartrand, J. (2013) A map and summary database of permafrost temperatures in Nunavut, Canada. Geological Survey of Canada Open File 7393. doi:10.4095/292615

NRCan's June 2019 Conclusion

NRCan had suggested to the Proponent that it would be beneficial to do larger scale terrain sensitivity mapping of the railway corridor that includes other indicators of potential instability or drainage issues that might influence infrastructure design. While preparation of such a map is not essential, what is important is that the Proponent has delineated all areas of problematic terrain where ground instability or drainage issues might occur along the proposed corridor that might require attention in the infrastructure design. NRCan also realizes that as design for the railway advances, additional site specific investigations will be conducted which will improve characterization of the terrain characteristics in the corridor. The Geotechnical Recommendations report has acknowledged that there are some sections of the corridor for which information on subsurface materials is limited and they suspect that excess ice may be present. Hatch, the authors of the report, has recommended that additional field investigations may be required to confirm permafrost conditions including ground ice content and settlement potential, to inform final alignment and infrastructure design. NRCan agrees with this recommendation.

NRCan had commented that there was limited information on ground thermal conditions along the corridor. NRCan had recommended that instrumentation to measure ground temperatures be installed to improve characterization of the ground thermal regime to inform decisions with respect to embankment design. In response to NRCan-01, the Proponent stated that temperature cables had been installed at proposed bridge abutments and also instrumentation would be installed as part of the railway operation and maintenance management plan. In the Geotechnical Recommendations report (e.g. App. G, H), Hatch has indicated that if more ground temperature data were available, boundary conditions could be better estimated in thermal modelling utilized to inform infrastructure design. NRCan agrees that it would be beneficial to have more ground temperature data to improve characterization of ground thermal conditions in the corridor. Although the Proponent has indicated that thermistors will be installed as part of their monitoring and management plans, NRCan suggests that it would be useful to install this instrumentation in the corridor prior to construction so that the information acquired could be utilized to inform infrastructure design including the implementation of any mitigation required to ensure infrastructure performance and to minimize impacts on the environment.

NRCan's June 2019 Recommendations

NRCan recommends the following to support detailed design and environmental monitoring and management programs:

- Conduct additional field investigations (including borehole drilling), as recommended by Hatch, particularly in sections of the corridor with limited data and where permafrost is potentially ice-rich, to confirm permafrost conditions and inform final alignment and infrastructure design.
- Install additional instrumentation along the corridor to measure ground temperatures to improve characterization of the ground thermal regime and inform infrastructure design. It is suggested that this instrumentation be installed prior to construction to support final design as well as the railway operation and management plan.

NRCan's Final (July 2019) Conclusion

In response to NRCan's comments the Proponent has outlined the field investigations planned that will facilitate the mapping of additional areas where the railway corridor will deviate from the existing road. Additional boreholes will be drilled 2019/20 in these areas to provide additional information on subsurface conditions. They have also indicated that additional boreholes will be drilled during construction but prior to earthworks (pre-drilling program) to improve delineation of ice-rich areas and to determine appropriate measures required to deal with ice-rich permafrost prior to any excavation of cuts or placement of embankment fill. Installation of thermistors are also planned during 2019/20 and pre-drilling programs. Data acquired from the thermistors will be utilized to characterize the baseline ground thermal conditions prior to construction. NRCan finds the Proponent's approach to be reasonable and encourages them to follow through on the proposed plans.

NRCan's July 2019 Recommendations

NRCan recommends that the Proponent follow through on the plans outlined in their response to NRCan to support detailed design and environmental monitoring and management programs. Specifically NRCan recommends the Proponent:

- Conduct the summer 2019 mapping program in areas where the railway corridor deviates from the road
- Conduct the winter 2019/20 drilling program, described in their response, to obtain additional subsurface data to support design
- Conduct the pre-drilling program, described in their response, to improve delineation of ice-rich areas to support implementation of appropriate measures to deal with permafrost conditions prior to cuts or embankment construction
- Install thermistors during the 2019/20 and pre-drilling programs to establish baseline conditions along the corridor prior to construction.

2.1.3 Issue 2: Thermal analysis/modelling to support railway embankment design

Reference:
EIS Guidelines 7.2.1, 8.1.7, 9.4.14
EIS Main Document, TSD 2, 6, 8

Additional documents reviewed following submission of technical comments
Response to NRCan-01, -02 (March 2019); QIA-25 Att. 1; QIA- 24, 26; CIRNAC-02 Att. 2
Geotechnical Recommendations Report (including App. D,E,F,G,H)
Draft Railway Operation and Maintenance Management Plan
Response to NRCan, including attached design memo (June 2019)

Issue

Construction and operation of infrastructure can have impacts on the ground thermal regime that can lead to permafrost warming and thawing and subsequent ground instability and settlement which can affect infrastructure performance. Climate change can exacerbate these impacts on the ground thermal regime. An understanding of the current ground thermal regime and how it may change over time is therefore essential for adequate design of the Northern Railway embankment to limit thawing of foundation soils. Such information is also required to determine aggregate needs for ongoing maintenance of embankments and therefore footprints of borrow and quarry areas and the impact of the project on the environment.

Proponent's Conclusion

The Proponent recognizes that the ground thermal regime may be altered in response to infrastructure construction and operation as well as a changing climate (e.g. TSD 6, TSD 2) Estimates of embankment settlement and design options to deal with this have also been provided (TSD 2, Att. 5.2, Table 6-2). The railway alignment does avoid potentially thaw sensitive soils in some areas of the corridor (TSD 2, 8). The Proponent has indicated that where the route crosses areas where ice-rich permafrost is likely present, cuts will be avoided and an embankment thickness of 1500 mm will be utilized (TSD 2 Att. 6.3 Table 7.1). There were no results of thermal analysis to support embankment design presented in the EIS. In response to IR NRCan-3 and those of other parties, the Proponent has indicated that some thermal analysis was being conducted and they are also completing long-term settlement calculations and these reports will be provided once completed as part of the technical response . Climate change will also be incorporated into updates of thermal models (response to IR CIRNAC-14).

NRCan's Initial Conclusion

NRCan generally agrees with the approach for the embankment design. The Proponent has (as discussed in Issue 1), characterized the terrain sensitivity along the route and have indicated that thicker embankments will be required where there is potential for thaw settlement. Since no results from thermal analysis have been provided it is a bit unclear how potential thaw settlement has been estimated and whether the proposed embankment thicknesses will be sufficient or whether future borrow needs for maintenance have been adequately estimated. Recent permafrost warming in response to increases in air temperature has been observed in the region (e.g. Smith et al. 2015; Romanovsky et al. 2018). There are also sections of route that cross ice-rich terrain including areas underlain by massive ice several metres thick, as noted in borehole logs and geophysical surveys (TSD 2, Att. 6.2, App. A,B,E,F,J). A good understanding of how the ground thermal regime and thaw depth may change over the operating life of the railway is therefore important for informing the stability and creep analysis and implementation of mitigation measures. In addition to the effect of climate fluctuations, changes to the ground thermal regime resulting from the presence of the embankment including snow accumulation and potential for meltwater ponding as well as other changes to drainage would also need to be considered in the thermal analysis. NRCan realizes that the Proponent may have acquired some information regarding potential changes to ground thermal regime and thaw settlement from monitoring of the performance of the Tote Road embankment. However, NRCan assumes there will be differences in embankment design for the railway as well as the level of tolerance for deformation.

NRCan is supportive of the thermal analysis and modelling the Proponent has indicated (response to IR NRCan-3, CIRNAC-14) they have conducted or intend to conduct. This analysis will be critical for design of bridges at water crossing but also for overland sections of the route that cross ice-rich permafrost. However, since the details will only be provided in the technical response it is not possible for NRCan to evaluate the Proponent's analysis. NRCan would suggest that the detailed and final design be informed by the results of the thermal analysis. NRCan also suggests that this analysis should incorporate any ground thermal data collected within the proposed corridor as well as any information on recent changes in ground thermal conditions that may be available from temperature measurements elsewhere in the project area. The Proponent should also consider 2-D thermal modelling as this would facilitate assessments of the impact of snow accumulation that may occur on the windward side of the embankment as well as impoundment of water that might occur following snow melt or other changes in drainage caused by the presence of the embankment. This would facilitate the characterization of potential changes in the ground thermal regime adjacent to the embankment or beneath the side slopes and the implications for differential movements and deformation. ongoing measurement of ground temperatures and changes in surface elevation would be important components of the performance monitoring program as well as environmental monitoring and management programs.

Initial Recommendations

NRCan recommends the Proponent consider the following to support detailed and final design of the railway embankments:

- Thermal analysis and modelling to support stability, creep and thaw settlement analysis for design of water crossings and also to support embankment design for overland sections of the route. The incorporation of ground temperature information collected along the route along with that collected elsewhere in the project area that facilitate quantification of fluctuations in ground thermal conditions should also be considered.
- 2D thermal modelling in order to understand the potential impacts of the presence of the embankment, in additional to climate effects on the thermal regime adjacent to the embankment and beneath the side slopes.
- The implementation of a monitoring program that includes ongoing measurement of ground temperatures and changes in surface elevation as part of the performance monitoring and environmental monitoring and management programs.

References

Romanovsky, V. E., Smith, S. L., Isaksen, K., Shiklomanov, N. I., Streletskiy, D. A., Kholodov, A. L., Christiansen, H. H., Drozdov, D. S., Malkova, G. V., Marchenko, S. S. (2018) [Arctic] Terrestrial Permafrost [in "State of the Climate in 2017"]. Bulletin of the American Meteorological Society (supplement) 99 (9):S161-S165. doi:10.1175 /2018BAMSStateoftheClimate.1

Smith, S. L., Lewkowicz, A. G., Duchesne, C., Ednie, M. Variability and change in permafrost thermal state in northern Canada. Paper 237 In: GEOQuébec 2015 (Proceedings 68th Canadian Geotechnical Conference and 7th Canadian Conference on Permafrost), Québec, 2015. GEOQuébec 2015 Organizing Committee

NRCan's June 2019 Conclusion

At the time of NRCan's initial review, the Proponent had not provided details of the thermal analysis and modelling that had been conducted to support thaw settlement, creep or stability analysis required to inform infrastructure design, including embankment and bridge design. The Proponent did indicate in response to NRCan-02 that thermal analysis had been completed and details would be provided in a subsequent report. Additional information was provided in response to technical comments (e.g. QIA-25 Att. 1; CIRNAC-02 Att. 2) and the Geotechnical Recommendations report.

Thermal analysis has been completed with consideration of climate change for a 20 year period (2019-2039), for fills, cuts, culverts and bridge abutments (e.g. Geotechnical Recommendations Report, App. F,G,H; Response to QIA-25 Att. 1). These analyses have been utilized for example to determine if there is any detrimental effect on permafrost for various embankment thicknesses (App. F). NRCan agrees the modelling approach is reasonable for this stage of design and will allow initial estimates of ground thawing that might occur over a 20 year period. Although 2D thermal modelling has been utilized in most cases, for the bridge foundation design a 1D model has been used. The Proponent has indicated that advection in the overlying body has not been considered but conservative adjustments have been made for active layer thickness based on available ground temperature data, which is limited to two of the four bridge sites (Response to QIA-25 Att.1). Given that ground temperatures can vary with distance from water bodies, it would be beneficial to use 2D thermal modelling as design advances to better characterize current and future ground thermal conditions.

The Proponent has indicated (e.g. Geotech. Rec. Rept., App. G) that typical thermal parameters from literature and historical information from the site was utilized. They propose reviewing their analysis when additional data is made available from for example, future site specific geotechnical investigations (see Issue 1). NRCan agrees with this approach and encourages the Proponent to continue to revise parameters as further information is available and revise their thermal analysis accordingly. The Proponent has also indicated that local factors were not modelled that could impact the ground thermal regime such as slope and aspect, ground water conditions and presence of surface water (e.g. Geotech. Rec. Rept App. G). As design progresses it is suggested that the Proponent incorporate site specific factors into the thermal analysis to refine the design of the railway including embankment and culvert design. NRCan also suggests that the Proponent consider the potential for snow accumulation adjacent to the embankment or where surface topography has been modified by cuts. In the thermal modelling for cuts for example (NRCan assumes a similar case for fills), winter n-factors used are relatively high which would be the case for areas that are wind blown or have thin snowcover, where winter ground conditions would be colder (Geotech. Rec. Rept App. G). However, in areas where snow may accumulate, winter n-factors would be lower as the ground is insulated from cold winter conditions, resulting in warmer winter ground conditions. The accumulation of snow and potential for ponding of water during melt, can have implications for the ground thermal regime beneath the embankment side slopes and also their stability. It is suggested that these effects be considered in the thermal analysis as design advances.

Thermal modelling has been done for a 20 year period (includes climate warming), which NRCan assumes is to cover the operating period of the railway. However, temperature changes that occur at the surface, take time to propagate to greater depths. Modelling over a longer period is therefore suggested to account for any residual effects on the terrain resulting from construction and operation of infrastructure and fluctuations in climate. Consideration of longer time period would also be beneficial, should the railway need to operate to a later future time due to delays in construction or if the railway operating life should be extended to accommodate development of other deposits.

The Proponent has conducted creep and slope stability analysis (Geotech. Rec. Rept. App. D, E). A conservative approach has generally been used which is reasonable given that information on some parameters may be limited. It is however unclear from the information provided whether the Proponent has considered that ground temperatures may increase over the operating period of the railway. For the creep settlement analysis it appears that a ground temperature of -7°C at the depth of zero annual amplitude has been utilized. Warming at depths of 15 m (0.5 – 0.7°C per decade) has been observed in the region over the last decade (Romanovsky et al. 2018). As design advances it is suggested that the creep and slope stability analysis incorporate the results of the thermal analysis, including climate warming.

A revised Draft Railway Operation and Maintenance Management Plan was submitted recently. This document provides more details on the additional monitoring that will be required above the normal railway standard due to the sensitivity of permafrost environments to changes in the ground thermal regime. The Proponent plans to install instrumentation to monitor ground temperatures and ground movements such as thermistors, survey monuments, inclinometers and also conduct LiDAR surveys. Instrumented test embankment fill sections will be included in the plan. NRCan is supportive of this approach. The information acquired from planned geotechnical investigations and instrumentation prior to construction will also help to identify problematic areas where monitoring will be critical and potential locations for test sections. It is suggested that it would be beneficial to install instrumentation, including in areas adjacent to proposed embankments, prior to construction to better characterize pre-construction conditions and also establish a baseline against which change can be measured. This will facilitate the assessment and attribution of impacts that may arise due to construction of the embankment, fluctuations in climate or alterations in snow cover and drainage and therefore inform mitigation decisions. Thresholds and triggers to determine when mitigation is required are to be developed in future geotechnical monitoring programs.

NRCan's June 2019 Recommendations

NRCan recommends the following as design advances:

- Continue to refine the thermal, creep and stability analysis and development of monitoring programs through incorporation of new information collected from proposed geotechnical investigations and new instrumentation.
- Incorporate effects of local factors into the 2D thermal modelling to support detailed design of embankments and water crossings such as potential for snow accumulation and presence of water bodies. Incorporation of these results into thaw settlement estimates and creep and slope stability analysis is also recommended.
- Consider establishment of instrumented sites prior to construction to establish pre-construction baseline conditions to better assess and attribute impacts related to the railway and to determine appropriate mitigation that may be required should established thresholds and triggers be exceeded.

NRCan Final (July 2019) Conclusion

NRCan had made a number of recommendations (June 2019) with respect to the thermal, creep and stability analysis that is required to support detailed and final design of the railway embankments and water crossings. In their response, BIMC addressed each recommendation and also provided (as an attachment) a design memo from Hatch that provided results of their analysis on the impact of climate warming (increase in air temperature) on railway cut sections and pile foundations, including those used for bridges. The original analyses considered a 20 year mine life period but the more recent analysis considers a 30 year period. NRCan had suggested in its June 2019 comments that modelling over a longer time period should be considered as railway operation beyond 20 years could be required to accommodate any delays in construction or development of other deposits. The Proponent appears to address this concern in the memo. NRCan notes that the approach utilized for incorporation of climate change in design and the thermal analysis for cuts and pile foundations is based on that found in CSA Plus 4011-19 which is becoming accepted practice. The results of the analysis provide greater certainty with respect to the estimates for recommended insulation thickness for cut slopes. For pile foundations in the port area, the results indicate that there will be small reductions in pile resistance for the 30 year design life compared to 20 years. To deal with this, Hatch has recommended that extending piles deeper into permafrost or increasing the number of piles may be required. For bridge foundations, the increase in design life results in greater total settlement in the abutments and piers. These however, are expected to be within the design limits for future vertical adjustments and therefore increased pile embedment length is not recommended by Hatch but the maintenance and monitoring requirements will increase.

BIMC, in their response, indicated that they will continue to refine their thermal, creep and stability analysis as well as the rail monitoring plans through incorporation of new data acquired from their field investigation programs (see Issue 1). They have also indicated that they will incorporate local factors (e.g. snow accumulation, presence of water bodies) as suggested by NRCan during final design of embankments and bridges. As suggested by NRCan, monitoring sites will be selected prior to construction and others will be established during construction. NRCan is supportive of this approach as this will facilitate better characterization of baseline conditions required to inform final design, monitoring of infrastructure performance and assessment of impacts that may result from construction of the railway and inform the implementation of mitigation measures that may be required. BIMC also outlined again their approach to construction in permafrost regions and NRCan agrees that they are generally following accepted practices as well as consider railway design in permafrost regions elsewhere, where permafrost is generally warmer than it is at Mary River.

NRCan is appreciative of the additional information provided by the Proponent and agrees with their approach. NRCan would recommend that BIMC follows the recommendations made by Hatch in the design memo as well as the approach outlined in the response to NRCan comments.

NRCan's July 2019 Recommendations

NRCan recommends that the Proponent implement the recommendations provide by Hatch in the design memo and the plans for further analysis and instrumentation as outlined in their response to NRCan to support detailed design and environmental monitoring and management programs. Specifically NRCan recommends the Proponent:

- Implement the recommendations made by Hatch to accommodate the 30 year design life including those related to pile length embedment and number of piles required for foundations.
- Continue to refine the thermal, stability and creep analysis incorporating new data collected during geotechnical investigations and from instrumentation along the railway corridor to support final design of embankments and bridges.
- Consider local factors (such as snow accumulation and presence of water bodies) in the 2D thermal modelling to support final design of embankments, cuts and bridges.
- Establish instrumentation as outlined in their response, prior to and during construction to improve characterization of baseline ground conditions, support final design, evaluate impacts due to construction and railway performance, and to inform the implementation of mitigation/maintenance measures when triggers are reached

3. Overall Conclusions

NRCan is generally satisfied with the information provided for this phase of the project development. Within the context of the department's areas of expertise, NRCan finds the conclusions presented in the final EIS to be reasonable. NRCan maintains its specific recommendations with respect to permafrost and terrain stability, as well as encouraging BIMC to follow the recommendations in the design memo for the Northern Railway Corridor provided by Hatch, but in general agrees with the Proponent's approach within NRCan's area of review.

NRCan appreciates the opportunity provided by the Nunavut Impact Review Board to participate in this review. We would be pleased to answer any questions regarding our comments from the Board, its staff, the Proponent, or other Parties on this review.

4. Summary of Recommendations

Natural Resources Canada's (NRCan) final recommendations for Baffinland Iron Mines Corporation's proposed Phase 2 Development at the Mary River Mine are separated into those relating to terrain and permafrost conditions in the Northern Railway Corridor and those relating to thermal analysis/modelling to support railway embankment design.

In relation to terrain and permafrost conditions in the Northern Railway Corridor, NRCan recommends that the Proponent follow through on the plans outlined in their response to NRCan to support detailed design and environmental monitoring and management programs. Specifically NRCan recommends the Proponent:

- Conduct the summer 2019 mapping program in areas where the railway corridor deviates from the road
- Conduct the winter 2019/20 drilling program, described in their response, to obtain additional subsurface data to support design
- Conduct the pre-drilling program, described in their response, to improve delineation of ice-rich areas to support implementation of appropriate measures to deal with permafrost conditions prior to cuts or embankment construction
- Install thermistors during the 2019/20 and pre-drilling programs to establish baseline conditions along the corridor prior to construction.

In relation to thermal analysis/modelling to support railway design, NRCan recommends that the Proponent implement the recommendations provided by Hatch in the design memo and the plans for further analysis and instrumentation as outlined in their response to NRCan to support detailed design and environmental monitoring and management programs. Specifically NRCan recommends the Proponent:

- Implement the recommendations made by Hatch to accommodate the 30 year design life including those related to pile length embedment and number of piles required for foundations.
- Continue to refine the thermal, stability and creep analysis incorporating new data collected during geotechnical investigations and from instrumentation along the railway corridor to support final design of embankments and bridges.
- Consider local factors (such as snow accumulation and presence of water bodies) in the 2D thermal modelling to support final design of embankments, cuts and bridges.
- Establish instrumentation as outlined in their response, prior to and during construction to improve characterization of baseline ground conditions, support final design, evaluate impacts due to construction and railway performance, and to inform the implementation of mitigation/maintenance measures when triggers are reached.