ÉVITER LA DESTRUCTION DE LACS POUR Y DÉVERSER DES RÉSIDUS MINIERS

OPTIONS DE REMBLAIEMENT DES FOSSES EXCAVÉES À LA MINE LAC BLOOM (CHAMPION IRON), QUÉBEC, CANADA

STEVEN H. EMERMAN, PH.D.
Malach Consulting (LLC)

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508-250 City Centre Ave
Ottawa, ON K1R 6K7 Canada
info@miningwatch.ca
Téléphone+1 (613) 569-3439

7000, avenue du Parc, bureau 411
Montréal, QC H3N 1X1 Canada
info@eausecours.org
Téléphone+1 (438) 476-0881

54, avenue Laurier Est, 2e étage
Montréal, QC H2J 1E7 Canada
fr@fondationrivieres.org
Téléphone+1 (514) 272-2666

Steven H. Emerman, Ph.D.
Malach Consulting, LLC
785 N 200 W, Spanish Fork, Utah 84660, États-Unis
SHEmerman@gmail.com
Téléphone +1 (801) 921-1228

RÉSUMÉ (*rapport principal et annexe*)

Le projet d'agrandissement de la mine du Lac Bloom par Minerai de Fer Québec (Champion Iron) n'a pas considéré de façon sérieuse un scénario de remblaiement des deux fosses à ciel ouvert, comme l'exige notamment la Loi sur les mines du Québec et les directives ministérielles. Les études actuelles n'incluent pas d'analyse détaillée portant sur les coûts-bénéfices du remblaiement des fosses, pas plus qu'elles n'incluent d'analyses rigoureuses qui rencontrent les exigences en vertu des normes des Autorités canadiennes en valeurs mobilières (ACVM) pour soutenir les affirmations du promoteur selon lesquelles, d'une part, le traitement du minerai nécessiterait l'exposition en continu de toutes les sections des fosses à ciel ouvert et, d'autre part, qu'un remblaiement couvrirait des ressources minérales potentiellement exploitables. Cette dernière affirmation est notamment contredite par les études de faisabilité de 2017 et 2019, de même que par le rapport technique de 2013 (bien que ce dernier ne répondait pas aux normes réglementaires des autorités en valeurs mobilières). L'un des scénarios préliminaires de remblaiement partiel de la fosse (environ 33% de la fosse) soumis en réponse à la demande du Bureau d'audiences publiques sur l'environnement (BAPE) mènerait, selon la minière, à des pertes de réserves équivalentes à environ 10% des revenus bruts totaux anticipés pour les phases I et II du projet, principalement à cause d'une augmentation anticipée du facteur de dilution des concentrations en fer (0.8 à 5%) et de la difficulté d'assurer une dilution adéquate des contaminants. En présumant un prix moyen du fer à 84.10 $US/t (aujourd'hui à plus de 120 $US/t, soit près de 43% plus élevé), la minière prévoit des profits nets, avant taxes, de 2.9 milliards $US (3.7 milliards $CD) et des revenus bruts totaux de 18.2 milliards $US (23.7 milliards $CD) sur une période de 20 ans. En somme, notre analyse conclut : (1) qu'il serait techniquement et économiquement possible de retourner une partie des résidus miniers dans les fosses excavées (remblaiement partiel) pour prévenir la destruction permanente et irréversible de sept lacs et écosystèmes aquatiques; (2) que cette option permettrait non seulement d'éviter la destruction des lacs, mais également de réduire les risques de déversements miniers occasionnés par des bris de digues de rétention des résidus, tout en réduisant l'empreinte globale du projet; (3) que les coûts totaux (capitaux et opérationnels) de cette solution de rechange correspondraient sensiblement aux mêmes coûts (voire possiblement moindres) que le projet proposé actuellement; (4) qu'une perte anticipée d'environ 10% des revenus et des profits serait tout à fait absorbable selon les projections financières de l'entreprise, bien que des études additionnelles pourraient permettre d'optimiser les opérations pour réduire ces pertes, notamment en réduisant le facteur de dilution et en considérant de mettre de côté des réserves (stockpiles) du Pit West pour diluer les contaminants du Pit Chief; (5) la double affirmation selon laquelle (a) il y aurait des ressources additionnelles possiblement exploitables et que (b) l'on doit laisser 100% de la fosse ouverte à cet effet n'est, d'une part, aucunement démontrée par une étude qui rencontre les normes réglementaires des autorités mobilières et, d'autre part, contredite par les études actuelles; (6) que si l'entreprise souhaite maintenir cet argumentaire, elle devrait déposer des nouvelles études techniques, financières et environnementales qui rencontrent les normes réglementaires des autorités mobilières, en incluant des analyses coûts-bénéfices de divers scénarios de remblaiement partiel des fosses pour éviter la destruction des lacs; (7) que la capacité du parc à résidus miniers existant que l'entreprise prévoit agrandir est suffisante au moins jusqu'en 2025, voire possiblement jusqu'en 2026, ce qui laisse suffisamment de temps pour faire toutes les études nécessaires et évaluer les solutions de rechange adéquates.

LIGHTNING SUMMARY

The proposal for expansion of the Bloom Lake mine by Champion Iron lacks serious consideration of a scenario for backfilling of the two open pits, as required by the Quebec Mining Act. There is no detailed cost estimate for backfilling, no justification for the claim that iron ore processing will require the continuous exposure of all portions of the pits, and the claim that backfilling will cover potential future mineral resources is contradicted by reports to investors that are required by the disclosure standards under the Canadian Securities Administrators(CSA). Backfilling would prevent the destruction of seven lakes and reduce the risk of catastrophic failure of tailings dams.

ABSTRACT

Minerai de Fer Québec [Quebec Iron Ore], a wholly-owned subsidiary of the Australian company Champion Iron, has proposed an expansion of the existing Bloom Lake iron mine in eastern Quebec, Canada. The expanded mine would process 807 Mt of ore (29% Fe) from two open pits over 20 years, leaving behind 1278 Mt of mine waste, including 706 Mt of waste rock and 572 Mt of mine tailings. The proposal includes the construction of a new tailings facility for the storage of 296.4 Mt of excess coarse tailings, which would involve the filling of wetlands and seven lakes. From the perspective of protection of human life and the environment, the backfilling of open pits with mine waste is generally regarded as a best practice except when it would endanger underground mine workings below the pit or when greater chemical or physical stability could be achieved by surface storage. The backfilling of open pits has been applied at hundreds of mine sites in North America and worldwide. In particular, the Quebec Mining Act requires a "rehabilitation and restoration plan" with "in the case of an open-pit mine, a backfill feasibility study." Although the 2017 Feasibility Study included plans for backfilling at least part of the waste rock, the 2019 Environmental Impact Study rejects any possibility of backfilling. In place of a backfill feasibility study, Minerai de Fer Québec stated that backfilling would require re-handling of the waste material, which is always true, and which was not accompanied by any cost-benefit analysis, as required in guidelines of the Quebec Ministry of Energy and Natural Resources. Minerai de Fer Québec also claimed that the ore processing technology would require continuous access to ore from all portions of the open pits, but without any detailed explanation. Minerai de Fer Québec finally claimed that backfilling will cover potential future mineral resources. In particular, Minerai de Fer Québec has claimed that, if the iron ore price would rise from 60 to 80 USD/t, the mineral resources would increase from 893 to 1540 Mt. The claim of 1540 Mt of resources at a price of 80 USD/t is contradicted by the 2017 and 2019 Feasibility Studies, as well as by the 2013 SRK Technical Report by the previous mine owner. The 2013 report, which is not compliant with the Canadian Securities Administrators (CSA) standards, was carried out at an assumed price of 120 USD/t and predicted under 1400 Mt of resources, even approaching an asymptotic cut-off grade of 0% Fe. Based on 15 mining projects, including eight in Quebec, the geometric mean cost of open-pit backfill is 1.20 USD/t. Using this base cost

scenario, the cost of backfilling all the excess tailings (356 million USD) would be only slightly greater than the cost of constructing and operating a new tailings storage facility (328.4 million USD).

ABOUT THE AUTHOR

Dr. Steven H. Emerman is the owner of Malach Consulting, which specializes in evaluating the environmental impacts of mining for mining companies, as well as governmental and non-governmental organizations. Dr. Emerman has evaluated proposed and existing mining projects in North America, South America, Europe, Africa, Asia and Oceania, and has testified and presented his assessments before various governmental bodies, including the U.S. House of Representatives Subcommittee on Indigenous Peoples of the United States. Dr. Emerman has over 30 years of experience teaching hydrology and geophysics, and has over 70 peer-reviewed publications in these areas. Dr. Emerman is currently a member of the U.S. Society on Dams (Tailings Dam Committee), the Society for Mining, Metallurgy and Exploration (Tailings and Waste Committee), and chairs the Diversity in the Geosciences Committee of the Geological Society of America. Dr. Emerman is also a member of the American Geophysical Union and the Canadian Dam Association. Dr. Emerman is the author of the chapter on "Waste Management" for the upcoming SME (Society for Mining, Metallurgy and Exploration) Underground Mining Handbook. Dr. Emerman holds a M.A. in Geophysics from Princeton University and Ph.D. in Geophysics from Cornell University. Until retirement, Dr. Emerman was Associate Professor at Utah Valley University (2008-2018).

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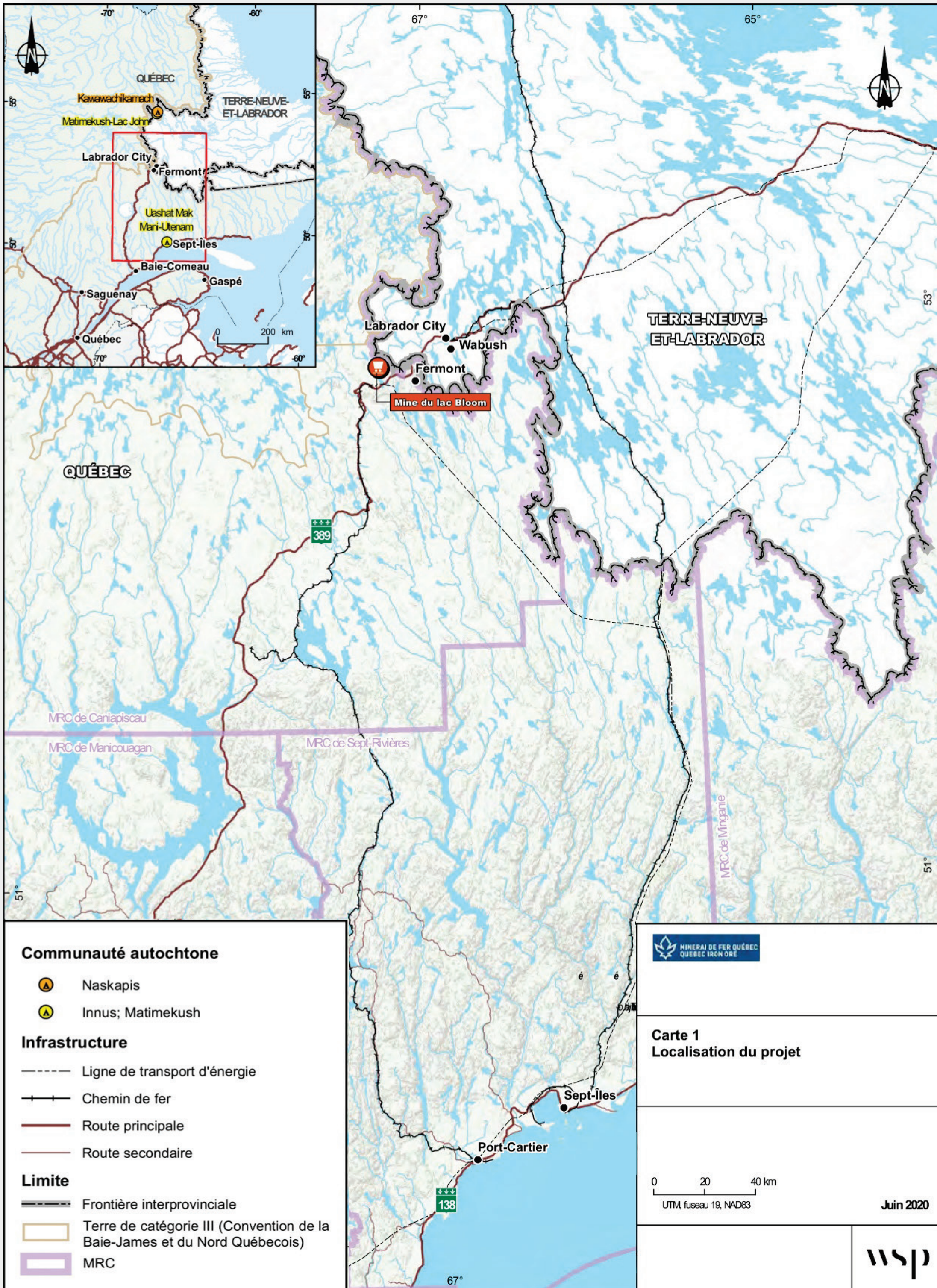

Figure 1. Minerai de Fer Québec [Quebec Iron Ore], a wholly-owned subsidiary of the Australian company Champion Iron, has submitted a proposal for an expansion of the Bloom Lake mine in eastern Quebec, Canada. Figure from Minerai de Fer Québec (2020a).

Minerai de Fer Québec [Quebec Iron Ore], a wholly-owned subsidiary of the Australian company Champion Iron, has proposed an expansion of the existing Bloom Lake iron mine in eastern Quebec, Canada (see Figs. 1, 2a-b and 3; Minerai de Fer Québec, 2019a, 2020a). The proposed expanded mine would process 807 Mt of ore (average grade 29% Fe) from two open pits over 20 years, exporting 235.22 Mt of iron concentrate (66.2% Fe), and leaving behind 468.01 Mt of coarse tailings, and 87.77 Mt of fine tailings (see Table 1). To reach the ore body, the expanded mining project would also remove 706 Mt of waste rock, including the overburden (unconsolidated deposits overlying the bedrock). The current Bloom Lake mine includes two open pits, two waste rock dumps (Mazaré and Triangle), the Pignac overburden dump, Basin A for fine tailings, and two storage facilities for coarse tailings (HPA-Ouest and HPA-Sud) (see Fig. 2a). The proposed expansion would increase the size of the open pits and would involve an additional dump for waste rock (Sud) and an additional facility for storage of coarse tailings (HPA-Nord) (see Fig. 2b). Although there is still additional capacity in the existing tailings storage facilities, HPA-Nord would be required to store a maximum excess of 296.4 Mt of coarse tailings.

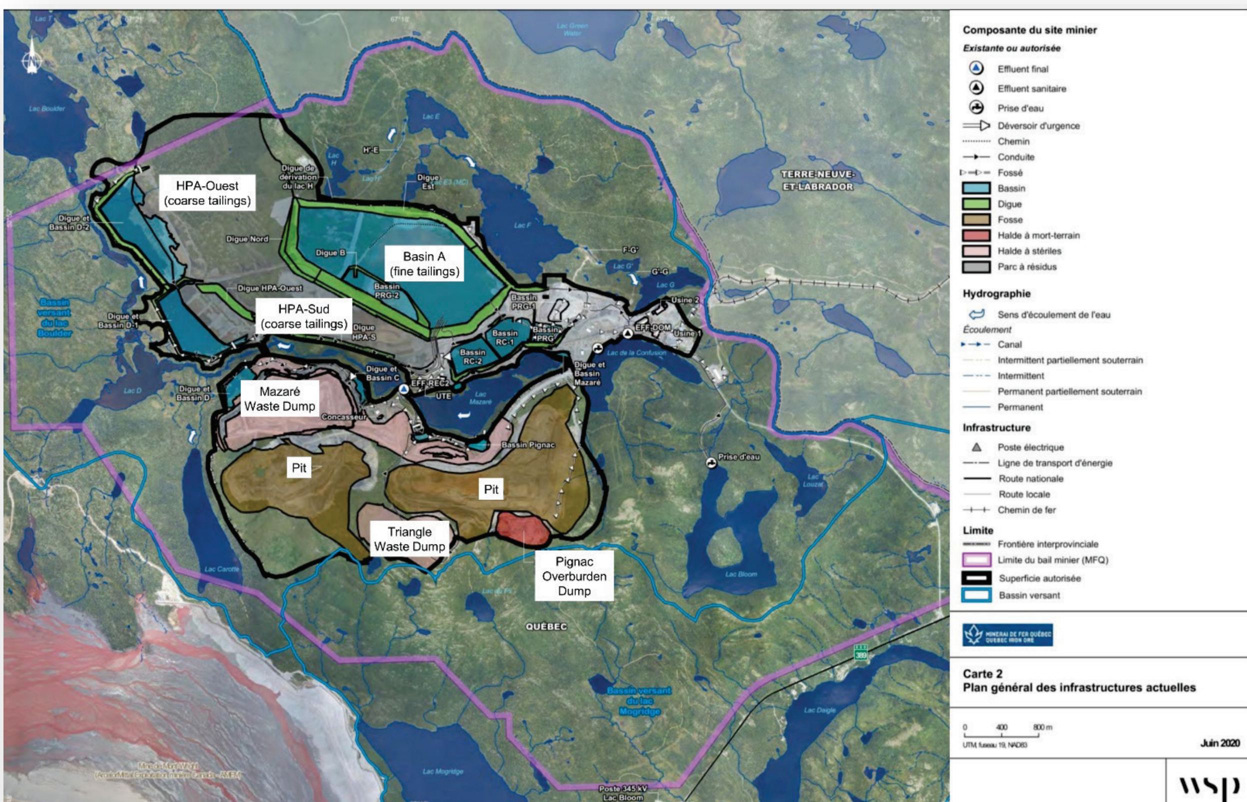

Figure 2a. The current Bloom Lake mine includes two open pits, two waste rock dumps (Mazaré and Triangle), the Pignac overburden dump, Basin A for fine tailings, and two storage facilities for coarse tailings (HPA-Ouest and HPA-Sud).

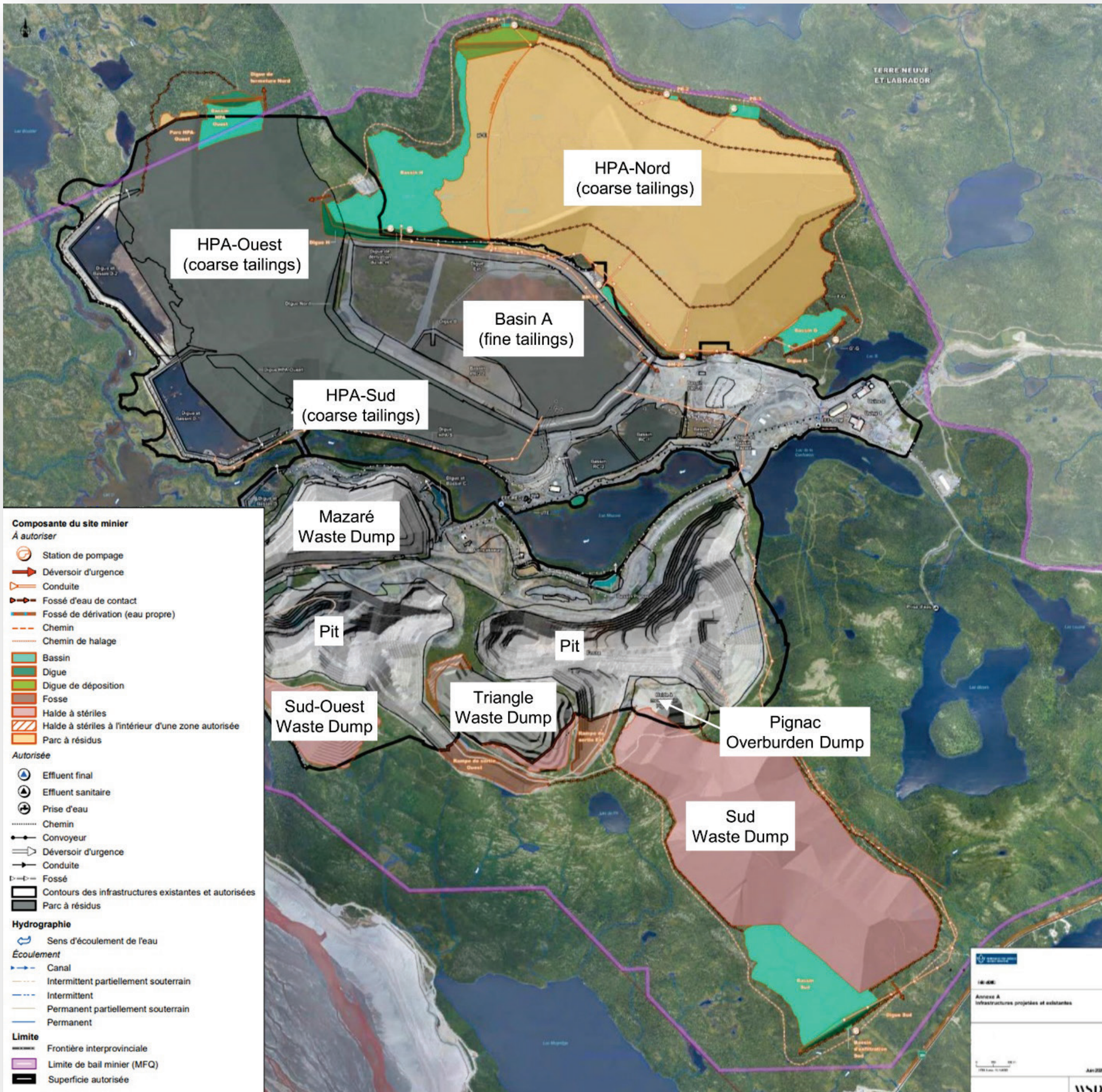

Figure 2b. The proposed expansion of the Bloom Lake mine would involve an additional dump for waste rock (Sud) and an additional facility for storage of coarse tailings (HPA-Nord). The construction of the HPA-Nord tailings storage facility would require the filling of wetlands and seven lakes (compare with Fig. 2a).

A key environmental concern is that the construction of the new tailings storage facility HPA-Nord in its planned location would require the filling of wetlands and seven lakes, including two fairly large lakes, Lakes E and F, with surface areas of about 27 ha and 88 ha, respectively (compare Figs. 2a-b). An obvious alternative to the construction of a new tailings storage facility is the backfilling of the excess tailings into the open pit. It is also possible to consider backfilling a portion of the waste rock and the remainder of the tailings into the open pits following the cessation of mining or concurrent with the mining. Based on in-situ densities of ore and waste rock of 3.40 t/m^3 and 2.71 t/m^3, respectively (see Table 1), the final combined volumes of the two pits would be 497.87 Mm^3. Given the maximum waste dump capacity of 741.5 Mt and 370.6 Mm^3 (Minerai de Fer Québec, 2019a), the excavated and compacted waste rock would have a bulk density of 2.00 t/m^3, so that 706 Mt of waste rock would have a volume of 353 Mm^3 when placed back into the pit. Based on the densities of coarse and fine tailings of 1.3 t/m^3 and 1.4 t/m^3, respectively (see Table 1), the total volume of tailings would be 435.12 Mm^3. Since, as is typical, the combined volume of waste rock and tailings would exceed the combined volumes of the pits, choices would have to be made regarding whether it was preferable to backfill waste rock or tailings, or a combination of both in co-disposal, as well as whether the pits should be partially or completely backfilled or not all.

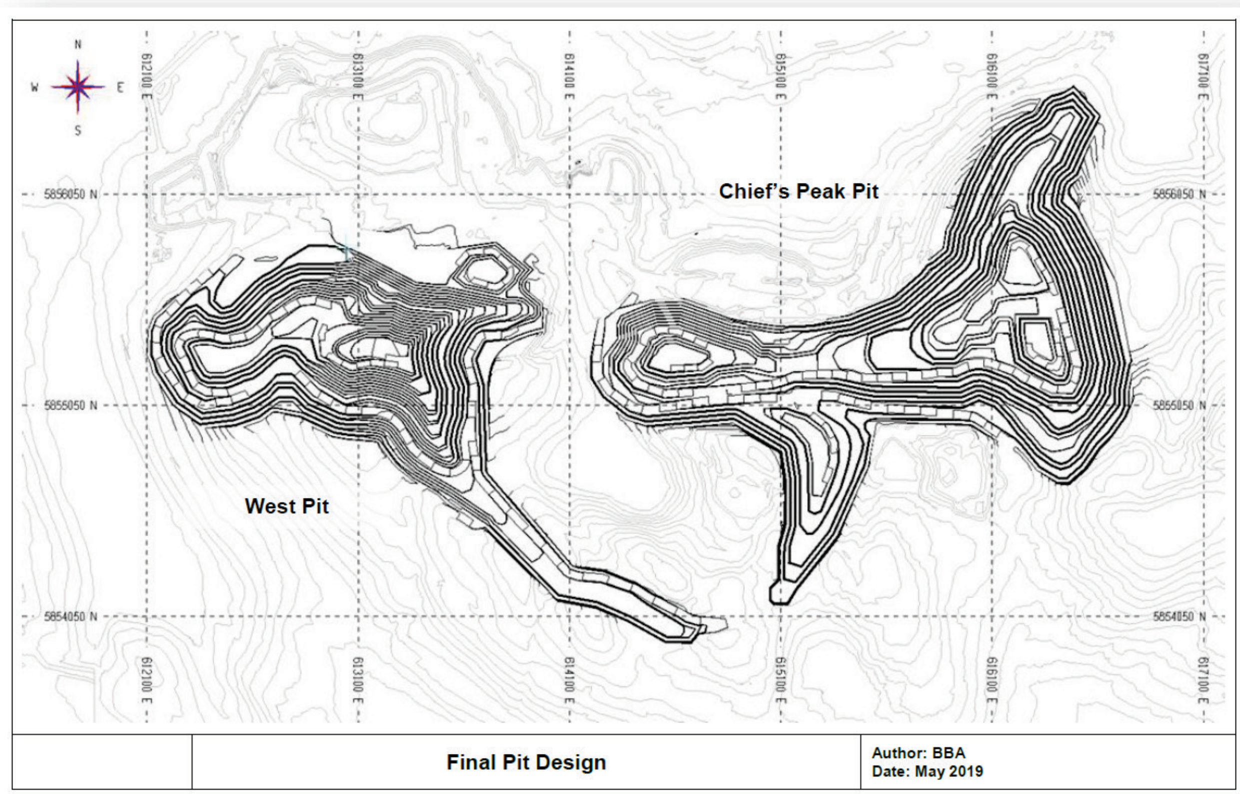

Figure 3. The proposed expansion of the Bloom Lake mine would involve the mining of two open pits (compare with Figs. 2a-b). Based on the removal of 807 Mt of ore with in-situ density 3.40 t/m3 and 706 Mt of waste rock with in-situ density 2.71 t/m3, the combined total pit volume would be 498 Mm3 (see Table 1). The Quebec Mining Act requires a “rehabilitation and restoration plan” with “in the case of an open-pit mine, a backfill feasibility study” (LégisQuébec, 2020). Figure from Minerai de Fer Québec (2019a).

Table 1. Parameters for open-pit backfill calculations[1]

Material	Dry Mass (Mt)	Dry Bulk Density (t/m^3)
Ore	807	3.40
Coarse tailings	486.01	1.3
Fine tailings	85.77	1.4
Concentrate	235.22[3]	—
Waste rock	706	2.71 (in-situ)
		2.00 (excavated and compacted)[2]

[1]Minerai de Fer Québec (2019a)
[2]Based on waste dump capacity of 741.5 Mt and 370.6 Mm^3
[3]Difference between masses of ore and tailings

Section 232.3 of the 2013 Quebec Mining Act requires that "the rehabilitation and restoration plan shall contain…in the case of an open-pit mine, a backfill feasibility study" (LégisQuébec, 2020). The *Guide de préparation du plan de réaménagement et de restauration des sites miniers au Québec* [Preparation Guide for the Redevelopment and Restoration Plan for Mining Sites in Quebec] further explains that "*Dans le cas d'une exploitation à ciel ouvert, le plan de restauration doit comporter une analyse coûts-avantages sur la possibilité de remblaiement de la fosse. Les fosses peuvent être remblayées avec des matériaux meubles, des substances minérales, des résidus miniers ou des stériles miniers. Cependant, pour être acceptable au point de vue environnemental, des validations quant à la stabilité chimique et physique à court et à long terme sont alors requises…Dans certains cas, lorsque le MERN juge que les conditions s'y prêtent et si l'analyse démontre l'impossibilité de procéder au remblayage de la fosse, toutes les voies d'accès doivent être condamnées…*" [In the case of surface mining, the restoration plan must include a cost-benefit analysis of the possibility of backfilling the pit. Pits can be backfilled with loose materials, minerals, mine tailings or mine waste rock. However, to be acceptable from an environmental point of view, validations as to the chemical and physical stability in the short and long term are then required…In certain cases, when the MERN judges that the conditions are suitable and if the analysis shows the impossibility of proceeding to the backfilling of the pit, all the access roads must be condemned…] (Ministère de l'Énergie et des Ressources naturelles [Ministry of Energy and Natural Resources], 2017). In other words, the government of Quebec does not mandate the backfilling of open pits, but does mandate a feasibility study, including an analysis of costs and benefits.

The current plan for the expansion of the Bloom Lake mine does not include any backfilling of the open pits. In light of the mining legislation in Quebec, the objective of this report is to address the following questions:

1) Do the documents provided by Minerai de Fer Québec contain a thorough consideration of the economic and technical feasibility of partial or complete backfilling of the open pits, including an analysis of the costs and benefits?
2) If the backfill analysis by Minerai de Fer Québec is insufficiently thorough, can the economic and technical feasibility of partial or complete backfilling of the open pits be re-considered without the development of a detailed plan?

Before discussing the methodology for answering the above questions, I will first review two key mining concepts, which are the estimation of mineral resources and mineral reserves, and the current practice of open-pit backfill. Additional information about the proposed expansion of the Bloom Lake mine will be provided following the review of mining concepts.

REVIEW OF MINING CONCEPTS

Mineral Resources and Mineral Reserves

Any proposed mining project involves the creation of a Feasibility Study, which includes, among other information, estimates of the mineral resources and mineral reserves. In general, mineral resources refer to the size of an ore body containing a mineral of value (typically, above some specified cut-off grade), while mineral reserves refer to the quantity of ore that can be economically mined given current technology. In Canada this Feasibility Study is called the National Instrument (NI) 43-101 and is required by the Canadian Securities Administrations for mining companies that are listed on stock exchanges within Canada. The rules governing the creation of an NI 43-101 incorporate the CIM (Canadian Institute of Mining, Metallurgy and Petroleum) Definition Standards on Mineral Resources and Reserves (CIM, 2014a-b). These same definition standards will be followed in this report.

According to CIM (2014a), "A Mineral Resource is a concentration or occurrence of solid material of economic interest in or on the earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction." Since there must be "reasonable prospects for eventual economic extraction," the conversion of an ore body into a commodity cannot be only a theoretical possibility. In other words, the estimation of resources must be based upon a particular cut-off grade with an assumed commodity price, along with many other factors. The conversion of resources into reserves is based upon "Modifying Factors," which may include "mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors" (CIM, 2014a).

Mineral resources are then subdivided into inferred resources, indicated resources and measured resources, according to the level of confidence in the existence of the resources, with the greatest confidence placed in measured resources, and the least confidence in inferred resources. CIM (2014a) explains, "An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling." On the other hand, "An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit" (CIM, 2014a). The difference between indicated resources and measured resources is that measured resources can be used to support "**detailed** mine planning and **final** evaluation of the economic viability of the deposit" (emphasis added; CIM, 2014a).

By contrast, “a Mineral Reserve is the economically mineable part of a measured and/or Indicated Mineral Resource” (CIM, 2014a). Note that an inferred mineral resource cannot be regarded as a mineral reserve, or economically mineable. By analogy with mineral resources, mineral reserves are subdivided into probable reserves and proven reserves. According to CIM (2014a), “A Probable Mineral Reserve is the economically mineable part of an indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors applying to a Probable Mineral Reserve is lower than that applying to a Proven Mineral Reserve...A Proven Mineral Reserve is the economically mineable part of a Measured Mineral Resource. A Proven Mineral Reserve implies a high degree of confidence in the Modifying Factors.” Clearly, the specified cut-off grade and the anticipated commodity price are important factors in determining which portion of an indicated or measured resource is an economically mineable reserve and whether a reserve is probable or proven.

Open-Pit Backfill

The permanent aboveground storage of mine tailings, the relatively wet and fine-grained material that remains after the mineral of interest has been separated from the ore, is one of, if not the most, problematic aspect of mine waste management (Emerman, in press). Solid mine waste refers principally to waste rock and tailings, but also includes other forms of waste that occur in smaller quantities, such as water treatment sludges, dredge spoils, and excavated soils. The mine tailings must be confined behind a dam, so that the worst-case scenario is a catastrophic failure of the tailings dam with potential loss of life and the release of a large quantity of toxic material into the environment. Although tailings dams and water-retention dams are both built for the purpose of restricting the flow of material, they are fundamentally different types of civil engineering structures. This important point was emphasized in the standard textbook on tailings dams by Vick (1990), “A recurring theme throughout the book is that there are significant differences between tailings embankment and water-retention dams…Unlike dams constructed by government agencies for water-retention purposes, tailings dams are subject to rigid economic constraints defined in the context of the mining project as a whole. While water-retention dams produce economic benefits that presumably outweigh their cost, tailings dams are economic liabilities to the mining operation from start to finish. As a result, it is not often economically feasible to go to the lengths sometimes taken to obtain fill for conventional water dams.” In addition to the economic unfeasibility of traveling the distances that are sometimes ideal for obtaining appropriate fill, Vick (1990) gives many other examples of ways in which it is not economically feasible to build a tailings dam in the same way as a water-retention dam. An earthen water-retention dam is constructed out of rock and soil that is chosen for its suitability for the construction of dams. However, a tailings dam is normally built out of construction material that is created by the mining operation, such as the waste rock that is removed before reaching the ore, or the mine tailings themselves after proper compaction. In addition, a water-retention dam is built completely from the beginning before its reservoir is filled with water, while a tailings dam is built in stages as more tailings are produced that require storage and as material from the mining operation (such as waste rock) becomes available for construction.

The consequences of the very different constructions of tailings dams and water-retention dams are the very different safety records of the two types of structures. According to a widely-cited paper by Davies (2002), "It can be concluded that for the past 30 years, there have been approximately 2 to 5 'major' tailings dam failure incidents per year…If one assumes a worldwide inventory of 3500 tailings dams, then 2 to 5 failures per year equates to an annual probability somewhere between 1 in 700 to 1 in 1750. This rate of failure does not offer a favorable comparison with the less than 1 in 10,000 that appears representative for conventional dams. The comparison is even more unfavorable if less 'spectacular' tailings dam failures are considered. Furthermore, these failure statistics are for physical failures alone. Tailings impoundments can have environmental 'failure' while maintaining sufficient structural integrity (e.g. impacts to surface and ground waters)." Both the total number of tailings dams and the number of tailings dams failures cited by Davies (2002) are probably too low. However, the Independent Expert Engineering Investigation and Review Panel (2015) found a similar failure rate in tailings dams of 1 in 600 per year during the 1969-2015 period in British Columbia.

The permanence of an aboveground tailings storage facility cannot be overemphasized. By contrast, at the end of its useful life, or when it is no longer possible to inspect and maintain the dam, a water-retention dam is completely dismantled. On the other hand, a tailings dam must confine the mine tailings in perpetuity, although normally the inspection and maintenance of the dam cease at some pre-determined date following the end of the mining project. Although some mine closure plans call for the conversion of a tailings storage facility into a man-made feature resembling and with the stability of a natural landform, this is not a sufficient guarantee of permanent security. It is quite common for natural landforms to fail by landsliding, although without the release of hundreds of millions of tons of potentially toxic material. In the same way, all natural landforms undergo erosion, although the erosion of a closed tailings facility could lead to the windborne or waterborne transport of toxic materials.

According to <u>Safety First: Guidelines for Responsible Mine Tailings Management</u>, "Tailings facilities must be reviewed, inspected, monitored, and maintained until they reach a permanent state where the potential for failure is essentially impossible. Operating companies must not be allowed to walk away from tailings facilities until the closed tailings facility can withstand, without failure, the Probable Maximum Flood (PMF) and the Maximum Credible Earthquake (MCE)…and can remain in that state indefinitely with no further inspection, monitoring or maintenance. Because tailings facilities exist in perpetuity, any facility that is deemed closed without being able to withstand PMF and MCE creates unmonitored and unregulated liability for future generations. In the cases where tailings facilities are unable to close under these conditions with current technology, they must have permanent monitoring, inspection and maintenance" (Morrill et al., 2020). Although the conversion of a tailings facility into a state of permanent safety is a laudable goal, there are very few case studies in which it could be convincingly argued that an abandoned tailings storage facility has the ability to withstand the maximum flood and seismic events indefinitely. ANCOLD (2012) puts forth the same goal that a closed tailings storage facility should be able to withstand the MCE indefinitely.

For the above reasons, the maximum backfilling of mine tailings into either open pit or underground mine workings is regarded as a best practice (Mudd et al., 2011; Independent Expert Engineering Investigation and Review Panel, 2015; Morrill et al., 2020; ICMM-UNEP-PRI, 2020; Emerman, in press). Waste rock and water treatment sludges can also be backfilled into either open pits or underground mine workings (Johnson and Carroll, 2007), although with a lower priority (due to the lower risk of catastrophic failure). MEND (1995) reviewed the practice of open-pit backfilling with 12 detailed case studies. Twenty years later, the review was updated by Arcadis (2015) with 12 additional case studies (including three case studies that were updated from the earlier review). In addition to the prevention of catastrophic failures of aboveground tailings facilities and the long-term costs of preventing such failures, open-pit backfilling can facilitate the return of the surface to its pre-mining state with less risk of permanent alienation of the land from a useful or natural purpose. Open-pit backfilling also reduces the risk of seepage of contaminated mine water to surface water bodies or aquatic ecosystems. Along the same lines, open-pit backfilling has more and safer options for the permanent physical and chemical isolation of hazardous materials. Open-pit backfilling can even improve the physical and chemical stability of the pit and stabilize the pit walls.

After the risk of catastrophic failure of tailings dams, the risk of the release of acid mine drainage into the environment is generally regarded as the second greatest hazard of aboveground mine waste storage. In open-pit backfill projects, the mine waste is typically placed below the water table, which, if covered within an appropriate time frame, prevents oxidation of the sulfides. An impermeable dry cover placed onto backfilled mine waste (without the risk of erosion of the cover of an aboveground facility) can also prevent oxidation of sulfides (Arcadis, 2015). In the case of the Marlin gold-silver mine in Guatemala, filtered non-sulfidic tailings were backfilled into the open pit, which prevented the oxidation of the sulfidic pit walls (Montana Exploradora de Guatemala, S.A., 2012). Along these lines, it should be noted that surface water covers have been used to prevent the oxidation of sulfidic tailings in aboveground tailings storage facilities. However, due to their detrimental impact on the physical stability of the tailings dams, surface water covers on aboveground facilities can no longer be regarded as a best practice (Expert Engineering Investigation and Review Panel, 2015; Morrill et al., 2020).

MEND (1995) and Arcadis (2015) considered only case studies in which mine waste was backfilled into an exhausted open pit. However, there are also cases in which the backfill of mine waste into an open pit has occurred concurrently with continued mining in another portion of the pit. In fact, concurrent open-pit backfilling is quite common in aggregate mining and in surface coal mining in the midwestern USA, as well as increasingly common in gold and base metal mining. Concurrent backfilling and mining is facilitated in the aggregates industry due to the much higher ratio of ore to mine waste than is common in base metals mining (D. Bieber, pers. comm). Concurrent backfilling and mining in surface coal mines reduces costs by reducing haulage distances. In addition, reclaiming coal mine pits within 2-3 pit widths from the active excavation face reduces reclamation time and facilitates incremental reclamation bond releases (J. Petrea, pers. comm.). Concurrent backfilling and mining is also common in oil sands mines of Alberta, in which tailings storage facilities with tailings dams are constructed inside working open pits (with much reduced consequences in the event of tailings dam failure) (K. Chovan, pers.

comm.). Examples of base metal mines with concurrent open-pit backfilling and mining include the Old Tintaya copper mine in Peru (X. Ochoa, pers. comm.) and nearly all nickel mines in New Caledonia (Dufayard et al., 2020). The relevant example of New Caledonian nickel mines will be explored further in the Discussion section.

In fact, open-pit backfilling is contraindicated under only three circumstances (Arcadis, 2015). Sometimes the exhaustion of an open pit is followed by the opening of underground mine workings below the pit. In that case, open-pit backfilling can be too hazardous for the stability of the underground mine. On the other hand, the Marlin gold-silver mine was able to backfill the open pit with filtered, compacted tailings by sealing the contact between the open pit and the underlying underground mine with a grout barrier (Montana Exploradora de Guatemala, S.A., 2012).

The second contraindication is that, under some circumstances, greater physical and chemical stability could be achieved through aboveground storage of mine waste. For example, the base and walls of an open pit could be heavily fractured (perhaps as a result of blasting), so that groundwater contamination could be less likely if the mine waste were stored on the surface above a low-permeability soil. Another example is that, without backfilling, the exhausted pit could develop a pit lake. One advantage of a pit lake is that it acts as a hydraulic sink with all groundwater flowing toward the pit, thus preventing the seepage of contaminated water out of the pit. In that case, if there were a strong pre-existing hydraulic gradient, the complete backfilling of the pit could result in a rapid flow of groundwater through the pit, thus facilitating the seepage of contaminants out of the pit. Even under those circumstances, the partial backfill of the pit to just above the water table can retain the pit as a hydraulic sink without the detrimental impacts (such as impacts on wildlife) of a potentially contaminated pit lake (Johnson and Carroll, 2007). From a financial standpoint, the third contraindication is that backfilling the pit could prevent the future mining of additional ore that might be present below the pit. However, the mere possibility of additional ore (that might be economically mineable at some future time) would have to be balanced against all of the previously mentioned benefits of open-pit backfilling. Those benefits can be social, environmental and economic.

While backfilling can be cheaper than the alternatives in some cases, there can be a high cost associated with open-pit backfilling. However, in terms of protecting people and the environment (through preventing the catastrophic failure of tailings dams), cost cannot be the determining factor (Independent Expert Engineering Investigation and Review Panel, 2015; Morrill et al., 2020). Even so, the cost of open-pit backfilling must be balanced against the cost of construction, operation and closure of a tailings storage facility. The cost of long-term maintenance of a tailings storage facility after the cessation of a mining project must also be considered and should not be transferred to the government or downstream communities. The least expensive backfill projects have allowed a tailings slurry to flow by gravity directly from the ore processing plant into an exhausted open pit, such as at the Marymia gold mine in Western Australia (Arcadis, 2015). The haulage of material always comes at a cost, but significant savings can arise through never removing the waste rock from the open pit, which is common at nickel mines in New Caledonia (Dufuyard et al., 2020). Depending upon the properties of the pit and the mine waste, significant engineering can be required to obtain appropriate physical and chemical isolation of mine waste within the pit. Finally, it may be necessary to construct temporary waste storage facilities on the surface before the mine waste can be backfilled into the pit.

There are apparently only two jurisdictions that have mandated the backfilling of open pits. California has required backfill of open-pit metallic mines to the maximum extent possible since 2003 (Department of Conservation, 2003, 2007). California Code of Regulations (CCR) §3704.1(a) states, "An open pit excavation created by surface mining activities for the production of metallic minerals shall be backfilled to achieve not less than the original surface elevation, unless the circumstances under subsection (h) are determined by the lead agency to exist" (Department of Conservation, 2003). CCR §3704.1(h) then explains, "The requirement to backfill an open pit excavation to the surface pursuant to this section using materials mined on site shall not apply if there remains on the mined lands at the conclusion of mining activities, in the form of overburden piles, waste rock piles, and processed or leached ore piles, an insufficient volume of materials to completely backfill the open pit excavation to the surface, and where, in addition, none of the mined materials has been removed from the mined lands in violation of the approved reclamation plan. In such case, the open pit excavation shall be backfilled …to an elevation that utilizes all of the available material remaining as overburden, waste rock, and processed or leached ore."

The emphasis in the New Caledonian legislation is not on filling the open pit, but on not leaving waste materials outside of the pit. According to Dufuyard et al. (2020), "The mines of New Caledonia are subject to the highest environmental standards and regulations…The disturbance area is restricted to the ultimate pit limits, and all mining activity must stay in this confined area." In some cases, open-pit backfilling has been required by a regulatory agency for a particular mine, such as at the Ranger uranium mine in Northern Territory, Australia (Mudd et al., 2011). In other cases, open-pit backfilling has become a standard practice, for example, at uranium mines in Saskatchewan (Arcadis, 2015), or, as already mentioned, at aggregate mines, at surface coal mines in the midwestern USA, and at oil sands mines in Alberta.

Since the passage of the 2013 Quebec Mining Act, a number of plans for large open-pit mining projects in Quebec have included at least partial backfilling. The proposed expansion of the Canadian Malartic gold mine would involve backfilling 165-200 Mt of waste rock and about 100 Mt of tailings produced during 2022-2028 (Ministère de l'Énergie et des Ressources naturelles, 2018), or approximately all of the waste rock and tailings that would be generated after 2021 (BAPE, 2016). The proposed Nouveau Monde Matawinie graphite mine would backfill 43 Mt or 40% of all mine waste (Nouveau Monde Graphite, 2018; BAPE, 2020). The proposed Royal Nickel Dumont mine would backfill 114 Mt of waste rock (Royal Nickel Corporation, 2013a-b; Canadian Environmental Assessment Agency, 2015). Each of the above projects would involve some degree of concurrent backfilling and mining in the same pit. In each case, the discussion between the mining companies and provincial regulatory agencies has been the Province's urging of the companies to consider backfilling a greater proportion of the mine waste (BAPE, 2009, 2014, 2016, 2020).

Mineral Resource and Mineral Reserve Estimates

This subsection will review the mineral resource and mineral reserve estimates for the Bloom Lake iron deposit through three iterations (see Table 2). The document Technical Report—Bloom Lake Mine—Quebec Province, Canada prepared for the previous mine owner, Cliff Natural Resources, by SRK Consulting, includes the disclaimer "This document has been prepared to follow a similar format of the National Instrument 43-101 (NI 43-101) **but some sections do not follow the guidelines**" (emphasis added; Cliff Natural Resources, 2013). A copy of the report submitted to the BAPE Review Panel (document DA14) includes a legal disclaimer on the cover page that states: "This report (the "**Report**") has been prepared by SRK Consulting (U.S.), Inc. for Cliffs Natural Resources, the previous owner and operator of the Bloom Lake Mine, **and is not in compliance with National Instrument 43-101** – *Standards of Disclosure for Mineral Projects* ("NI 43-101"). Neither Quebec Iron Ore Inc. nor Champion Iron Limited or any of its subsidiaries have done, or caused to be done, any work in connection with this Report or any information contained therein. The historical mineral resources and other historical data and information mentioned in this Report are strictly historical in nature and are non-compliant with NI 43-101 and should therefore not be relied upon. A "qualified person" as defined by NI 43-101 has not done sufficient work to upgrade or classify the historical estimates as current mineral resources or mineral reserves, and Quebec Iron Ore Inc., Champion Iron Limited and their affiliates are not treating the historical estimates as current mineral resources or mineral reserves." Throughout the rest of this report, the document (Cliff Natural Resources, 2013) will be referred to as the 2013 Technical Report. The 2013 Technical Report (Cliff Natural Resources, 2013) does refer to earlier documents with mineral resource and mineral reserve estimates for the Bloom Lake iron deposit that did follow all of the guidelines for an NI 43-101..

The 2013 Technical Report assumed a cut-off grade of 15% Fe and an iron ore price of 120 USD/t for the estimation of mineral resources (see Table 2). The study then estimated measured, indicated, and inferred resources of 446.1 Mt, 919.8 Mt and 419.0 Mt, respectively (see Table 2). Typically, the sum of measured and indicated resources (1365.8 Mt in this case) is of greatest interest, since it is the only portion of resources that can be converted to reserves. The reserves were estimated assuming a cut-off grade of 20% Fe and an iron ore price of 112 USD/t (see Table 2). The 2013 Technical Report estimated proven reserves of 417.4 Mt and probable reserves of 633.9 Mt, for a sum of 1051.3 Mt of proven and probable reserves. (see Table 2).

Table 2. Evolution of mineral resource and reserve estimates for Bloom Lake iron deposit

	2013[1]	2017[2]	2019[3]
Resources			
Cut-off Grade (% Fe)	15	15	15
Iron Ore Price (USD/t)	120	60	61.50
Measured (Mt)	446.1	439.7	379.1
Indicated (Mt)	919.8	471.9	514.4
Measured + Indicated (Mt)	1365.8	911.6	893.5
Inferred (Mt)	419.0	80.4	53.5
Reserves			
Cut-off Grade (% Fe)	20	15	15
Iron Ore Price (USD/t)	112	50	60.89
Proven (Mt)	417.4	264.1	346.0
Probable (Mt)	633.9	147.554	461.0
Proven + Probable (Mt)	1051.3	411.713	807.0

[1]Cliffs Natural Resources (2013)
[2]Minerai de Fer Québec (2017)
[3]Minerai de Fer Québec (2019a)

The 2017 and 2019 Feasibility Studies (Minerai de Fer Québec, 2017, 2019a) contain similar resource and reserve estimates, with both considerably reduced from the estimates in the 2013 Technical Report, which is not compliant with the CSA standards. The 2019 Feasibility Study was based on a greater amount of geological information, although the authors of the 2019 Feasibility Study (Minerai de Fer Québec, 2019a) acknowledged that they did not have access to all of the geological information that could have been available. According to the 2019 study, "Results for the 2018 drill program were pending during the preparation of the block model for the current resource estimate…The QP [Qualified Person] has not been provided with all the results and, therefore, conclusions can only be partial based on the limited information received for the 2018 drilling program…Drillhole information up to 2018 was considered for this estimate with only partial information from the 2018 drilling program used for 3D modelling and classification…It must be noted that the 2018 drill program was used for classification purposes although assay results had not been received. The QP does not recommend doing so, but verifications allowed determining that these drillholes affected a very limited amount of material throughout the deposit (less than 1% of the tonnage)…Once results are received by QIO [Quebec Iron Ore] and included in a future update of the block model, it is anticipated that tonnage will not be affected, but grade could locally be slightly lower or higher for the limited amount of blocks within interpolation reach of the 2018 drillholes…The geological model should be re-interpolated to include the 2018 drilling program, which was still pending during the course of this mandate. This is not expected to be material to the project, but could help improve reconciliation locally" (Minerai de Fer Québec, 2019a). At the present time, the 2019 Feasibility Study has not been updated based on results from the 2018 drilling program.

The 2017 and 2019 Feasibility Studies were based on much lower iron ore prices than the 2013 Technical Report (not compliant with CSA standards), which is consistent with the drop in iron ore prices (62% Fe) that occurred between 2013 and 2017-19 (see Table 2 and Fig. 4). The 2017 study assumed iron ore prices of 60 USD/t and 50 USD/t for resource and reserve estimates, respectively, while the 2019 study used iron ore prices of 61.50 USD/t and 60.89 USD/t for resource and reserve estimates, respectively (see Table 2; Minerai de Fer Québec, 2017, 2019a). Both the 2017 and 2019 Feasibility Studies assumed a cut-off grade of 15% Fe for both resource and reserve estimates The 2017 Feasibility Study estimated measured, indicated, and inferred resources of 439.7 Mt, 471.9 Mt and 80.4 Mt, respectively, with a sum of 911.6 Mt of measured and indicated resources (see Table 2). The same study estimated proven and probable reserves of 264.1 Mt and 147.554 Mt, respectively, with a sum of 411.713 Mt of proven plus probable reserves (see Table 2). The 2019 Feasibility Study estimated measured, indicated, and inferred resources of 379.1 Mt, 514.4 Mt and 53.5 Mt, respectively, with a sum of 893.5 Mt of measured and indicated resources (see Table 2). The same study estimated proven and probable reserves of 346.0 Mt and 461.0 Mt, respectively, with a sum of 807.0 Mt of proven plus probable reserves (see Table 2), which is, of course, the basis for the current plan to mine 807 Mt of ore (Minerai de Fer Québec, 2019a). It is noteworthy that the very large inferred resources of the 2013 report (419.0 Mt) had largely vanished by the 2017 and 2019 studies (80.4 Mt and 53.5 Mt, respectively) (see Table 2). In addition, while the 2017 Feasibility Study converted only 45% of measured plus indicated resources into reserves, the 2019 Feasibility Study converted 90% of measured plus indicated resources into reserves (see Table 2).

Although the mineral resource map in the 2019 Feasibility Study includes no scale or any geographical information (see Fig. 5a), the map could be overlain onto the final pit design (see Fig. 3) by matching topographical features (see Fig. 5b). As expected, the final pit design is nearly coincident with the mapped resources (see Fig. 5b). The only exceptions are small spots of inferred resources to the west of Chief's Peak Pit, small spots of indicated resources to the north of West Pit, and minor indicated and inferred resources between the southern limbs of the two open pits (see Fig. 5b). The important point is that the resource map gives no suggestion of significant iron ore resources existing outside of the final pit design (see Fig. 5b).

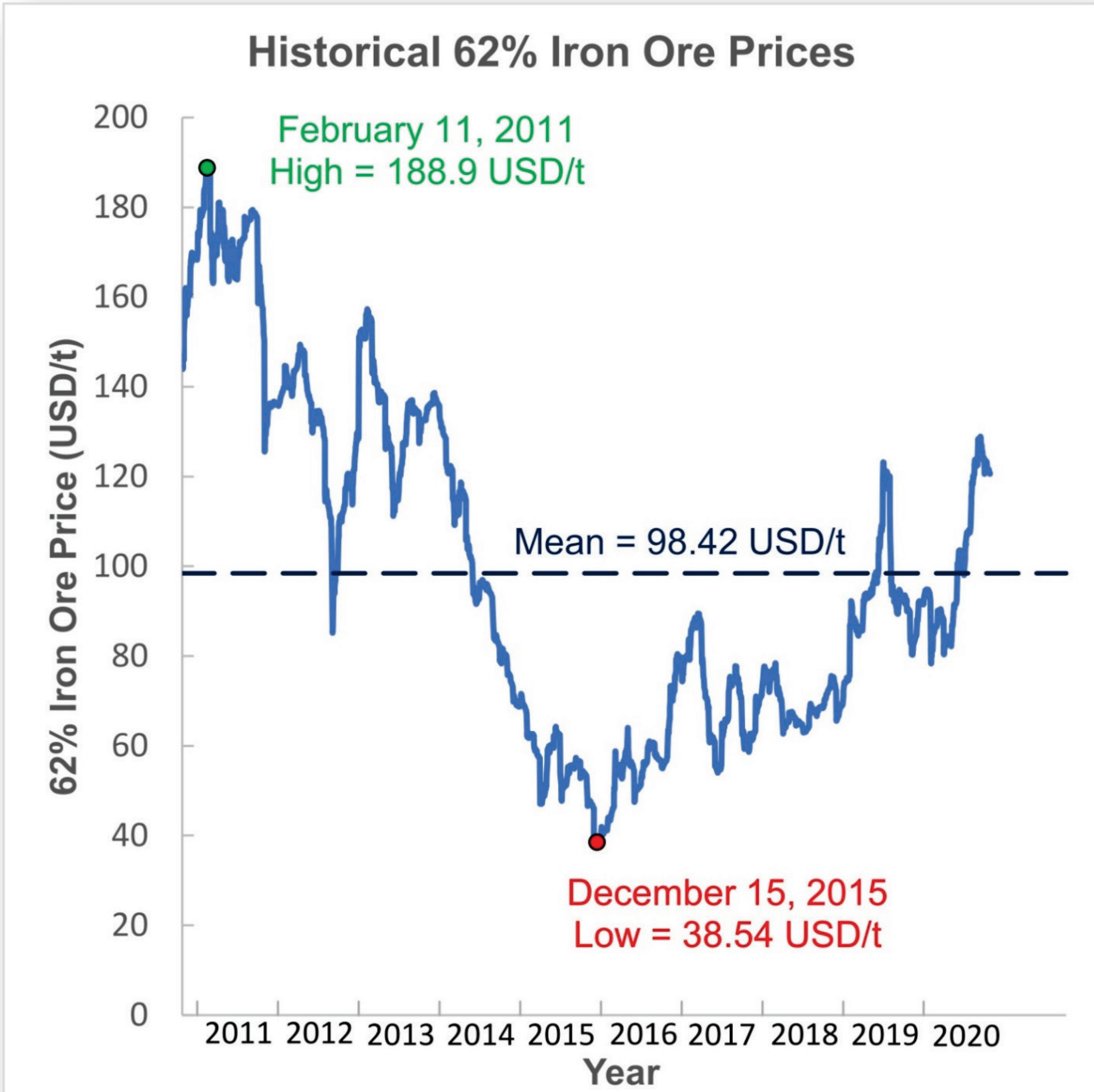

Figure 4. Iron ore prices (62% Fe) have undergone considerable variation over the past 10 years with a high of 188.9 USD/t, low of 38.54 USD/t, and mean of 98.42 USD/t. By comparison, the 2019 Feasibility Study assumed 61.50 USD/t, 60.89 USD/t, and 84.10 USD/t for the calculation of resources, reserves, and net present value (NPV), respectively (see Table 2 and Fig. 7; Minerai de Fer Québec, 2019a).

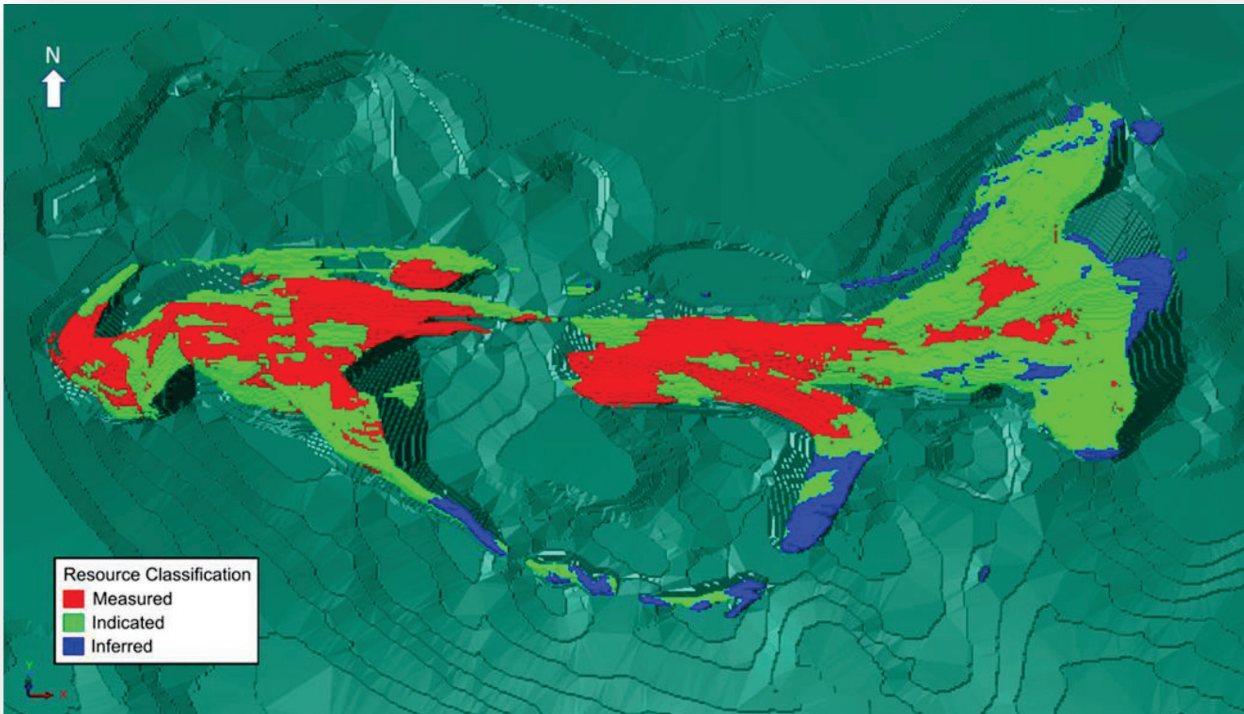

Figure 5a. According to the 2019 Feasibility Study (Minerai de Fer Québec, 2019a), the Bloom Lake iron deposit includes 379.1 Mt of measured resources, 514.4 Mt of indicated resources, and 53.5 Mt of inferred resources, for a total of 947.0 Mt, based on a cut-off grade of 15% Fe and an iron ore price of 61.50 USD/t (see Table 2). Figure from Minerai de Fer Québec (2019a), which does not indicate the elevation of the map.

Consideration of Open-Pit Backfill Option

The 2017 Feasibility Study (Minerai de Fer Québec, 2017) assumed that the mining project would include open-pit backfill of waste rock that would occur with concurrent backfilling and mining in the same pits. The study did not specify what portion of the waste rock would be backfilled or whether the open pits would be partially or completely backfilled. The 2017 Feasibility Study also included two open pits, but the Chief's Peak Pit in the 2019 Feasibility Study (see Figs. 3 and 5b) was called the East Pit in the 2017 Feasibility Study. According to the 2017 Feasibility Study, "A total of 186 Mt of waste material is mined throughout the life-of-mine. At least half the tonnage has to be stored in waste dumps before in-pit waste dumping can commence and be committed to…In-pit waste storage is initiated in 2022 once the East Pit Phase 1 is depleted. The West Pit Phase 1 in-pit dump will start in 2026 and will consist in filling the mined out bottom portion of the west pit. Finally, the West Pit Final in-pit dumping is planned from year 2034 onwards. Waste rock will be pushed from the pit rim…From year 5 onwards, in-pit dumping will occur whenever possible, once a phase gets fully depleted" (Minerai de Fer Québec, 2017). The 2017 Feasibility Study did not include any discussion of the possibility of open-pit backfilling of mine tailings.

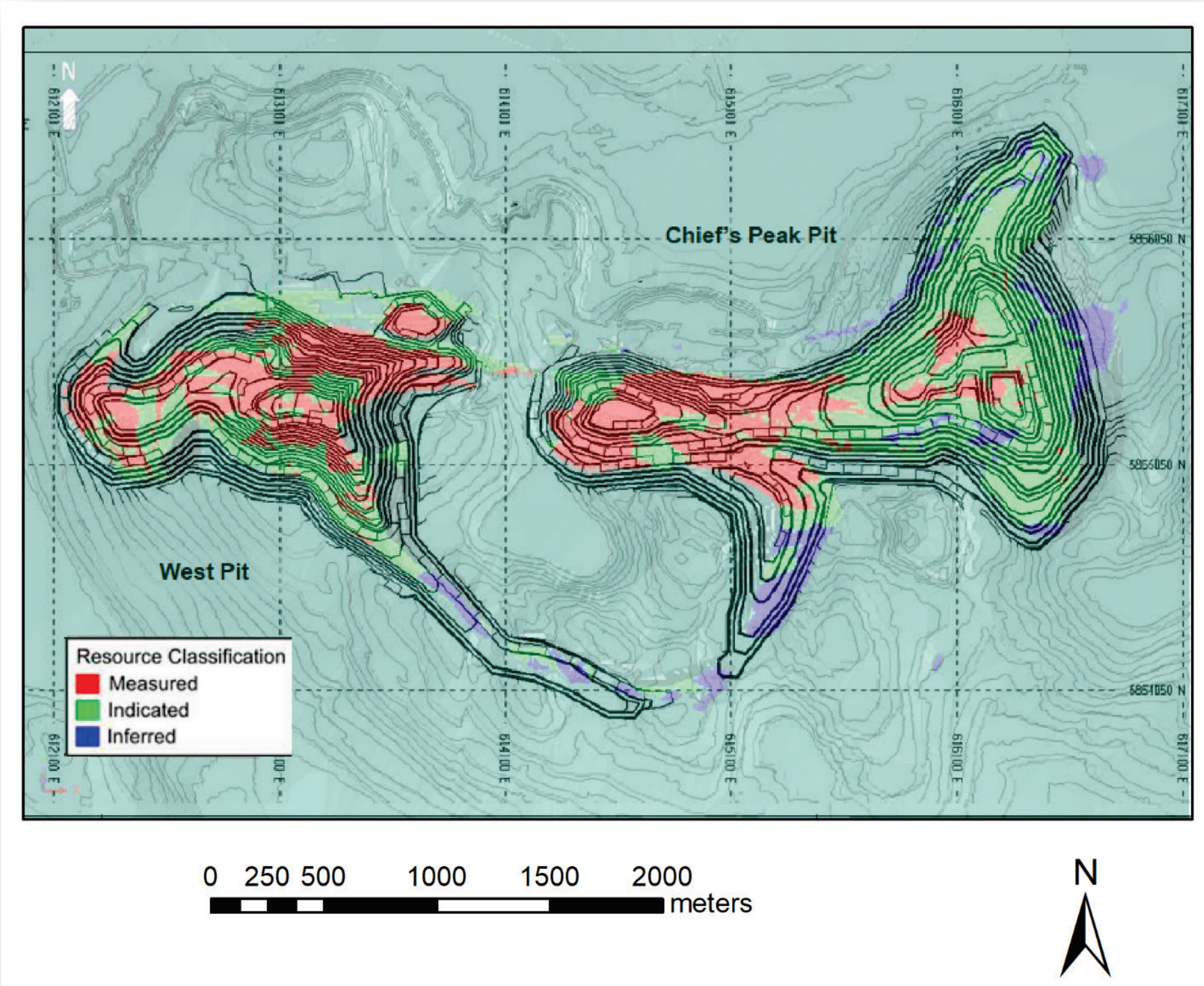

Figure 5b. Although the resource map from the 2019 Feasibility Study (Minerai de Fer Québec, 2019a) does not include a scale or any geographical information (see Fig. 5a), it was overlain onto the final pit design (see Fig. 3) by matching topographical features. As expected, the final pit design is nearly coincident with the mapped resources and does not show significant resources outside the pit shell from an aerial view. Minerai de Fer Québec (2019a) does not indicate the elevation of the resource map.

By contrast, all documents produced by Minerai de Fer Québec from 2019 onwards rejected any possibility of open-pit backfilling with three justifications. The first justification was that "in-pit dumping has not been planned for the project to avoid the possibility of future re-handling" (Minerai de Fer Québec, 2019a) Open-pit backfilling nearly always involves re-handling of waste material because the mine waste has to be temporarily stored on the surface (as acknowledged in the 2017 Feasibility Study) or elsewhere in the pit before it be placed into its permanent storage site within the pit. The only exceptions are cases in which tailings are transported into open pits directly from the ore processing plant (Arcadis, 2015).

The second justification was that backfilling the open pits would make it impossible to mine additional iron ore in the event of a future increase in price. According to Minerai de Fer Québec (2020), "*Ainsi, il est nécessaire de s'assurer qu'il n'y a plus de ressources économiquement disponibles avant de pouvoir remplir une fosse exploitée. L'analyse de la possibilité de déposer des stériles dans la fosse planifiée démontre que cette option d'entreposage est contre-indiquée dans le cas de la mine du lac Bloom, parce que cela empêcherait l'exploitation des ressources si le prix venait qu'à augmenter suffisamment et mettrait en péril l'exploitation d'une ressource potentiellement exploitable dans le future"* [Thus, it is necessary to ensure that there are no more economically available resources before being able to fill an exploited pit. The analysis of the possibility of depositing waste rock in the planned pit shows that this storage option is contraindicated in the case of the Bloom Lake mine, because it would prevent the exploitation of resources if the price came to increase sufficiently and would endanger the exploitation of a potentially exploitable resource in the future]. The Main Report of the Environmental Impact Study (Minerai de Fer Québec, 2019b) clarified that the claim of future mineral resources that would exist in the event of an increase in price was based entirely upon a single technical note. According to Minerai de Fer Québec (2019c), "*Ainsi, il est nécessaire de démontrer qu'il n'y a plus de ressources économiquement disponibles avant de pouvoir remplir une fosse exploitée. Pour le présent projet, la possibilité de déposer des stériles dans la fosse planifiée a été évaluée et est résumée dans une note technique jointe à* ***l'annexe C de l'évaluation des solutions de rechange au projet (annexe 2, volume 3a)***" [Thus, it is necessary to demonstrate that there are no more economically available resources before being able to fill an exploited pit. For this project, the possibility of depositing waste rock in the planned pit was assessed and is summarized in a technical note attached to **Annex C of the Assessment of Alternatives to the Project (Annex 2, Volume 3a)]** (emphasis in the original).

The technical note in question is an undated three-page memo from Dr. Hugues Longuépée, Geological Director of Champion Iron Mines. The memo stated that, at a sale price of 60 USD/t, there were 693 Mt of resources. This value of 693 Mt of resources is not found in any other document from either Minerai de Fer Québec or Cliff Natural Resources, the previous mine owner. The stated value might be a misprint and might refer to the 893.5 Mt of measured plus indicated resources that are stated in the 2019 Feasibility Study (see Table 2; Minerai de Fer Québec, 2019a). For simplicity, in the rest of this report, it will be assumed that the value of 693 Mt stated by Dr. Longuépée should be 893.5 Mt. However, the memo also states that "*Les ressources ont été définies comme le matériel pouvant être miné tout en générant un profit, aussi minime soit-il, selon les paramètres économiques mentionnés dans l'étude de faisabilité de 2017* [Resources were defined as the material that can be mined while generating a profit, however small, according to the economic parameters mentioned in the 2017 Feasibility Study] and did not mention the existence of any subsequent Feasibility Study.

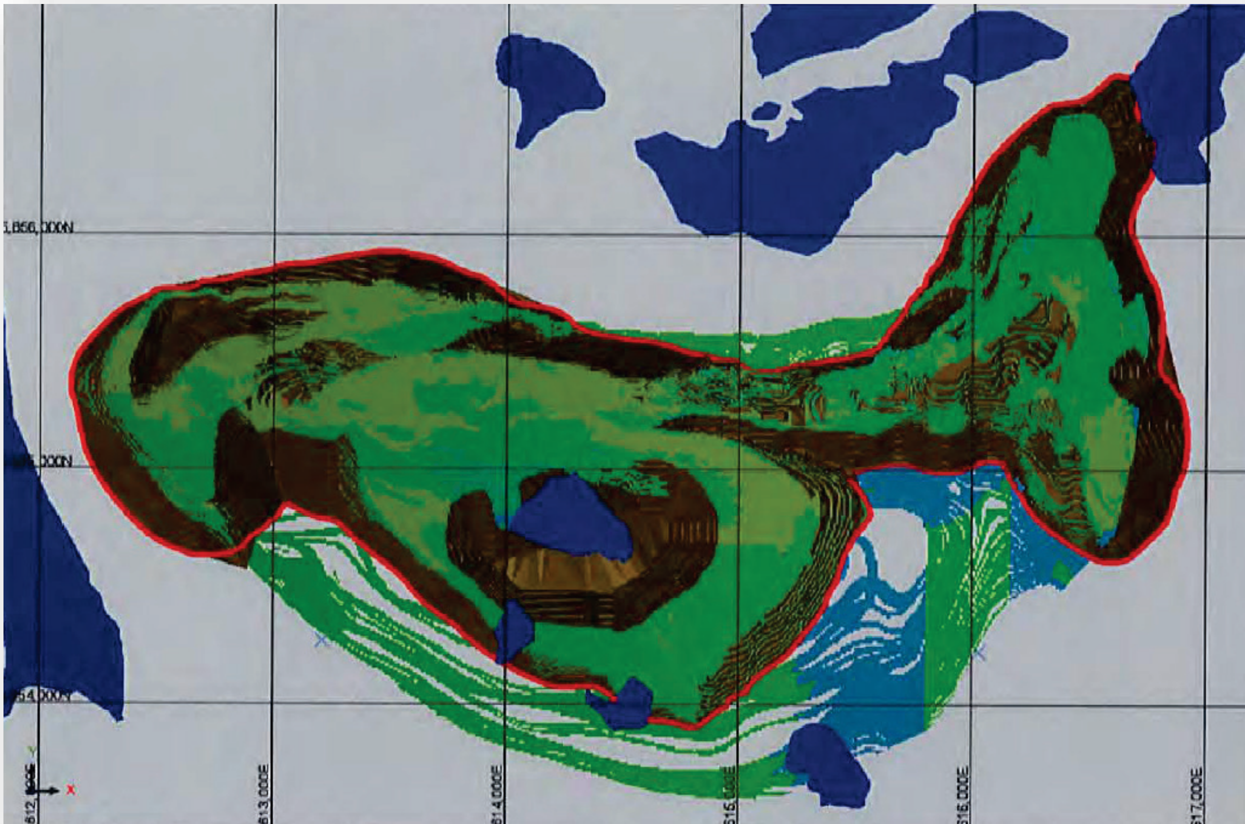

Figure 6. Minerai de Fer Québec (2019c) predicted that mineral resources of 1540 Mt would be present if the iron ore price rose to 80 USD/t, although this is not demonstrated by any study that complies with the Canadian Securities Administrators' standards. According to Minerai de Fer Québec, the red line is the outline of the single combined open pit that would be required to mine the additional resources, which seem to occur mostly near the middle (compare with Figs. 2a-b and 3). The additional mineral resources were used as justification for not backfilling the open pits. Figure from Minerai de Fer Québec (2019c).

The memo then stated that, if the sale price of iron ore were to increase to 80 USD/t, then the mineral resources would increase to 1540 Mt and designed a single, combined open pit that would be needed to exploit the additional resources (see Fig. 6). According to the memo, *Finalement, la dernière figure [Fig. 6] montre la position des ressources additionnelle, c'est-à-dire les ressources qui permettraient de générer du profit à la suite d'une augmentation du prix de 60 USD/t à 80 USD/t, par rapport à la fosse finale établie pour le même prix de vente. On remarque que ces ressources (illustrées en différentes teintes de vert) se retrouvent un peu partout. Toutefois, il faut noter que les bandes de minerai situées au sud représente une très mince bande discontinue qui est techniquement impossible à extraire"* [Finally, the last figure [Fig. 6] shows the position of the additional resources, that is to say the resources that would make it possible to generate a profit following a price increase from 60 USD/t to 80 USD/t, compared to the final pit established for the same selling price. We notice that these resources (illustrated in different shades of green) are found everywhere. However, it should be noted that the ore bands located to the south represent a very thin discontinuous band that is technically impossible to extract]

(Minerai de Fer Québec, 2019c). There was no further information as to how to interpret the colors or shades, either in terms of their grades or the confidence in their existence, or any other aspect. The three-page memo included no further explanation, other than the production of a map of resources (see Fig. 6). Finally, the memo did not discuss reserves or clarify whether resources referred to measured, indicated or inferred resources.

The third justification was that the ore processing technology would require that all portions of the pit be continuously available until the closing of the mine. According to Minerai de Fer Québec (2019c), "*En effet, étant donné l'hétérogénéité spatiale des caractéristiques géométallurgiques du minerai exploité au lac Bloom, MFQ [Minerai de Fer Québec] ne peut se permettre de fermer une section de fosse sans attendre vers la fin de la vie de la mine afin de permettre d'avoir accès aux différents types de minerai et ainsi maintenir la stabilité du mélange de minerai fourni au concentrateur. Ceci est nécessaire pour permettre d'assurer une récupération en fer optimale à l'usine et ainsi réduire la quantité de fer qui se retrouve au parc à résidus (ressource perdue). Cette approche permet ainsi d'exploiter de manière optimale et en conformité avec les principes de développement durable les ressources en fer du gîte minier du lac Bloom*" [In fact, given the spatial heterogeneity of the geometallurgical characteristics of the ore mined at Bloom Lake, QIO [Quebec Iron Ore] cannot afford to close a section of the pit without waiting towards the end of the mine's life in order to allow access to the various types of ore and thus maintain the stability of the ore mixture supplied to the concentrator. This is necessary to ensure optimal iron recovery at the plant and thus reduce the amount of iron that ends up in the tailings facility (lost resource). This approach thus makes it possible to optimally exploit the iron resources of the Bloom Lake mining deposit in accordance with the principles of sustainable development]. This last justification did not address the possibility of carrying out backfilling after (as opposed to concurrently with) the exploitation of the pit.

METHODOLOGY

Based on the preceding sections, the objective of this report can be subdivided into the following questions:

1) What would be the comparative costs of open-pit backfill and the construction of a new tailings storage facility?
2) What would be the costs of partial or complete backfill of the open pits?
3) How would the costs of open-pit backfill compare with the net present value (NPV) of the mining project?
4) What would be the benefits of backfill of the open pits?
5) Are the predictions of the additional mineral resources that would be covered by open-pit backfill consistent with previous Feasibility Studies?
6) Is the requirement of continuous exposure of the entire open pits justified by the mineral processing technology?

The unit cost of open-pit backfill (per metric ton of dry mine waste) was determined based on 15 open-pit backfill plans that were publicly available and which included costs (see Table 3). The plans were a mix of proposed, in-progress and completed backfill projects. In some cases, the cost was a pre-implementation estimate with no available information as to the actual cost. Out of the 15 backfill plans, 13 were in Canada, and eight were in Quebec. Costs that were stated in CAD were converted to USD using 1 CAD = 0.76 USD, while prices that were stated euros were converted using 1 euro = 1.19 USD. Plans for backfill of waste rock that were based on volume were converted to mass using a bulk density of 1.84 t/m^3 for excavated and compacted waste rock (Porter and Bleiwas, 2003). A plan for backfill of water and tailings with a stated volume and solids content was converted to mass of dry tailings using a particle density of 3.0 t/m^3.

The total cost of backfilling all of the excess coarse tailings was determined by multiplying the unit cost by the mass of tailings (296.4 Mt). The alternative cost of constructing and operating a new tailings storage facility was determined by adding the estimated pre-production capital cost for tailings and water management to the estimated Life-Of-Mine operating costs for tailings and water management (Minerai de Fer Québec, 2019a). The operating cost was stated as a unit cost per metric ton of dry concentrate (Minerai de Fer Québec, 2019a), but was converted into a unit cost per metric ton of dry coarse tailings using the proportion given in Table 1. The total cost of a new tailings storage facility was an underestimate because it did not take into account the cost of safe closure of the facility. Minerai de Fer Québec (2019a) estimated a total mine closure and restoration cost of 75.9 million USD, but did not specifically address the cost of closure of the tailings storage facility. However, the statement that "final rehabilitation and closure costs will be incurred in 2040 (Year 20)," or the last year of 20 years of mining, implied that there is no intention to carry out long-term monitoring and maintenance of the tailings storage facility. It is concerning that, out of the closure and restoration costs, Champion Iron Limited (2020a) allocated 14.57 million USD for operation of a water treatment plant for five years, but without arguing that only five years of water treatment would be necessary. Costs in Minerai de Fer Québec (2019a) that were stated in CAD were converted to USD using 1 CAD = 0.76 USD.

Scenarios for partial or complete backfill of the open pit were determined, for a given fraction of the pit volume, using the goals of either minimizing the total mass of remaining mine waste (waste rock + tailings) or minimizing the cost of backfilling. The mass of tailings that could be backfilled was calculated under the assumption that 75% of the pore space of waste rock could be occupied by tailings (BAPE, 2016). For simplicity, no distinction was made between backfilling coarse tailings and fine tailings. Because of the greater bulk density of waste rock, as compared to tailings (see Table 1), and because tailings could occupy some of the same volume occupied by the waste rock, the total mass of remaining mine waste is minimized by filling the available pit volume with as much waste rock as possible and then adding as much tailings as possible. For the same reason, and because the cost is primarily based on the mass of material that must be transported, the cost is minimized by filling the available pit volume with as much tailings as possible and then adding as much waste rock as possible. Note that, for filling a given fraction of the pit volume, minimizing the total mass of remaining mine waste is equivalent to maximizing the cost of backfill, and vice versa.

The various backfill costs were also compared with the net present value (NPV) of the mining project. The pre-tax and after-tax NPV for the expansion project (Phase 2 only) were estimated by Minerai de Fer Québec (2019a) as 1164.2 million USD and 726.3 million USD, respectively, under the assumption of an 8% discount rate, a long-term iron ore price (62% Fe index plus premium for extra Fe content) of 84.10 USD/t, and an exchange rate of 1 CAD = 0.76 USD, among other factors. The pre-tax and after-tax Internal Rates of Return for Phase 2 only range between 33.4% and 42.4%. The total Life-Of-Mine revenues, as well as the pre-tax and after-tax NPV for both Phase 1 and 2 combined are estimated at 18.2 billion USD, 2850.0 million USD, and 1811.8 million USD, respectively (Minerai de Fer Québec, 2019a; Champion Iron Limited, 2020b). Minerai de Fer Québec (2019a) also assessed the sensitivity of the NPV to the iron ore price by assuming that the iron ore price varied by ± 10%, ± 20% and ± 30% (corresponding to iron ore prices ranging from 58.87 USD/t to 109.33 USD/t), and assuming that all other factors were unchanged. The long-term iron ore price included a premium of 12.70 USD/t, so that the price of 84.10 USD/t (62% Fe plus premium) would correspond to 71.40 USD/t (62% Fe). It was not explained as to why the iron ore price assumed for the calculation of the NPV was so different from the iron ore (62% Fe) prices of 61.50 USD/t and 60.89 USD/t that were used in the same document for the estimations of resources and reserves, respectively (see Table 2). It should be noted that the iron ore price assumed for the calculation of NPV (84.10 USD/t) is slightly greater than the iron ore price (80 USD/t) at which Minerai de Fer Québec (2019c) claimed that mineral resources would increase from 893.5 Mt to 1540 Mt. The question regarding additional mineral resources was addressed by comparison with the 2013 Technical Report and the2017 and 2019 Feasibility Studies (Cliff Natural Resources, 2013; Minerai de Fer Québec, 2017, 2019a), Finally, the question regarding the need for continuous exposure of the open pit was addressed by comparison with other open-pit mines, principally nickel mines in New Caledonia (Dufuyard et al., 2020).

RESULTS

Costs and Benefits of Open-Pit Backfill

The unit costs for open-pit backfill have ranged from 0.28 USD/t to 15.00 USD/t, with 10 out of the 15 studies in the range 0.72 USD/t to 1.50 USD/t (see Table 3). The very high outlier (15.00 USD/t) included the additional cost of remediation of acid mine drainage from waste rock that had been stored on the surface at the Soviet-era Lichtenberg uranium mine in former East Germany (Arcadis, 2015). The very low outlier (0.28 USD/t) was achieved through the transport of uranium tailings as a slurry by gravity directly from the ore processing plant into an exhausted open pit (Arcadis, 2015). In no other case was it apparent why the cost was particularly high or low. Instead of removing the outliers, the expected value was calculated as the geometric mean (1.20 USD/t), which suppresses the impact of outliers. The calculation of the median would be an alternative approach, which would yield a nearly identical result (1.18 USD/t). Throughout the remainder of this report, the value of 1.20 USD/t will be used as the best estimate for the unit cost of open-pit backfill.

Based on the preceding unit cost for open-pit backfill, the cost of backfilling the excess coarse tailings (356 million USD) and the cost of constructing and operating a new facility for the permanent aboveground storage of the excess coarse tailings (328.4 million USD) are remarkably similar (see Table 4). The cost of operating the new tailings storage facility might be an underestimate, since Klohn Crippen Berger (2017) found a typical operating cost of 1.20 USD/t for tailings and water management for thickened tailings technology, which would be used at the Bloom Lake mine (Minerai de Fer Québec, 2019a), within an industry range of 0.5-2.50 USD/t, as opposed to the operating cost of 0.98 USD/t given by Minerai de Fer Québec (2019a) (see Table 4). The unit cost of open-pit backfill and the unit cost of tailings and water management are also quite similar and probably primarily reflect the energy cost of transporting material. The total cost of a new tailings storage facility is also an underestimate, since it does not include the cost of closure of the facility, which would be some fraction of the total cost of mine closure (75.9 million USD). On the other hand, even if all of the excess coarse tailings were backfilled, there could still be some costs associated with the temporary aboveground storage of the excess tailings. **In summary, taking into account the preceding uncertainties, there is no purely economic reason for choosing between the backfilling and the permanent aboveground storage of the excess coarse tailings.**

Table 3. Unit costs for open-pit backfill for selected mining projects

Mine	Location	Ore	Quantity (Mt)		Cost (million USD)	Unit Cost (USD/t)
			Waste Rock	Tailings		
Lichtenberg[1]	Germany	U	230[2]	—	3450[3]	15.00
Whistle[1]	Ontario	Cu-Ni	6.4	—	19	2.97
Rabbit Lake[4]	Saskatchewan	U	—	8.8	23.06	2.62
Solbec[4]	Quebec	Cu-Pb-Zn	0.508[2]	0.1	1.0691[5]	2.11
Matawinie[6]	Quebec	graphite	49.5[7]		74.0[8]	1.50
Canadian Malartic[9]	Quebec	Au	—	92[10]	119[8]	1.29
Owl Creek[1]	Ontario	Au	3.648	—	4.7[8]	1.29
Canadian Malartic[9]	Quebec	Au	242.55	—	285[8]	1.18
Dumont[11]	Quebec	Ni	1251.8[12]	—	1463.5[8]	1.17[13]
Island Copper[4]	British Columbia	Cu	90	—	100	1.11
Dumont[14]	Quebec	Ni	984.6[15]	—	748.6-1279.8[8]	0.76-1.30
Captain N Extension[4]	New Brunswick	Pb-Zn	0.1	—	0.1	1.00
East Sullivan[4]	Quebec	Cu-Zn-Ag-Cd	0.37[2]	—	0.35	0.95
Canadian Malartic[16]	Quebec	Au	625	—	449[8]	0.72
Marymia[1]	W. Australia	Au	—	1.296094	0.3595	0.28
					Geometric Mean	1.20
					Median	1.18

[1]Arcadis (2015)
[2]Volume converted to mass using 1.84 t/m^3 (Porter and Bleiwas (2003)
[3]Euros converted to USD using 1 euro = 1.19 USD
[4]MEND (1995)
[5]Cost of backfilling waste rock only
[6]BAPE (2020)
[7]The proposed plan is to backfill 40% of 107.5 Mt of waste rock and tailings. The value is the additional cost of backfilling all but 15 Mt of waste rock and tailings.
[8]CAD converted to USD using 1 CAD = 0.76 USD
[9]BAPE (2009), Golder Associés Ltée (2009)
[10]Based on backfilling 143 Mm^3 of water and tailings with 45% solids content (Golder Associés Ltée, 2009) and assumed particle density of 3 t/m^3
[11]Royal Nickel Corporation (2013a)
[12]1070 Mt of waste rock and 181.8 Mt of overburden (unconsolidated deposits)

13 1.12 UDS/t for waste rock and 1.46 USD/t for overburden
14 BAPE (2014), Royal Nickel Corporation (2014)
15 826 Mt of waste rock and 158.6 Mt of overburden (unconsolidated deposits)
16 BAPE (2016), Mine Canadian Malartic (2016)

Table 4. Comparative cost of constructing new TSF vs. backfilling excess tailings

Excess Coarse Tailings (Mt)[1]	296.4
Backfill Option	
Backfill Unit Cost (USD/t)[2]	1.20
Total Cost	356
New TSF Option	
Construction Cost (million USD)[1]	38.2[3]
Operating Cost (USD/t dry concentrate)[1]	1.60[3]
Operating Cost (USD/t coarse tailings)[4]	0.98[5]
Operating Cost (million USD)	290.2
Total Cost (million USD)	328.4

1 Minerai de Fer Québec (2020a)
2 See Table 3.
3 Converted to USD using 1 CAD = 0.76 USD.
4 Based on ratio of coarse tailings to dry concentrate (see Table 1)
5 Typical operating costs for tailings and water management for thickened tailings is 1.20 USD/t with industry range of 0.50-2.50 USD/t (Klohn Crippen Berger, 2017).

The maximum mass of mine waste that could be backfilled into the open pits would be 706 Mt of waste rock and 281.52 Mt of tailings, leaving 281.52 Mt of tailings on the surface, at a cost of 1185 million USD (see Table 5). This cost does not include the cost of constructing or not constructing a new tailings storage facility or the costs of temporary aboveground storage of either waste rock or tailings. One scenario is that the 281.52 Mt of tailings that would be left on the surface after complete backfilling with minimum remaining mine waste could be accommodated in the already-budgeted new tailings storage facility (maximum capacity 296.4 Mt). A second scenario is that the remaining 281.52 Mt of tailings could be cycled through the two existing tailings storage facilities with some degree of concurrent backfilling and mining, as well as temporary surface storage, with no need for an additional tailings storage facility. In this second scenario, the cost of a new tailings storage facility (328.4 million USD) should be subtracted from the total cost of complete backfill with minimum remaining mine waste (1185 million USD), yielding an additional cost of 856.6 million USD for complete backfill.

The minimum cost of backfilling the entire open-pit volume would be 874 million USD with the backfilling of 156 Mt of waste rock and 571.78 Mt of tailings, leaving 550 Mt of waste rock on the surface (see Table 5). Since this scenario would backfill all of the tailings, a new tailings storage facility would not be required (except to the extent that some surface facility might be required for temporary storage). Subtracting the cost of the already-budgeted tailings storage facility (328.4 million) would then yield an additional cost for complete backfill of 545.6 million

USD. In summary, the minimum additional cost of complete backfill (that includes the cost of already-budgeted items) would be 545.6 million USD.

This minimum additional cost for complete backfill (545.6 million USD) is already 19% of the anticipated pre-tax NPV of the combined Phases 1 and 2 of the mining project (2850.0 million USD). On that basis, although backfill of the excess coarse tailings would not have any additional cost (since it would replace the new tailings storage facility), the complete backfill of the open pits seems to be financially unworkable. However, the NPV is highly dependent upon the sale price of iron ore. According to the calculations in the 2019 Feasibility Study (Minerai de Fer Québec, 2019a), the pre-tax NPV of the combined Phases 1 and 2 of the mining project could range from -2887.97 million USD to 7245.54 million USD, corresponding to iron ore prices ranging from 58.87 USD/t to 109.33 USD/t (see Fig. 7). At the higher iron ore price, the cost of complete backfill would be about 7.5% of the NPV. Even so, the range of prices considered by Minerai de Fer Québec (2019a) does not take into account the full range of possibility, since over the last 10 years alone, the price of iron ore (62% Fe) has varied between 38.54 USD/t and 188.9 USD/t (see Fig. 4; Investing.com, 2020). A best-fit line to the seven calculations of pre-tax NPV by Minerai de Fer Québec (2019a) predicts that the NPV could be as high as 22,917.44 million USD based on the iron ore 10-year high price of 188.9 USD/t and as low as -6171.50 million USD based on the iron ore 10-year low price of 38.54 USD/t (see Fig. 7). At the highest price above, the cost of complete backfill would be only 2% of the pre-tax NPV. Of course, at the lower iron ore prices, complete backfill would not be financially feasible, on top of other losses that would be incurred. **At this point, while partial backfill would be financially feasible, complete backfill should be regarded as a possibility, but probably not economically feasible.**

Table 5. Cost scenarios for partial and complete open-pit backfill[1]

Open-Pit Fill (%)	Waste Rock Fill (Mt)	Tailings Fill (Mt)	Remaining Waste Rock (Mt)	Remaining Tailings (Mt)	Cost (million USD)
Goal: Minimize total mass of remaining mine waste (waste rock + tailings)[2]					
10	100	12.86	606	558.92	135
20	199	25.71	507	546.07	270
30	299	38.57	407	533.21	405
40	398	51.42	308	520.36	540
50	498	64.28	208	507.50	675
60	597	77.13	109	494.65	809
70	697	89.99	9	481.79	944
80	706	150.67	0	421.11	1028
90	706	216.09	0	355.69	1107
100	706	281.52	0	290.26	1185
Goal: Minimize cost of backfilling[3]					
10	0	65.42	706	506.36	79
20	0	130.85	706	440.93	157
30	0	196.27	706	375.51	236
40	0	261.70	706	310.08	314
50	0	327.12	706	244.66	393
60	0	392.54	706	179.24	471
70	0	457.97	706	113.81	550
80	0	523.39	706	48.39	628
90	32	571.78	674	0.00	725
100	156	571.78	550	0.00	874

[1]Based on data in Table 1 and assumption that 75% of the porosity in backfilled waste rock can be filled with tailings (BAPE, 2016), and unit backfill cost of 1.20 USD/t (see Table 3)
[2]The remaining mine waste (sum of waste rock and tailings) is minimized by maximizing the backfill of waste rock.
[3]The cost is minimized by maximizing the backfill of tailings.

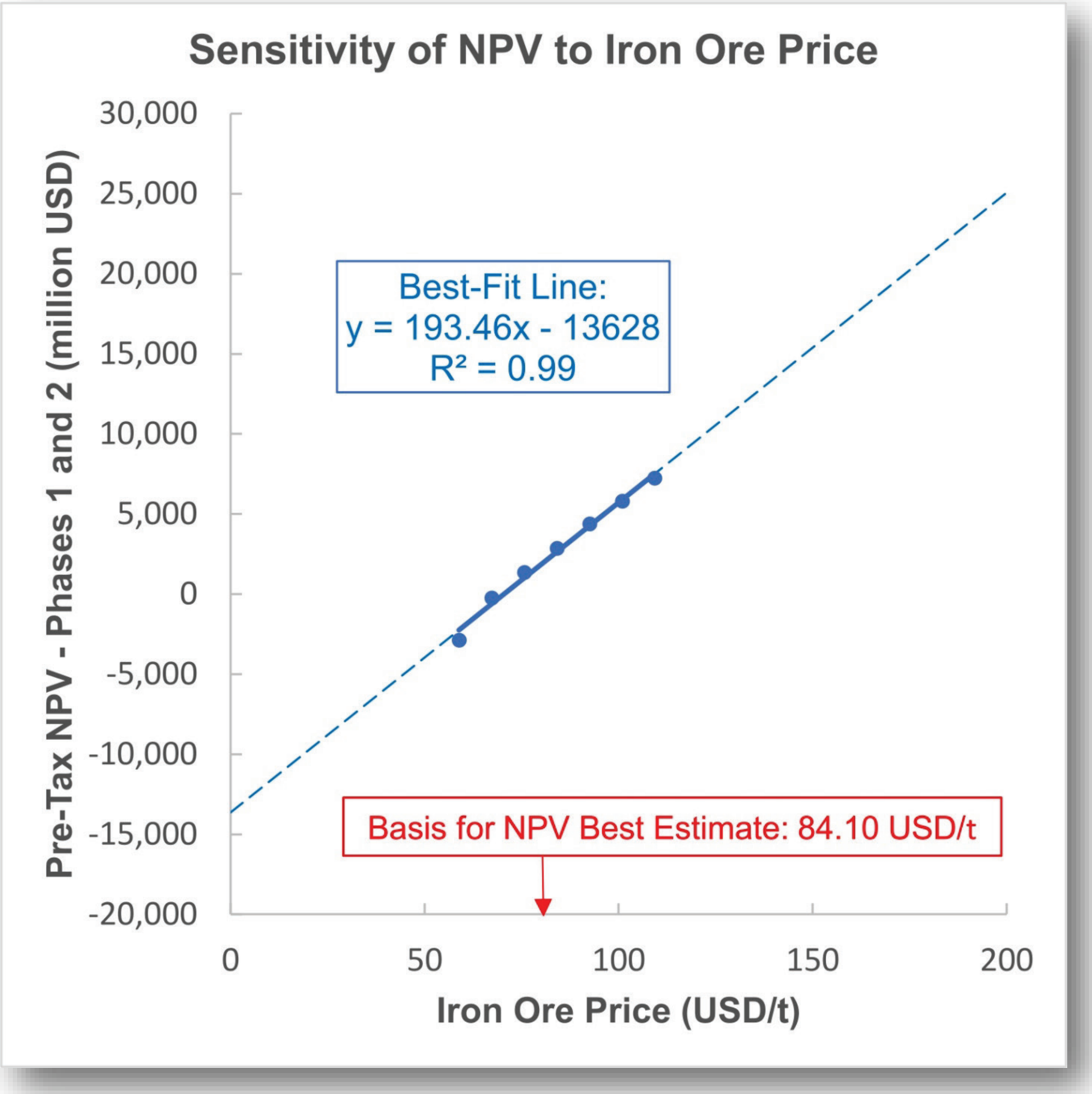

Figure 7. The 2019 Feasibility Study (Minerai de Fer Québec, 2019a) estimated a pre-tax net present value (NPV) of 2850.0 million USD, and a total Life-Of-Mine revenue of 18.2 billion USD for combined Phases 1 and 2 based on an iron ore price (62% Fe plus premium for extra Fe content) of 84.10 USD/t and converted to USD using 1 CAD = 0.76 USD. The same study (Minerai de Fer Québec, 2019a) also calculated the NPV assuming that the iron ore price varied by ± 10%, ± 20% and ± 30%, and assuming that all other factors were unchanged. The resulting pre-tax NPV ranged from -2887.97 million USD to 7245.54 million USD, corresponding to iron ore prices ranging from 58.87 USD/t to 109.33 USD/t. A best-fit line to the seven calculations of NPV predicts that the NPV could be as high as 22,917.44 million USD based on an iron ore 10-year high price of 188.9 USD/t and as low as -6171.50 million USD based on an iron ore 10-year low price of 38.54 USD/t (see Fig. 4).

The clear benefit of backfilling tailings, at least to the extent that a new tailings storage facility would not be needed, would be the preservation of the wetlands and the seven lakes at the site of the proposed tailings facility (compare Figs. 2a-b). Foregoing a new tailings facility would also have the benefits of removing the permanent threats of catastrophic failure and erosion of the tailings facility, as well as the seepage of contaminants into a groundwater system that rises to the surface. Nevertheless, the preservation of the lakes would be the most important benefit, since these lakes could never be restored to their pre-mining condition. The calculation of the monetary value of the lakes in terms of ecosystem and cultural services should be undertaken, but is beyond the scope of this report.

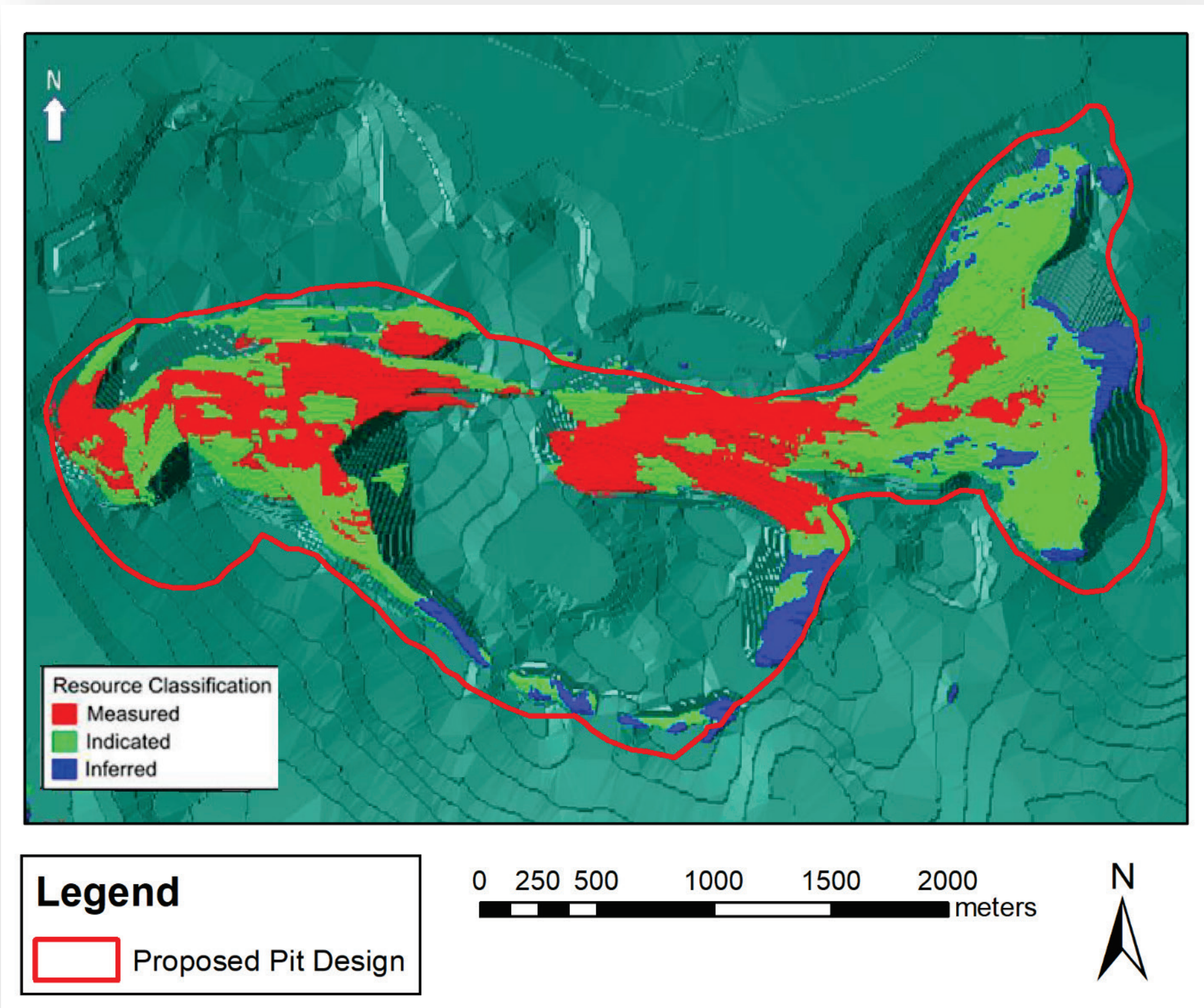

Figure 8. The resources that were predicted by Minerai de Fer Québec (2019c) to be present if the iron ore price rose to USD 80/t are vastly greater than the resources that were determined by Minerai de Fer Québec (2019a) to be present based on a price of USD 61.50/t and cut-off grade of 15% Fe (see Table 2 and Fig. 4a). The red line is the outline of the pit needed for exploiting the additional (not CSA compliant) resources (see Fig. 5a), while the map shows the resources determined by the 2019 Feasibility Study (see Fig. 4a; Minerai de Fer Québec, 2019a). Again, from an aerial perspective, it appears that there is no significant difference in the pit contours of either resource scenarios, except for joining the two pits in the middle section.

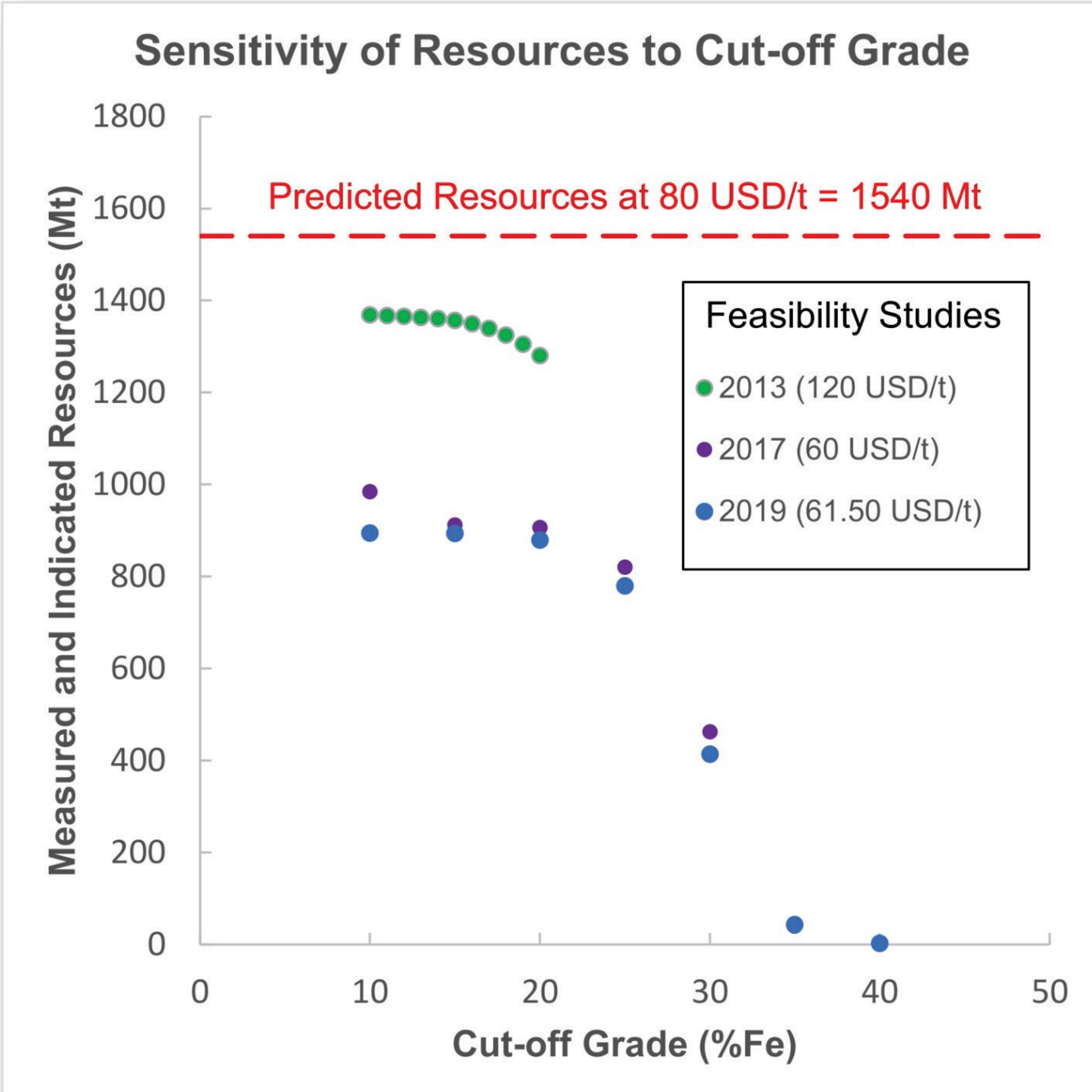

Figure 9. The 2017 and 2019 Feasibility Studies (Minerai de Fer Québec, 2017, 2019a) estimated measured plus indicated mineral resources at cut-off grades of 10%, 15%, 20%, 25%, 30%, 35%, and 40% Fe, based on iron ore prices of 60 and 61.50 USD/t, respectively. The 2013 Technical Report by the previous mine owner (Cliffs Natural Resources, 2013), which is not compliant with CSA standards, estimated measured plus indicated mineral resources at cut-off grades ranging from 10-20% Fe at intervals of 1% Fe, based on an iron ore price of 120 USD/t. By contrast, Minerai de Fer Québec (2019c) estimated resources of 1540 Mt at a price of 80 USD/t with no specified cut-off grade. This most recent resource estimate of 1540 Mt is inconsistent with the 2017 and 2019 Feasibility Studies, as well as the 2013 Technical Report, which while not compliant with CSA standards, and based on the sensitivity of estimates to cut-off grade, predicted under 1400 Mt of resources even when using an iron price 50% higher (120 vs 80 USD/t) and approaching an asymptotic cut-off grade of 0% Fe.

Possibility of Additional Mineral Resources

The claim by Minerai de Fer Québec (2019c) that 1540 Mt of mineral resources would be present at an iron ore price of 80 USD/t is not supported by any of the previous 2017 and 2019 Feasibility Studies, nor by the (not CSA compliant) 2013 Technical Report (Cliff Natural Resources, 2013; Minerai de Fer Québec, 2017, 2019a). By contrast, the 2013, 2017 and 2019 Technical Report and Feasibility Studies estimated measured plus indicated resources of 1365.8 Mt, 911.6 Mt, and 893.5 Mt, at iron ore prices of 120 USD/t, 60 USD/t, and 61.50 USD/t, respectively (see Table 2). A comparison of the outline of the proposed open pit that would be needed at a price of 80 USD/t implies the existence of resources that are vastly greater than were mapped by the 2019 Feasibility Study (compare Figs. 5a-b, 6 and 8). It is noteworthy that the claim of 1540 Mt of resources at 80 USD/t is supported by only a three-page memo that has nothing close to the level of detailed analysis that is found in the 2013 Technical Report (even if not compliant to the CSA standards) or in the 2017 and 2019 Feasibility Studies that were carried out in accordance with the National Instrument 43-101 that is required by the Canadian Securities Administrators. In particular, the three-page memo provides no argument as to why the previous Technical Report and Feasibility Studies should be regarded as incorrect.

In fact, all three previous Technical Reports and Feasibility Studies considered the additional mineral resources (both measured + indicated and inferred) that would exist as a function of ore grade. The 2017 and 2019 Feasibility Studies (Minerai de Fer Québec, 2017, 2019a) estimated mineral resources at cut-off grades of 10%, 15%, 20%, 25%, 30%, 35%, and 40% Fe, based on the same iron ore prices of 60 and 61.50 USD/t, respectively (see Fig. 9). The 2013 Technical Report (Cliffs Natural Resources, 2013) estimated mineral resources at cut-off grades ranging from 10-20% Fe at intervals of 1% Fe, based on an iron ore price of 120 USD/t (see Fig. 9). Although the three-page memo in Minerai de Fer Québec (2019c) mentioned only a future price and not a future cut-off grade, the prediction of vastly greater resources implies that a lower cut-off grade would be acceptable. The mineral resources estimated by the two Feasibility Studies and one Technical Report show very weak dependence on cut-off grade below cut-off grades of about 15% for the 2013 Technical Report and about 20% for the 2017 and 2019 Feasibility Studies (see Fig. 9). Based on the sensitivity of resource estimates to cut-off grade, the 2013, 2017 and 2019 Feasibility Studies predict about 1400 Mt, 1000 Mt and 900 Mt of measured plus indicated resources, respectively, even approaching an asymptotic cut-off grade of 0% Fe, all of which are much lower than the 1540 Mt of resources estimated by Minerai de Fer Québec (2019c) (see Fig. 9). The previous Technical Report and Feasibility Studies do include the disclaimer that "the reader is cautioned that the numbers presented in the following tables [of grade and tonnage sensitivity to cut-off grade] should not be misconstrued with a mineral resource statement" (Minerai de Fer Québec, 2019a). In other words, the mineral resources at cut-off grades other than the assumed cut-off grade (e.g., 15% Fe in the 2019 Feasibility Study; see Table 2) were not analyzed at the same level of detail as for the assumed cut-off grade. The 2013 Technical Report is also not compliant with the CSA standards (see above).

Requirement for Continuous Exposure of Open Pits

It is a known concept that particular ore processing technologies require a specified range of ore physical and chemical properties. However, this was not explained in any detail in the documents provided by Minerai de Fer Québec, except as a justification as to why there could be no backfilling, so that there would be continuous exposure of the entire open pit. There was no consideration of alternative technologies or any process control with the same technology that would preclude the need for continuous exposure of the pits. Moreover, it was not clarified as to whether the mining operation literally requires continuous exposure of the entire open pits, or only access to the necessary range of rock types that would be found within the pits. Furthermore, no detailed geological map of the pits has been provided that would make it possible to determine whether there is a possible sequence of mining and backfilling that makes it possible to have continuous access to all of the necessary rock types. Finally, if continuous exposure to the entire open pit is literally required, it is not clear how mining could proceed from two initial smaller and shallower pits to the final pit design (see Fig. 3). In the same way, it is not clear that all of the necessary rock types would still be present in the single, combined pit that would be needed to exploit the 1540 Mt of resources that would exist at an iron ore price of 80 USD/t (see Figs. 6 and 8). The obvious implication of all of the above uncertainties is that Minerai de Fer Québec appears as if it does not currently know what rocks with what physical and chemical properties will be found in which portions of the pit, which would be in contradiction with the state-of-the-art practices of mine planning and assessment of resources and reserves expected in the NI 43-101 that is required by the Canadian Securities Administrators.

DISCUSSION

At this point, it should be clear that Minerai de Fer Québec has not provided a backfill feasibility study as required under the 2013 Quebec Mining Act. In place of a backfill feasibility study, the mining company has provided three justifications for why they should not be expected to provide a backfill feasibility study. However, from a different perspective, each of the three justifications could be regarded as the starting point for a different aspect of a backfill feasibility study.

The justification based on the need for re-handling waste material and its associated cost could lead to the following questions:

1) How could waste rock be moved a minimum distance, or even not be removed from the pit, so as to minimize the transport cost of backfill?
2) How could either waste rock or tailings be safely and economically stored on the surface on a temporary basis prior to backfill?
3) How could additional tailings be cycled through the existing tailings storage facilities prior to backfill?
4) How could the mining sequence be optimized so as to minimize the temporary surface storage of waste rock and tailings?

5) How could the thickened tailings be piped into the open pits (preferably under gravity) so as to minimize the transport cost of backfill?

In a similar way, the justification based on the need for a mix of ore with appropriate physical and chemical properties could lead to the following questions:

1) What is the range of ore physical and chemical properties that are required by the ore processing technology?
2) How could the current ore processing technology be optimized or how could a different technology be chosen so as to accommodate a greater range of ore physical and chemical properties?
3) How could detailed drilling, or interpretation of the existing drilling results, be carried out so as to determine the spatial distribution of ore physical and chemical properties that will be encountered throughout the mining operation?
4) How can the mining sequence be optimized so that the required range of ore physical and chemical properties will always be available?

Although the above questions are not simple questions, they are known and start-of-the-art questions in the industry. Indeed, the optimization of a mining and backfill sequence in response to constraints, including the requirement of access to the appropriate mix of ore, is a standard part of mine planning. A single example of this is the article entitled "Dump planning optimization with environmental constraints" (Dufuyard et al., 2020) in the October 2020 issue of Mining Engineering. In the context of nickel mining in New Caledonia (among the top five global nickel producers), Dufuyard et al. (2020) write, "So, throughout these projects it may be necessary to backfill the pit with waste material. However, opening the space on the pit floor to accommodate the waste can be tricky. In addition to the opening of the pit floor, the blending of grades is important, which makes planning of the mine pushbacks and of the dump sequencing a difficult task. These deposits contain both manganese and magnesium, which need to be controlled to meet the plant technical requirements. This poses a significant challenge in mine planning as the excavation requires precise removal of material types in order to maintain the balance and meet the blend for the final product…Sequential planning of the waste dumps and how they connect into the haulage plan is very important in the life-of-mine plan." Dufuyard et al. (2020) then continue to give case studies as to how the sequence of mining and backfill have been optimized in various New Caledonian nickel mines. **In summary, the requirement of a proper mix of ore is not a reason to forego backfill, but a call for optimization of the mining and backfill sequence.**

Finally, the last justification based on the existence of 1540 Mt of resources if the iron ore price rose to 80 USD/t could lead to the following questions:

1) What is the detailed explanation (at the level of the previous Feasibility Studies) as to why an increase in iron ore price from 60 to 80 USD/t would cause measured plus indicated mineral resources to increase from 893.5 to 1540 Mt, especially since the 2013 Technical Report, while not compliant with CSA standards, identifies a maximum of 1365.8 Mt of such resources (or 1051.3 Mt of proven and probable reserves) using an iron ore price 50% higher (120 $USD/t)?

2) Based on the above detailed explanation, what information in the 2019 Feasibility Study is incorrect?
3) Based on the much larger and deeper open pit that would be necessary for mining the greater resources that would be available after an increase in iron ore price, would there still be the necessary exposure of all rock types that would be required by the ore processing technology?
4) Would there be someplace to store the additional tailings and waste rock that would be generated from mining 1540 Mt of resources? Would it be necessary to destroy additional wetlands and lakes in order to store the additional tailings and waste rock?
5) Would it be possible to backfill the additional tailings and waste rock that would be generated from mining 1540 Mt of resources?

The last two questions are essentially asking whether it would even be technically feasible to mine the 1540 Mt of resources that are claimed to exist at a higher iron ore price. In other words, could these resources be converted into reserves?

In summary, Minerai de Fer Québec believes that 1540 Mt of resources would be available after an increase in iron ore price to 80 USD/t. Minerai de Fer Québec further believes that 84.10 USD/t is a realistic long-term iron ore price, since that price was the basis for the estimate of the NPV in the 2019 Feasibility Study (Minerai de Fer Québec, 2019a). If the mining company believes both of the above, then it would be appropriate for the company to produce a revised Feasibility Study that demonstrates both the existence of the larger ore body and the technical and economic feasibility of mining the larger ore body. It would also be appropriate to produce a revised Environmental Impact Study for mining the larger ore body. Without the preceding revisions, there is no basis for foregoing backfill in order to prevent covering an ore body when the ore body might not exist, or it might not be technically, economically, and environmentally feasible to mine the ore body at all.

CONCLUSIONS

The chief conclusions of this report can be summarized as follows:

1) It is both technically and financially feasible to backfill excess coarse tailings to prevent the destruction of lakes.
2) Based on 15 mining projects, including eight in Quebec, the geometric mean cost of open-pit backfill is 1.20 USD/t.
3) The cost of backfilling all the excess tailings (356 million USD) is only slightly greater than the cost of constructing and operating a new tailings storage facility (328.4 million USD). By comparison, using a $84.10 USD/t iron ore price (62% Fe plus premium for extra Fe content) and prudent/conservative financial assumptions, the company is forecasting an after-tax NPV (net profit) at 8% discount rate of 1811.8 million USD, a pre-tax NPV of 2850.0 million USD, and a total Life-Of-Mine revenue of 18.2 billion USD.
3) The benefit of backfilling the excess tailings instead of constructing a new tailings storage facility would be the preservation of wetlands and seven lakes, which could never be restored to their pre-mining condition (a permanent and irreversible loss), as well reducing the overall footprint of the mining project and the risk of catastrophic failure of tailings dams.
4) The open pits could be completely filled at minimum additional cost (545.6 million USD) by backfilling all tailings and 156 Mt of waste rock, although this scenario would not be necessary to prevent the destruction of seven lakes, including two large lakes.
5) The claim that the ore processing technology would require continuous exposure of the entire open pits is not supported with sufficient explanation or detailed geological mapping, or by any discussion of alternative options for ore processing.
6) The claim of 1540 Mt of resources at a price of 80 USD/t is contradicted by the 2017 and 2019 Feasibility Studies, as well as the 2013 Feasibility Study2013 Technical Report by the previous mine owner. In particular, the 2013 study2013 report, while not compliant with CSA standards, was carried at an assumed price of 120 USD/t (50% higher) and predicted under 1400 Mt of resources even approaching an asymptotic cut-off grade of 0% Fe.
7) At this stage, the company cannot claim, on the one hand, that it plans to mine 807 Mt of ore reserves based on a 84.10 USD/t long-term iron ore price, and on the other hand, up to 1540 Mt of resources based an iron ore price of 80 USD/t, and on a third hand, up to 1400 Mt of resources based on 120 USD/t. And if the company believes the above, then the company would need to produce a revised Feasibility Study that demonstrates both the existence of the larger ore body and the technical and economic feasibility of mining the larger ore body. It would also need to produce a revised Environmental Impact Study for mining the larger ore body, including assessments of alternative scenarios to backfill the presumably larger open pit in order to prevent the destruction of lakes.

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APPENDIX

Abstract

In response to a request from BAPE, Minerai de Fer Québec has provided two open-pit In response to a request from BAPE, Minerai de Fer Québec has provided two open-pit backfill options for the proposed expansion of the Bloom Lake mine. Option FR involves backfilling 213 Mt of coarse tailings into the Chief's Peak/Pignac Pit. Instead of constructing a new HPA-Nord tailings storage facility, the remaining 83.4 Mt of excess coarse tailings (which could not be stored in the existing tailings storage facilities) would be accommodated by extending the existing HPA-Ouest facility to the northwest. This option would prevent the destruction of lakes. Option FS proposes backfilling 266 Mt of coarse tailings into the West Pit. Since Option FS does not include any backfilling of tailings, it would still be necessary to fill wetlands and seven lakes to the north of the mine by constructing a new HPA-Nord tailings storage facility. The projected unit backfill costs would be 0.88 USD/t for tailings and 0.845 USD/t for waste rock, which are considerably below the industry standard (1.20 USD/t). On that basis, the cost of backfilling all excess coarse tailings (261 million USD) would be significantly less than the cost of constructing a new tailings facility (328.4 million USD). Minerai de Fer Québec created two models for the loss of potential reserves or resources that could result from backfill. The first model was based on the 2019 Feasibility Study and estimated the loss of 97.8 Mt of reserves through the use of large equipment and ore that could not be blended, which still requires detailed explanation. The company claims that this option would result in a loss revenue of about 1.8 billion USD over 2.4 years, or about 10% of its expected total Life-of-Mine revenues. The second model was based on speculative resources that could be covered by backfill as the difference between the measured plus indicated resources (1365.8 Mt) of the 2013 Technical Report and the reserves (807.0 Mt) of the 2019 Feasibility Study. For the latter model, arithmetic errors in the calculation nearly double the potential resources. Even so, the procedure of the latter model is invalid for the following reasons:

1) The 2013 SRK Technical Report did not comply with the Canadian Securities Administrators' requirements and standards, including the NI 43-101standard (see above). Moreover, the 2013 Technical Report was based on far less geological information than the 2019 Feasibility Study.
2) Even if the 2013 Technical Report study were to be in compliance with the requirements of an NI 43-101, resource estimates were based on an unrealistic iron ore price of 120 USD/t, which is higher than any long-term iron ore price forecasted over the next 10-20 years, and nearly double the more realistic price of 60.89 USD/t that was used for the calculation of reserves in the 2019 Feasibility Study. Also, a much smaller differential number would have resulted by comparing the reserves from the 2013 Technical Report (1051.3 Mt) with the reserves from the 2019 Feasibility Study (807 Mt).

The previous justification by Minerai de Fer Québec that concurrent backfilling and mining cannot be carried out because of the need for continuous exposure of the entire open pits was clarified by showing that 44-46% of samples from the Chief's Peak Pit had CaO and MgO concentrations exceeded 3%, indicating unacceptable levels of actinolite. However, this problem

could be addressed by stockpiling ore from the West Pit (about 1% of samples with CaO and MgO concentrations exceeding 3%) for blending with ore from the Chief's Peak Pit or by investigating technologies for separating actinolite from iron concentrate.

Introduction and Methodology

On November 5th, 2020, Minerai de Fer Québec (2020b) released a new document entitled "Options d'entreposage dans la fosse (reponse a la demande du BAPE)" [Options for in-pit backfill (response to the request from BAPE)]. The new document described two options for open-pit backfill. The document also further clarified the previous justifications for not carrying out open-pit backfill and added further justifications. The purpose of this Appendix is to answer the following question: Does the new submission by Minerai de Fer Québec (2020b) resolve the concerns about the lack of a backfill feasibility study that were expressed in the main report of this document? I will first summarize the new submission by Minerai de Fer Québec (2020b) before addressing the methodology for answering the above question.

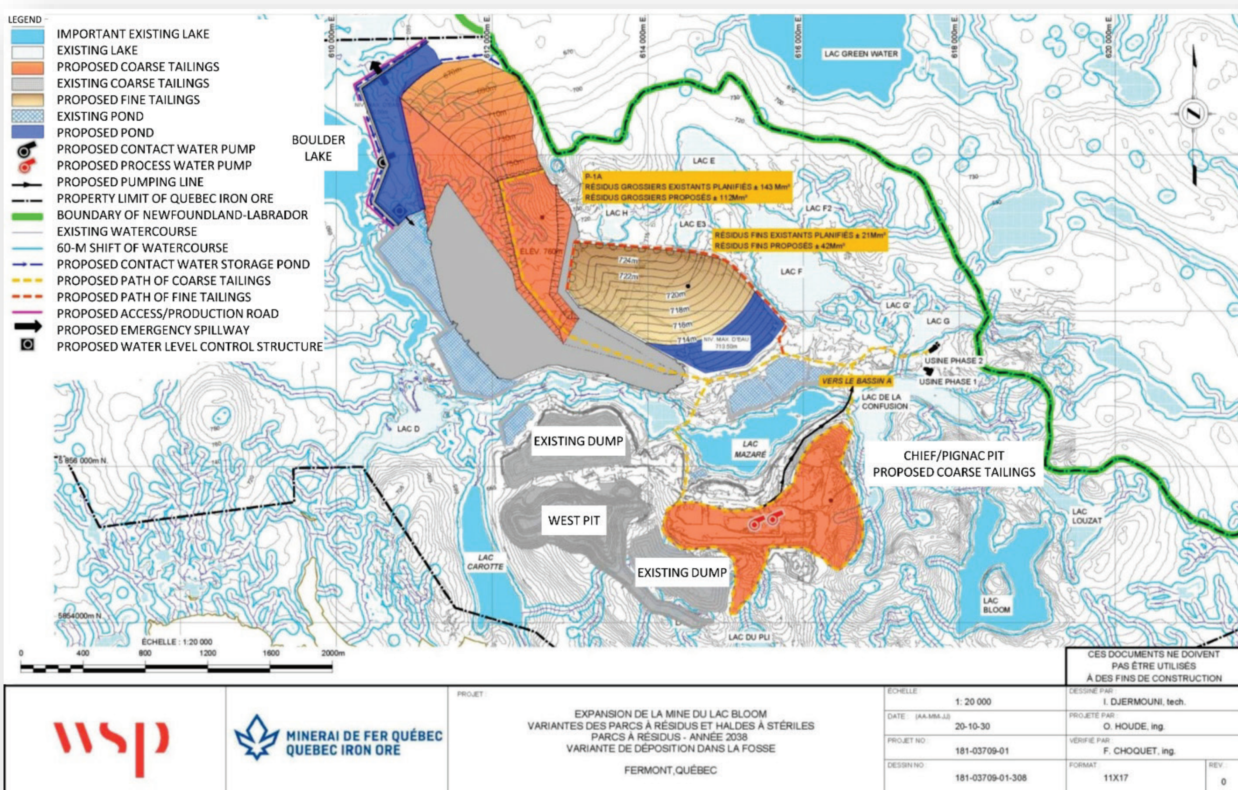

Figure A1. In response to a request from BAPE, Minerai de Fer Québec (2020b) has developed two open-pit backfill options for the proposed expansion of the Bloom Lake mine. Out of the 296.4 Mt of excess coarse tailings (which could not be stored in the existing tailings storage facilities), Option FR proposes backfilling 213 Mt of coarse tailings into the Chief's Peak/Pignac Pit. Instead of constructing a new HPA-Nord tailings storage facility, the remaining 83.4 Mt of coarse tailings would be accommodated by extending the existing HPA-Ouest facility to the northwest (compare with Figs. 2a-b). While option FR does not include any backfilling of waste rock, it would prevent the destruction of lakes. Figure from Minerai de Fer Québec (2020b) with overlay of English labels.

Out of the 296.4 Mt of excess coarse tailings (which could not be stored in the existing tailings storage facilities), the first option FR would involve backfilling 213 Mt of coarse tailings into the Chief's Peak/Pignac Pit (see Fig. A1). (The Chief's Peak/Pignac Pit in the new document seems to be the same as the Chief's Peak Pit in previous documents with the western part of the pit called "Pignac.") Instead of constructing a new HPA-Nord tailings storage facility with the destruction of seven lakes, the remaining 83.4 Mt of coarse tailings would be accommodated by extending the existing HPA-Ouest facility to the northwest (compare Fig. A1 with Figs. 2a-b). While option FR would not include any backfilling of waste rock, it would prevent the destruction of lakes. Option FR would require 163.6-173.3 million USD for capital costs, 7.6-8.7 million USD for operating costs, and 7.4-17.0 million USD for closure costs, for a total backfill cost of 177.7-199.0 million USD (see Table A1). All costs in Minerai de Fer Québec (2020b) in CAD were converted to USD using 1 CAD = 0.76 USD.

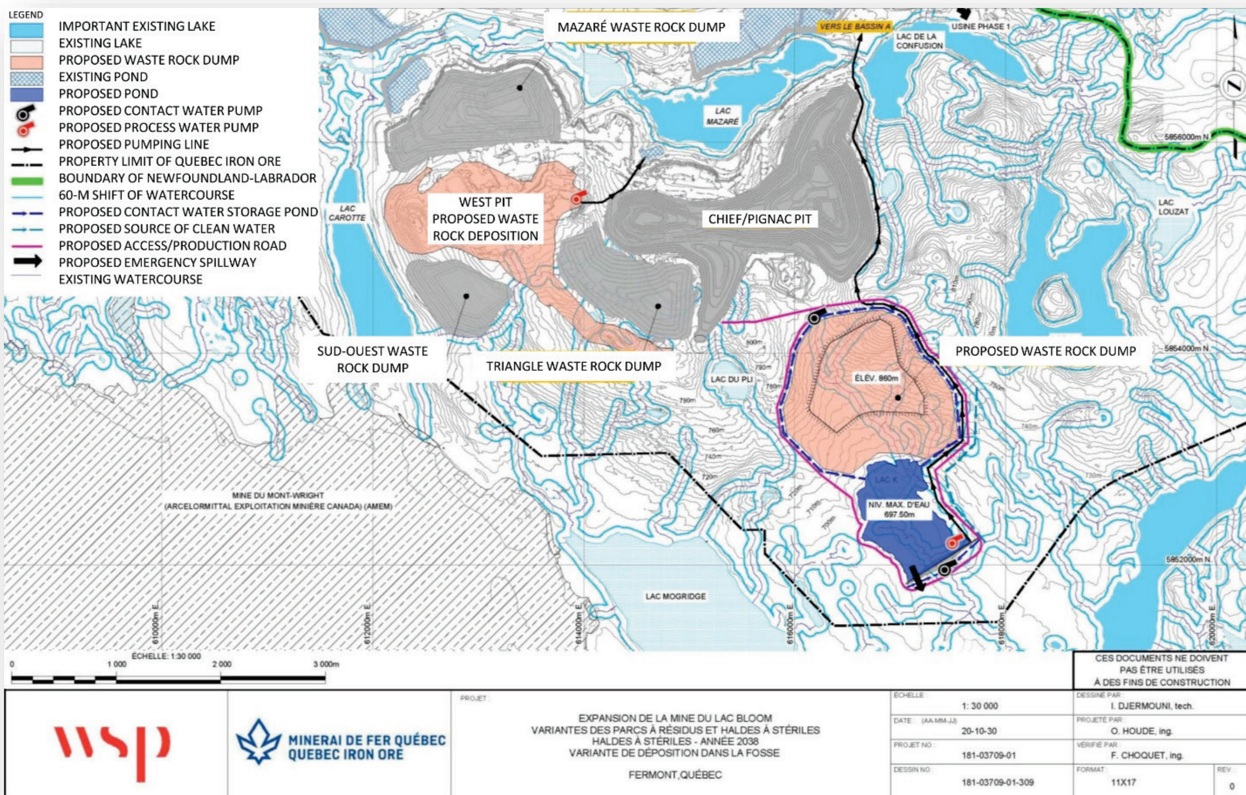

Figure A2. In response to a request from BAPE, Minerai de Fer Québec (2020b) has developed two open-pit backfill options for the proposed expansion of the Bloom Lake mine. Option FS proposes backfilling 266 Mt of coarse tailings into the West Pit. Since Option FS does not include any backfilling of tailings, it would not prevent the destruction of wetlands and seven lakes to the north of the mine by constructing a new HPA-Nord tailings storage facility (compare with Figs. 2a-b). Figure from Minerai de Fer Québec (2020b) with overlay of English labels.

Option FS would take the opposite approach and backfill waste rock and no tailings (see Fig. A2). Option FS proposes backfilling 266 Mt of coarse tailings into the West Pit. Since Option FS does not include any backfilling of tailings, it would be still be necessary to fill wetlands and seven lakes to the north of the mine by constructing a new HPA-Nord tailings storage facility (compare Fig. A2 with Figs. 2a-b). Option FS would require 186.2-187.7 million USD for capital costs, 30.2-30.9 million USD for operating costs, and 7.2-8.5 million USD for closure costs, for a total backfill cost of 223.7-227.2 million USD (see Table A1).

Minerai de Fer Québec (2020b) further pursued the argument that open-pit backfill would prevent the mining of additional mineral resources in the event of an increase in the price of iron ore. The document did not refer to the three-page memo in Minerai de Fer Québec (2019c) that claimed that 1540 Mt of mineral resources would exist in the event of an increase in iron ore price from 60 to 80 USD/t. Instead Minerai de Fer Québec (2020b) calculated the potential loss of mineral resources by comparing the difference between the measured plus indicated resources in the 2013 Technical Report, which is not compliant with the Canadian Securities Administrators' standards (Cliff Natural Resources, 2013) with the reserves in the 2019 Feasibility Study (Minerai de Fer Québec, 2019a). According to Minerai de Fer Québec (2020b), "*La mise à jour récente du plan miner de MFQ en 2019 prévoit l'exploitation de 807 millions de tonnes de minerai. Or, le rapport technique de SRK de 2013 présentait un total de 446.1 millions de tonnes de ressources mesurées et 919,8 millions de tonnes de ressources indiquées (total combiné de 1 365.9 millions de tonnes). Ainsi, la soustraction des 807 millions de tonnes de minerai prévues au plan minier de 2019 de MFQ des 1 368,9 million de tonnes de ressources mesurées et indiquées du rapport de SRK de 2013 suggère qu'un potentiel minéral résiduel de 977,8 millions de tonnes serait encore en place suite à la complétion de la dernière mise à jour du plan minier de MFQ aux environs de 2040*" [The recent update of MFQ's mining plan in 2019 provides for the exploitation of 807 million tonnes of ore. However, SRK's 2013 technical report presented a total of 446.1 million tonnes of measured resources and 919.8 million tonnes of indicated resources (combined total of 1365.9 million tonnes). Thus, subtracting the 807 million tonnes of ore forecast in MFQ's 2019 mining plan from the 1,368.9 million tonnes of measured and indicated resources from the 2013 SRK report suggests that a residual mineral potential of 977.8 million tonnes would still be in place following the completion of the last update of MFQ's mining plan around 2040]. The report referred to as "SRK's 2013 technical report" by Minerai de Fer Québec (2020b) is the same report referred to as the 2013 Technical Report (Cliff Natural Resources, 2013) in this report. Although the preceding quote states either 1365.9 Mt or 1368.9 Mt for measured plus indicated resources, the 2013 Technical Report states 1365.8 Mt (see Table 2). (The discrepancy of 0.1 Mt between measured resources, indicated resources, and the sum of the two results from rounding errors (Cliff Natural Resources, 2013)).

It is most important that subtracting 807.0 Mt from 1365.8 Mt yields 558.8 Mt, not 977.8 Mt. The preceding miscalculation is an actual arithmetical, not a typographical error, because the same inflated lost resources of 977.8 Mt are continued in the calculations by Minerai de Fer Québec (2020b). According to Minerai de Fer Québec (2020b), "*Néanmoins, afin de fournir un aperçu de l'impact que pourrait engendrer le remblaiement de la moitié ouest (Bloom Ouest) ou est (montagne du chef et Pignac) de la fosse avec des stériles ou des résidus miniers sur le futur potentiel minéral du lac Bloom, une condamnation de la moitié du futur potentiel minéral déduit à partir du rapport de SRK de 2013, soit 488,9 millions de tonnes, a été considérée pour les fins du present exercice*" [Nevertheless, in order to provide an overview of the impact that the backfilling of half of the western (Bloom West) or eastern (Chief's Peak and Pignac) pit with waste rock or tailings could have on the future mineral potential of the Bloom lake deposit, a condemnation of half of the future mineral potential deduced from SRK's 2013 report, or 488.9 million tonnes, was considered for the purposes of this exercise]. Minerai de Fer Québec (2020b) then used the value of 488.9 Mt of lost resources to show a loss of 9204 million USD over 12 years from the loss of external contracts, provincial and municipal taxes, payments to First Nations, and salaries and benefits to mining company employees. At the very least, the above losses could possibly be reduced by a factor of 1.75, since the initial step of the calculation was an arithmetic error.

Minerai de Fer Québec (2020b) further clarified the need for continuous exposure of the entire open pits (which would preclude concurrent backfilling and mining) due to the contaminating effect of actinolite throughout the iron deposit. According to Minerai de Fer Québec (2020b), "*Le calcium et le magnésium sont utilisés comme des indicateurs de la présence de silicates comme l'actinolite qui, comme mentionné précédemment, ont un impact préjudiciable sur le processus de concentration du fer de haute pureté. Dans ce contexte, il est primordial pour MFQ d'avoir accès à tous les secteurs de la fosse afin de permettre de produire des mélanges de minerai qui permettent de pallier aux enjeux techniques que peuvent engendrer les éléments traces dans la production de concentré de fer de haute pureté… Cette limite de 3% en CaO et MgO est utilisée comme critère strict à respecter lors de l'élaboration des mélanges de minerai traités à l'usine de concentration pour permettre de produire le concentré de fer d'une haute pureté*" [Calcium and magnesium are used as indicators of the presence of silicates such as actinolite which, as mentioned earlier, have a detrimental impact on the process of concentrating high purity iron. In this context, it is essential for MFQ to have access to all the sectors of the pit in order to allow the production of ore mixtures which make it possible to overcome the technical issues that can be caused by trace elements in the production of iron concentrate from high purity… This limit of 3% in CaO and MgO is used as a strict criterion to be observed when developing ore blends processed at the concentration plant to allow the production of the iron concentrate of high purity]. (Minerai de Fer Québec (2020b) did not clarify whether the 3% limit referred to either CaO or MgO or the sum of the two oxides.) Drilling has shown many fewer samples above the 3% limit in the West Pit (1% of MgO and CaO composites) than in the Pignac (10% of MgO composites, 9% of CaO composites) and Chief's Peak Pits (44% of MgO composites, 46% of CaO composites) (see Fig. A3). On the above basis, according to Minerai de Fer Québec (2020b), the ore processing technology would require the continuous availability of ore from both pits for proper mixing before ore processing.

Minerai de Fer Québec (2020b) provided an additional justification for not backfilling by pointing out that a mining sequence with concurrent backfill and mining would necessitate mining a smaller area at any given time (see Fig. A4). According to Minerai de Fer Québec (2020b), "*L'opération minière sur une plus petite surface demanderait un remplacement de la flotte d'équipement minier par des équipements ayant une capacité supérieure afin de diminuer le nombre d'équipements en operation dans la fosse et de réduire la congestion. Lorsque du minerai est exploité dans une mine à ciel ouvert, une portion du minerai est perdue dans les zones de contacts minerai/sterile…Une perte de minerai de 0, 8% est prévue à l'étude de faisabilité produite par MFQ en 2019…Cette approche d'exploitation responsable de la ressource a spécifiquement* *prévu l'utilisation de petits équipements de chargement pour l'exploitation de ces zones de contact de manière à minimiser le minerai perdu avec le stérile. L'exploitation à l'aide de plus gros équipements miniers ne permettra plus de procéder avec la finesse requise dans ces zones de contact. Ainsi, la perte de minerai prévue à 0,8 % dans l'étude de faisabilité augmenterait dès lors à 5 %, une valeur jugée comme étant réaliste dans l'industrie pour l'utilisation de gros équipements de chargement. Cette hausse de la perte de minerai à 5 % entrainerait une perte de ressources de 33,8 millions de tonnes sur la vie de la mine*" [Mining operation on a smaller area would require replacement of the mining equipment fleet with equipment with a higher capacity in order to decrease the number of equipment operating in the pit and reduce congestion. When ore is mined in an open pit mine, a portion of the ore is lost in the ore/waste rock contact areas…An ore loss of 0.8% is forecast in the feasibility study produced by MFQ in 2019…This responsible resource mining approach specifically provided for the use of small loading equipment to mine these contact zones in order to minimize the ore lost with the waste rock. Mining with larger mining equipment will no longer allow the required delicacy to be achieved in these contact areas. Thus, the ore loss forecast at 0.8% in the feasibility study would therefore increase to 5%, a value considered to be realistic in the industry for the use of large loading equipment]. The loss of an additional 4.2% of the reserves (807 Mt) would amount to 33.9 Mt (stated as 33.8 Mt in Minerai de Fer Québec (2020b)). This would represent a 525% increase in dilution factor, which is significant and would need further demonstration.

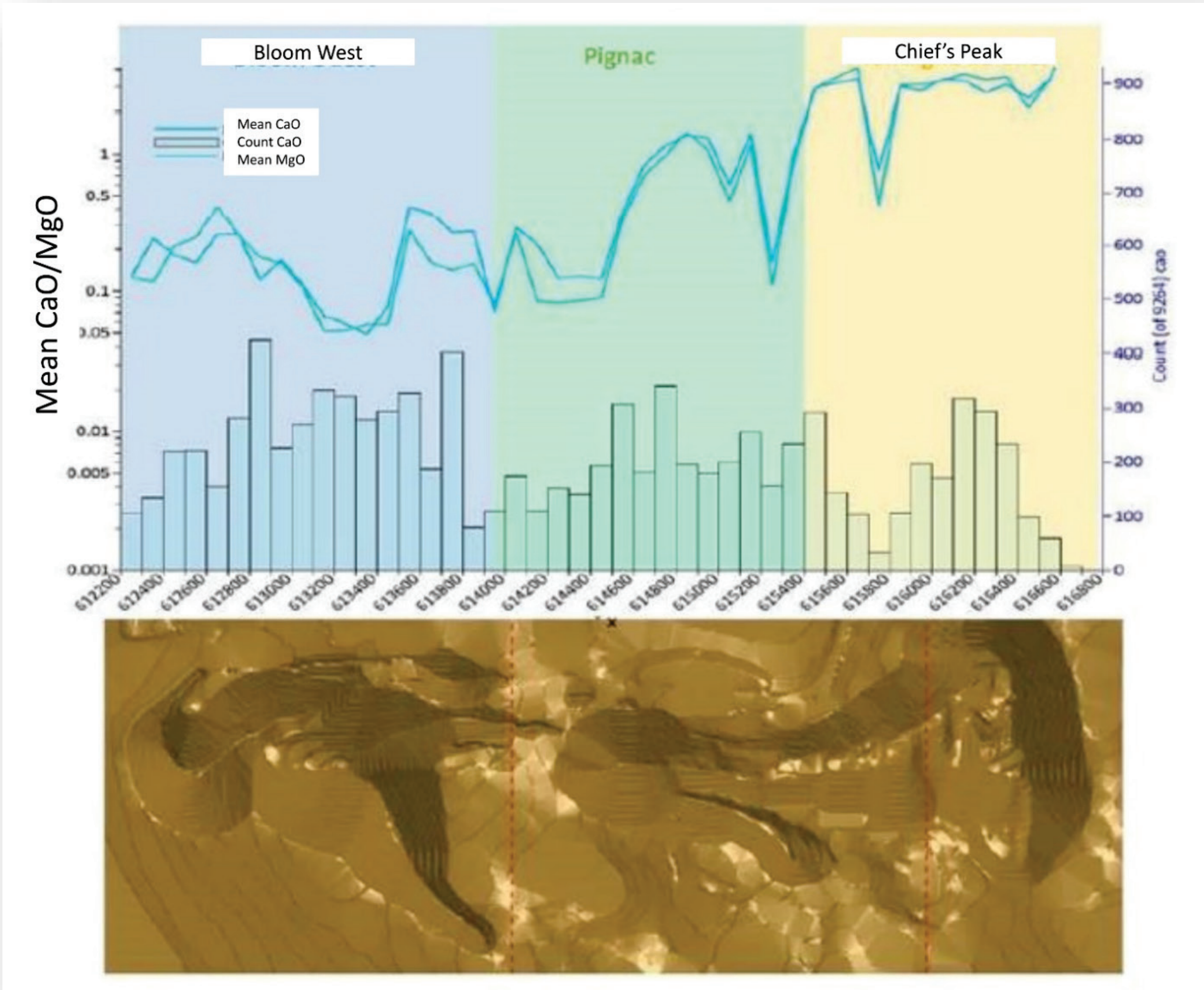

Figure A3. According to Minerai de Fer Québec (2020b), "*Le calcium et le magnésium sont utilisés comme des indicateurs de la présence de silicates comme l'actinolite qui, comme mentionné précédemment, ont un impact préjudiciable sur le processus de concentration du fer de haute pureté. Dans ce contexte, il est primordial pour MFQ d'avoir accès à tous les secteurs de la fosse afin de permettre de produire des mélanges de minerai qui permettent de pallier aux enjeux techniques que peuvent engendrer les éléments traces dans la production de concentré de fer de haute pureté… Cette limite de 3% en CaO et MgO est utilisée comme critère strict à respecter lors de l'élaboration des mélanges de minerai traités à l'usine de concentration pour permettre de produire le concentré de fer d'une haute pureté*" [Calcium and magnesium are used as indicators of the presence of silicates such as actinolite which, as mentioned earlier, have a detrimental impact on the process of concentrating high purity iron. In this context, it is essential for MFQ to have access to all the sectors of the pit in order to allow the production of ore mixtures which make it possible to overcome the technical issues that can be caused by trace elements in the production of iron concentrate from high purity…This limit of 3% in CaO and MgO is used as a strict criterion to be observed when developing ore blends processed at the concentration plant to allow the production of the iron concentrate of high purity]. The figure shows many fewer samples above the 3% limit in the West Pit (1% of MgO and CaO composites) than in the Pignac (10% of MgO composites, 9% of CaO composites) and Chief's Peak Pits (44% of MgO composites, 46% of CaO composites). As opposed to foregoing backfilling, a possible solution would be to stockpile ore from West Pit for mixing with ore from other pits. In addition, the removal of actinolite from iron concentrate is a known technology, as well as an active area of research and development. Figure from Minerai de Fer Québec (2020b) with overlay of English labels.

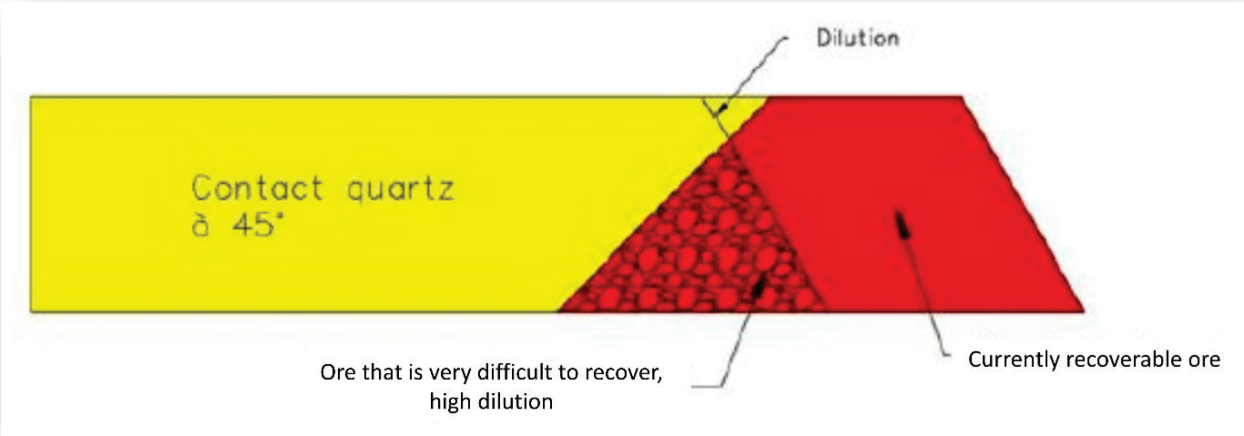

Figure A4. A mining sequence with concurrent backfill and mining would necessitate mining a smaller area at any given time. According to Minerai de Fer Québec (2020b), "*L'opération minière sur une plus petite surface demanderait un remplacement de la flotte d'équipement minier par des équipements ayant une capacité supérieure afin de diminuer le nombre d'équipements en operation dans la fosse et de réduire la congestion. Lorsque du minerai est exploité dans une mine à ciel ouvert, une portion du minerai est perdue dans les zones de contacts minerai/stérile (figure 20). Une perte de minerai de 0, 8% est prévue à l'étude de faisabilité produite par MFQ en 2019…Cette approche d'exploitation responsable de la ressource a spécifiquement prévu l'utilisation de petits équipements de chargement pour l'exploitation de ces zones de contact de manière à minimiser le minerai perdu avec le stérile. L'exploitation à l'aide de plus gros équipements miniers ne permettra plus de procéder avec la finesse requise dans ces zones de contact. Ainsi, la perte de minerai prévue à 0,8 % dans l'étude de faisabilité augmenterait dès lors à 5 %, une valeur jugée comme étant réaliste dans l'industrie pour l'utilisation de gros équipements de chargement. Cette hausse de la perte de minerai à 5 % entrainerait une perte de ressources de 33,8 millions de tonnes sur la vie de la mine*" [Mining operation on a smaller area would require replacement of the mining equipment fleet with equipment with a higher capacity in order to decrease the number of equipment operating in the pit and reduce congestion. When ore is mined in an open pit mine, a portion of the ore is lost in the ore/waste rock contact areas (Figure 20). An ore loss of 0.8% is forecast in the feasibility study produced by MFQ in 2019…This responsible resource mining approach specifically provided for the use of small loading equipment to mine these contact zones in order to minimize the ore lost with the waste rock. Mining with larger mining equipment will no longer allow the required delicacy to be achieved in these contact areas. Thus, the ore loss forecast at 0.8% in the feasibility study would therefore increase to 5%, a value considered to be realistic in the industry for the use of large loading equipment]. The above conclusion is possible, but somewhat surprising (a 525% increase in dilution factor), and would require further explanation; and it is certainly not evident from the figure provided by Minerai de Fer Québec (2020b). Figure from Minerai de Fer Québec (2020b) with overlay of English labels.

Minerai de Fer Québec (2020b) also argued that concurrent backfilling and mining would result in the prevention of some amount of ore blending. High-actinolite ore that could not be blended with lower-actinolite ore would then have to be regarded as waste rock and shipped to the waste rock dumps. Minerai de Fer Québec (2020b) estimated the quantity of potential ore that would be converted into waste rock at 64 Mt. Adding the ore that would be lost through the use of large equipment (33.8 Mt) to the ore that could not be blended (64 Mt) yielded 97.8 Mt of lost ore out of the 807.0 Mt of reserves. Using the same logic as before, Minerai de Fer Québec (2020b) equated the loss of 97.8 Mt of ore to a loss of 1839 million USD, corresponding to the loss of external contracts, provincial and municipal taxes, payments to First Nations, and salaries and benefits to mining company employees.

Based upon the preceding summary of the new document by Minerai de Fer Québec (2020b), the question of this Appendix can be subdivided into the following questions:

1) Are the projected backfill costs consistent with other open-pit backfill projects?
2) How do the projected backfill costs affect the comparative costs of backfilling all of the excess tailings and constructing a new tailings storage facility?
3) How do the projected backfill costs affect the costs of partial or complete backfill of the entire open pits?
4) Is the comparison of the reserves in the 2019 Feasibility Study with the measured plus indicated resources in the 2013 Technical Report a valid procedure for estimating the potential resources that would be covered by backfill?
5) Is the need for blending of low-actinolite and high-actinolite ore from different pits a valid justification for not backfilling?
6) Is the loss of 97.8 Mt of ore (through the use of large equipment and ore that could not be blended) a valid calculation?

Table A1. Costs for backfill options FR and FS[1]

Option	Mass (Mt)	Total Cost[2] (million USD)			Unit Cost (USD/t)
		Capital	Operating	Closure	
FR (tailings only)	213	163.6-173.3	7.6-8.7	7.4-17.0	0.83-0.93
FS (waste rock only)	266	186.2-187.7	30.2-30.9	7.2-8.5	0.84-0.85

[1]Data from Minerai de Fer Québec (2020b)
[2]Costs converted from CAD using 1 CAD = 0.76 USD

Table A2. Comparative cost of constructing new TSF vs. backfilling excessive tailings[1]

Excess Coarse Tailings (Mt)[2]	296.4
Backfill Option	
Backfill Unit Cost (USD/t)[3]	0.88
Total Cost	261
New TSF Option	
Construction Cost (million USD)[2]	38.2[4]
Operating Cost (USD/t dry concentrate)[2]	1.60[4]
Operating Cost (USD/t coarse tailings)[5]	0.98[6]
Operating Cost (million USD)	290.2
Total Cost (million USD)	328.4

[1]Table 4 is updated based on the lower per unit cost for open-pit backfill given in Minerai de Fer Québec (2020b).
[2] Minerai de Fer Québec (2020a)
[3]Average of maximum and minimum per unit cost for tailings (see Table A1)
[4]Converted to USD using 1 CAD = 0.76 USD.
[5]Based on ratio of coarse tailings to dry concentrate (see Table 1)
[6]Typical operating costs for tailings and water management for thickened tailings is 1.20 USD/t with industry range of 0.50-2.50 USD/t (Klohn Crippen Berger, 2017).

Results

A comparison of backfill costs and quantities for the two options resulted in unit costs of 0.83-0.93 USD/t for tailings and 0.84-0.85 USD/t for waste rock (see Table A1). These unit costs are significantly lower than what has been typical for other backfill projects (1.20 USD/t; see Table 3). However, the unit backfill costs are still greater than two recent backfill plans for mines in Quebec, namely the Canadian Malartic gold mine (0.72 USD/t; see Table 3) and the lower estimate for the Dumont nickel mine (0.76 USD/t; see Table 3). Using an average backfill unit cost of 0.88 USD/t for tailings, the cost of backfilling all of the excess coarse tailings (296.4 Mt) would then be 261 million USD or less than 80% of the cost of constructing a new tailings storage facility (see Table A2). Therefore, backfilling all of the excess coarse tailings has become an even more attractive option, based upon the unit backfill costs provided by the new document (Minerai de Fer Québec, 2020b).

Based on average unit backfill costs of 0.88 USD/t for tailings and 0.845 USD/t for waste rock (see Table A1), the various scenarios for partial or complete backfill of the open pits also become more attractive (see Table A3). The minimum cost of backfilling the entire open-pit volume would now be 635 million USD with the backfilling of 156 Mt of waste rock and 571.78 Mt of tailings, leaving 550 Mt of waste rock on the surface (see Table A3). Since this scenario would backfill all of the tailings, a new tailings storage facility would not be required (except to the extent that some surface facility might be required for temporary storage). Subtracting the cost of the already-budgeted tailings storage facility (328.4 million) would then yield an additional cost for complete backfill of 306.6 million USD.

Table A3. Scenarios for partial and complete open-pit backfill[1]

Open-Pit Fill (%)	Waste Rock Fill (Mt)	Tailings Fill (Mt)	Remaining Waste Rock (Mt)	Remaining Tailings (Mt)	Cost (million USD)
Goal: Minimize total mass of remaining mine waste (waste rock + tailings)[2]					
10	100	12.86	606	558.92	95
20	199	25.71	507	546.07	191
30	299	38.57	407	533.21	286
40	398	51.42	308	520.36	382
50	498	64.28	208	507.50	477
60	597	77.13	109	494.65	573
70	697	89.99	9	481.79	668
80	706	150.67	0	421.11	729
90	706	216.09	0	355.69	787
100	706	281.52	0	290.26	844
Goal: Minimize cost of backfilling[3]					
10	0	65.42	706	506.36	58
20	0	130.85	706	440.93	115
30	0	196.27	706	375.51	173
40	0	261.70	706	310.08	230
50	0	327.12	706	244.66	288
60	0	392.54	706	179.24	345
70	0	457.97	706	113.81	403
80	0	523.39	706	48.39	461
90	32	571.78	674	0.00	530
100	156	571.78	550	0.00	635

[1]Based on data in Table 1, the assumption that 75% of the porosity in backfilled waste rock can be filled with tailings (BAPE, 2016), and mean tailings and waste rock unit backfill costs of 0.88 USD/t and 0.845 USD/t, respectively (see Table A1)

[2]The remaining mine waste (sum of waste rock and tailings) is minimized by maximizing the backfill of waste rock.

[3]The cost is minimized by maximizing the backfill of tailings.

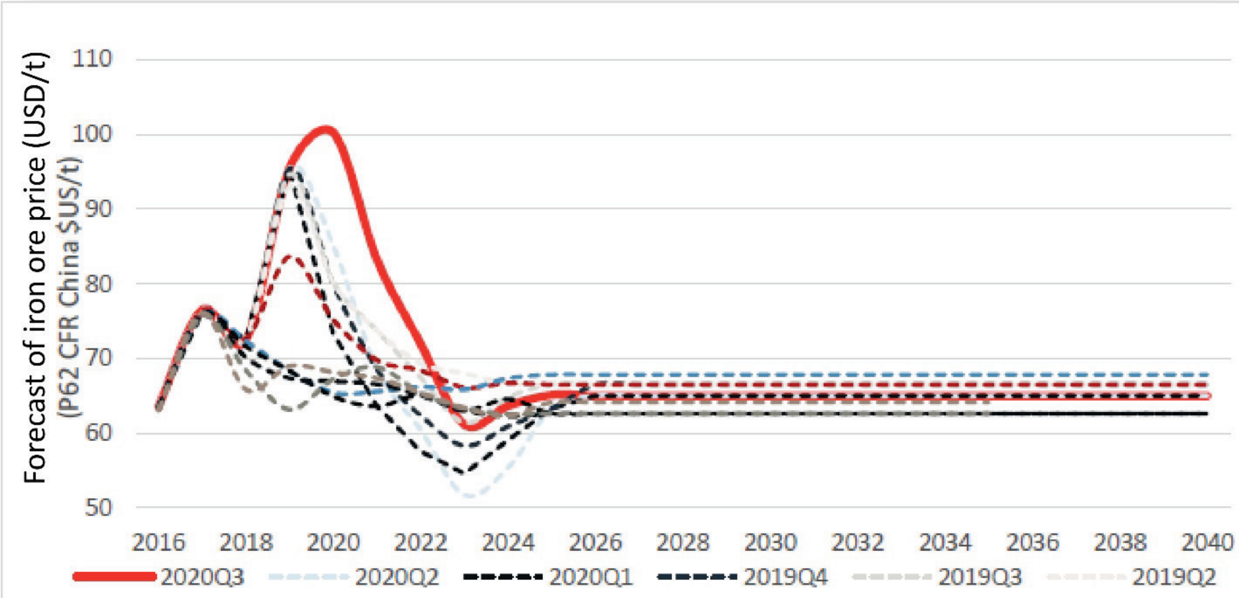

Figure A5. Not only are iron ore (62% Fe) prices highly volatile (see Fig. 4), but the forecasts of long-term iron prices vary considerably from quarter to quarter. The interpretation of Minerai de Fer Québec (2020b) is that "*les prévisions actuelles du prix du fer à long terme ne doivent ainsi pas servir d'unique facteur à considérer pour condamner des matériaux géologiques puisque ces dernières seront appelées à changer avec les temps tel qu'en témoigne la figure…*" [current long-term iron price forecasts should therefore not be used as the sole factor to be considered in condemning geological materials since these will be called upon to change over time as shown in the figure]. An alternative interpretation of the above figure is that an iron ore price of 120 USD/t, which was used in the estimation of mineral resources in the 2013 Technical Report (Cliff Natural Resources, 2013), is far from realistic at the present time or in the foreseeable future (through 2040). Therefore, there is no validity for using the 2013 Technical Report to argue that mineral resources would be covered by open-pit backfill. The figure is from Minerai de Fer Québec (2020b) with overlay of English labels. The source is stated as "Wood Mackenzie (2020)" with no further information.

The comparison of the reserves in the 2019 Feasibility Study with the measured plus indicated resources in the 2013 Technical Report as a means of estimating the potential resources that would be covered by backfill is not a valid procedure for at least four reasons. The first reason is that the reserves of the 2019 Feasibility Study were estimated at an iron ore price of 60.89 USD/t, while the measured plus indicated resources of the 2013 Technical Report were estimated at an iron ore price of 120 USD/t. Resources do not simply exist as physical objects, they exist only when they can be potentially extracted at a given sell price. This dependence of the existence of resources upon a commodity price is inherent in the definition of a mineral resource as "a concentration or occurrence of solid material of economic interest in or on the earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction" (CIM, 2014a). On the above basis, the reserves from the 2019 Feasibility Study and the resources from the 2013 Feasibility are incomparable quantities.

Minerai de Fer Québec (2020b) presented a graph (see Fig. A5) that showed that, not only are iron ore (62% Fe) prices highly volatile (see Fig. 4), but the forecasts of long-term iron prices vary considerably from quarter to quarter. The source of the graph was stated as "Wood

Mackenzie (2020)" with no further information (Minerai de Fer Québec, 2020b). The interpretation of Minerai de Fer Québec (2020b) is that "*les prévisions actuelles du prix du fer à long terme ne doivent ainsi pas servir d'unique facteur à considérer pour condamner des matériaux géologiques puisque ces dernières seront appelées à changer avec les temps tel qu'en témoigne la figure…*" [current long-term iron price forecasts should therefore not be used as the sole factor to be considered in condemning geological materials since these will be called upon to change over time as shown in the figure]. An alternative interpretation of the same figure is that an iron ore price of 120 USD/t, which was used in the estimation of mineral resources in the 2013 Technical Report (Cliff Natural Resources, 2013), is far from realistic at the present time or in the foreseeable future (through 2040).

The second reason as to why the reserves of the 2019 Feasibility Study and the measured plus indicated resources of the 2013 Technical Report are incomparable is that the 2019 study was based on far more geological information than the 2013 report. The 2013 Technical Report was based on 467 drillholes (108,284 meters) with a total of 10,082 assays (Cliff Natural Resources, 2013). The 2019 Feasibility Study was based on 569 drillholes (141,289 meters) and a total of 11,397 assays (Minerai de Fer Québec, 2019a). Even so, as mentioned earlier, the 2019 Feasibility Study did not take into account all of the available geological information.

The third reason is simply that resources are not reserves. The conversion of resources into reserves requires establishing the technical feasibility of mining, in addition to other modifying factors (CIM, 2014a). In the case of a future additional expansion of the Bloom Lake mine, the determination of technical feasibility would include finding a place to store the additional waste rock and tailings that would be generated. If the 2013 Technical Report and 2019 Feasibility Studies were to be compared at all, it would have to be a comparison of the reserves of the two studies. Comparing the 1051.3 Mt of reserves from the 2013 Technical Report with the 807.0 Mt of reserves from the 2019 Feasibility Study (see Table 2) yields only 244.3 Mt. The preceding value still cannot be regarded as "potential reserves" for the reasons stated above and continued below.

The problematic nature of confusing resources and reserves is illustrated in another figure presented by Minerai de Fer Québec (2020b) (see Fig. A6). According to Minerai de Fer Québec (2020b), "*La figure [ci-dessus 13] présente la coupe longitudinale de l'interprétation géologique de la fosse du plan minier de 2019 (en bleu). L'horizon de fer ne faisant pas partie du plan minier de MFQ de 2019 (en rose) présenté sur la figure se poursuit sous la fosse prévue actuellement… L'information disponible actuellement suggère un potentiel géologique continu sous la fosse. Il est toutefois à noter que MFQ ne peut affirmer qu'il s'agit d'une ressource puisqu'il n'a pas été démontré que celle-ci était rentable à exploiter dans le cadre d'une étude de faisabilité et n'a pas fait l'objet du processus 43-101*" **[**The figure above shows the longitudinal section of the geological interpretation of the pit from the 2019 mining plan (in blue). The iron horizon not part of the 2019 MFQ mining plan (in pink) shown in the figure continues below the currently planned pit…The information currently available suggests a continuous geological potential below the pit. It should be noted, however, that MFQ cannot affirm that it is a resource since it has not been shown that it was profitable to exploit as part of a feasibility study and has not been subject to the 43-101 process]. Since the 2013 Technical Report (Cliff Natural Resources, 2013) did not include any version of the above figure, it is not clear whether the lower iron horizon was included in the 1365.8 Mt of measured plus indicated resources or the 1051.3 Mt of reserves (see Table 2). However, it is equally unclear how the 2013 Technical Report could have arrived at 1365.8 Mt of measured plus indicated resources without including the lower iron horizon as a measured or indicated resource. There would certainly be considerable technical difficulties in converting the lower iron horizon from a resource (if it is a resource) into a reserve.

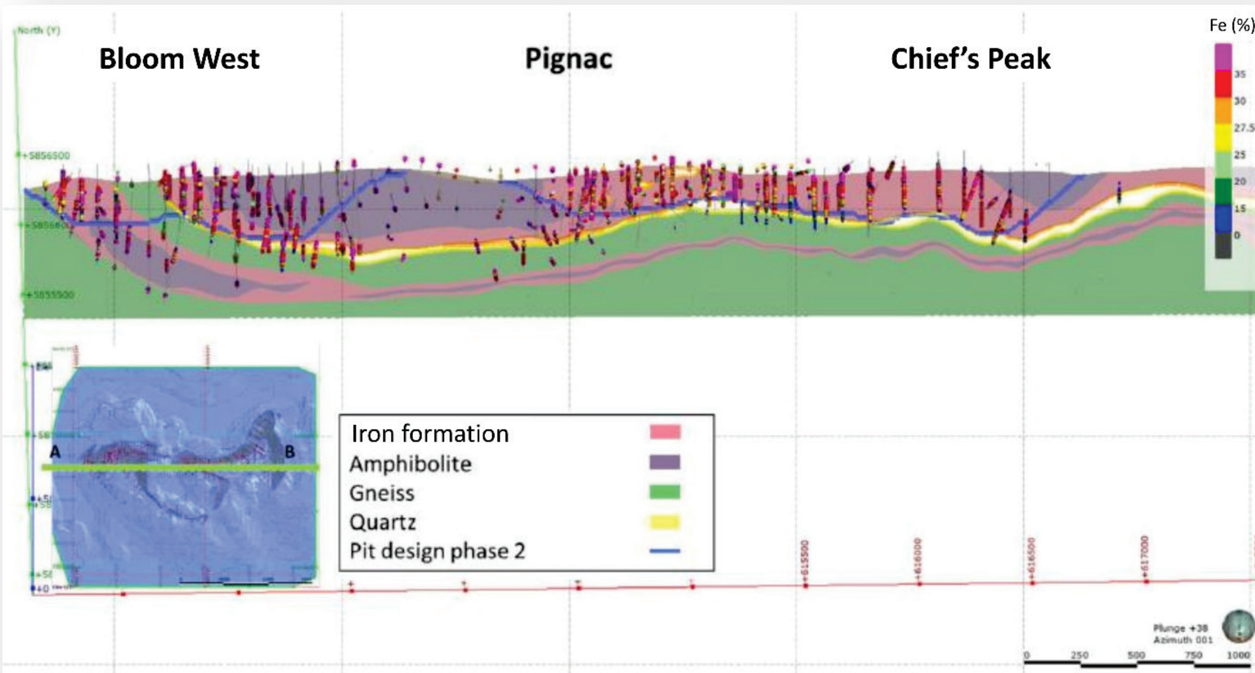

Figure A6. According to Minerai de Fer Québec (2020b), "*La figure [ci-dessus 13] présente la coupe longitudinale de l'interprétation géologique de la fosse du plan minier de 2019 (en bleu). L'horizon de fer ne faisant pas partie du plan minier de MFQ de 2019 (en rose) présenté sur la figure se poursuit sous la fosse prévue actuellement… L'information disponible actuellement suggère un potentiel géologique continu sous la fosse. Il est toutefois à noter que MFQ ne peut affirmer qu'il s'agit d'une ressource puisqu'il n'a pas été démontré que celle-ci était rentable à exploiter dans le cadre d'une étude de faisabilité et n'a pas fait l'objet du processus 43-101*" **[**The figure above shows the longitudinal section of the geological interpretation of the pit from the 2019 mining plan (in blue). The iron horizon not part of the 2019 MFQ mining plan (in pink) shown in the figure continues below the currently planned pit ... The information currently available suggests a continuous geological potential below the pit. It should be noted, however, that MFQ cannot affirm that it is a resource since it has not been shown that it was profitable to exploit as part of a feasibility study and has not been subject to the 43-101 process]. Since the 2013 Technical Report (Cliff Natural Resources, 2013) did not include any version of the above figure, it is not clear whether the lower iron horizon was included in the 1365.8 Mt of measured plus indicated resources (see Table 2). However, it is equally unclear how the 2013 Technical Report could have arrived at 1365.8 Mt of measured plus indicated resources (see Table 2) without including the lower iron horizon as a measured or indicated resource. The preceding indicates the problematic nature of arguing against open-pit backfilling on the basis of the 2013 Technical Report, which does not comply with the Securities standards, as well against open-pit backfilling on the basis of mineral resources, instead of mineral reserves.

The most important reason of all for not comparing the 2013 Technical Report and the 2019 Feasibility Study is that the 2013 report is not even a valid Feasibility Study. Minerai de Fer Québec (2020b) opens with a section labeled "*Avertissement*" [Warning] that states "*Le Rapport de SRK pour Cliffs a été préparé par SRK Consulting (U.S.), Inc. pour Cliffs, le propriétaire et exploitant précédent de la mine du lac Bloom, et n'est pas conforme au Règlement 43-101 sur l'information concernant les projets miniers (le « Règlement 43-101 »)…Les ressources minérales et les autres renseignements et données historiques mentionnés dans le present document par renvoi au Rapport de SRK pour Cliffs et dans le Rapport de SRK pour Cliffs sont de nature strictement historique, ne sont pas conformes au Règlement 43-101 et, par conséquent, aucune personne ne devrait s'y fier. Aucune « personne qualifiée », au sens du Règlement 43-101, n'a effectué le travail requis pour classer les ressources ou les réserves faisant l'objet de l'estimation dans les ressources minérales ou les reserves minérales à jour, et MFQ, Champion Iron Limited et les membres du même groupe ne considèrent pas les ressources ou les réserves faisant l'objet de l'estimation comme étant des ressources minérales ou des reserves minérales à jour*" [SRK's Report for Cliffs was prepared by SRK Consulting (US), Inc. for Cliffs, the previous owner and operator of the Bloom Lake mine, and does not comply with National Instrument 43-101 on information concerning mining projects ("Regulation 43-101")…Mineral resources and other historical information and data referred to in this document by reference to SRK's Report for Cliffs and in SRK's Report for Cliffs are strictly historical in nature, do not comply with NI 43-101 and, accordingly, no one should trust it. No "Qualified Person," within the meaning of NI 43-101, has performed the work required to classify the resources or reserves being estimated as mineral resources or up-to-date mineral reserves, and MFQ, Champion Iron Limited and its affiliates do not consider the resources or reserves being estimated to be up-to-date mineral resources or mineral reserves]. The fact that the 2013 Technical Report was not even written by "Qualified Persons" is certainly a significant shortcoming. It is beyond the comprehension of this author as to why Minerai de Fer Québec is relying on the 2013 Technical Report after saying that "*aucune personne ne devrait s'y fier*" [no one should trust it]. Whether a document should be trusted, regardless of the qualifications of the authors, depends upon the consequences of being wrong. In this case, the consequences of being wrong, namely the destruction of seven lakes without the potential benefit of ensuring future mineral resources, are considerable.

The clarification regarding the variable concentrations of actinolite in the ore body (see Fig. A3) are helpful in understanding the hesitation on the part of Minerai de Fer Québec to cover any parts of the pits prior to the cessation of mining (see Fig. A3). However, it is still not clear why it is necessary to maintain continuous exposure of the entirety of the open pits, as claimed by Minerai de Fer Québec, as opposed to continuous exposure of ore with appropriate ranges of actinolite concentrations. Moreover, it is also not clear that all possible solutions have been sufficiently explored. For example, sufficient low-actinolite ore from West Pit could be stockpiled so that it is always available for blending with higher-actinolite ore from Chief's Peak Pit (see Fig. A3). The current plan is to begin ore stockpiling in Year 6 of the 20-year plan (Minerai de Fer Québec, 2019a), but it is not clear why stockpiling cannot begin earlier. Finally, the removal of actinolite from the iron concentrate at the processing plant is both a known technology and an area of active research and development (e.g, Niiranen and Boehm, 2016). This technology is even acknowledged by Minerai de Fer Québec, 2020c), although it is rejected as too expensive.

In summary, the argument against backfill due to the need for ore blending requires further consideration.

The argument that 97.8 Mt of ore would be lost through backfill (through the use of large equipment and ore that could not be blended) cannot be assessed based on the information provided by Minerai de Fer Québec (2020b). In the first place, it is in no way clear from the diagram provided by Minerai de Fer Québec (2020b) (see Fig. A4) that the use of small equipment would result in the loss of 0.8% of the ore, while the use of large equipment would result in the loss of 5% of the ore (a 525% increase in the dilution factor). In the second place, the claim that 64 Mt of ore would be converted to waste rock because it could not be blended came with no further explanation than that it was a result of "*les estimations conservatrices*" [conservative estimates]. In summary, these arguments are possible, but are certainly not convincing.

Discussion

Through its insistence on the existence of vast potential mineral resources that would be covered by backfill, Minerai de Fer Québec has implicitly rejected its 2019 Feasibility Study (Minerai de Fer Québec, 2019a), which gives no indication of the existence of such resources. If that is the case, the solution is not to rely on the 2013 Technical Report, which was based on much less geological information and was not even a valid Feasibility Study, in that it was not carried out by "Qualified Persons." The solution would be to contract an entirely new Feasibility Study that would take into account the most recent geological information that was not considered in the 2019 Feasibility Study. Due to the contradictory conclusions that have resulted by the high volatility in iron ore prices and in the forecasts of iron ore prices (see Figs. 4 and A5), that Feasibility Study should be carried out for a range of possible iron ore prices.

Although some progress has been shown by the most recent document from Minerai de Fer Québec (2020b), the mining company has still not carried out a serious backfill feasibility study. In particular, in light of the lower unit backfill costs that have been projected by the mining company (compare Tables 3 and A1), serious consideration should be given to the possibilities of either backfilling all of the excess coarse tailings (see Table A2) or backfilling all of the fine and coarse tailings (see Table A3). The first possibility would prevent the destruction of seven lakes by removing the need for a new tailings storage facility. The second possibility would eliminate any future possibility of catastrophic failure of a tailings dam. Having said the above, the option FR proposed by Minerai de Fer Québec (2020b) is certainly a step in the right direction in that it prevents the destruction of the seven lakes to the north of the mine.

Conclusions

The conclusions of this Appendix can be summarized as follows:

1) The claim that 977.8 Mt of potential resources would be covered by backfill is based on arithmetic errors.
2) The comparison of the resources in the 2013 Technical Report and the reserves in the 2019 Feasibility Study is invalid because the 2013 resources were based on an iron ore price of 120 USD/t, while the 2019 reserves were based on an iron ore price of 60.89 USD/t.
3) The comparison of the resources in the 2013 Technical Report and the reserves in the 2019 Feasibility Study is invalid because the 2013 report was based on far less geological information than the 2019 study.
4) The comparison of the resources in the 2013 Technical Report and the reserves in the 2019 Feasibility Study is invalid because resources cannot be compared with reserves.
5) The comparison of the resources in the 2013 Technical Report and the reserves in the 2019 Feasibility Study is invalid because the 2013 report did not comply with the requirements of an NI 43-101 Disclosure of Financial Statements in that it was not performed by "Qualified Persons."
6) The justification by Minerai de Fer Québec that concurrent backfilling and mining cannot be carried out because of the need for ore blending needs further consideration, including the possibilities of stockpiling low-actinolite ore and technologies for removing actinolite from iron concentrate.
7) The argument by Minerai de Fer Québec that that 97.8 Mt of ore would be lost through backfill (through the use of large equipment and ore that could not be blended) still requires detailed explanation.

Additional References

Minerai de Fer Québec [Quebec Iron Ore], 2020b. Mine de fer du Lac Bloom – Augmentation de la capacité d'entreposage des résidus et stériles miniers—Étude d'impact sur l'environnement – Mise à jour—Options d'entreposage dans la fosse (reponse a la demande du BAPE) [Bloom Lake iron mine – Increasing the storage capacity for mine tailings and waste rock – Environmental impact study – Update—Options for in-pit backfill (response to the request from BAPE)], 66 p. Available online at: http://voute.bape.gouv.qc.ca/dl/?id=00000179853

Minerai de Fer Québec [Quebec Iron Ore], 2020c. Mine de fer du Lac Bloom – Augmentation de la capacité d'entreposage des résidus et stériles miniers—Étude d'impact sur l'environnement – Mise à jour—Questions compémentaires du BAPE (DQ1)_2 novembre 2020 [Bloom Lake iron mine – Increasing the storage capacity for mine tailings and waste rock – Environmental impact study – Update—Complementary questions from BAPE (DQ1), Movember 2, 2020, 794 p. Available online at: https://voute.bape.gouv.qc.ca/dl/?id=00000181607

Niiranen, K. and A. Boehm, 2016. Silicates – a new challenge for mineral processing for LKAB in Kiruna, Wweden: IMPC 2016—XXVIII International Mineral Processing Congress Proceedings, 9 p.