DEPARTMENT OF NATURAL RESOURCES

Internal Memo

Date: **08/06/2019**

To: **File**

From: **Jason Boyle, State Dam Safety Engineer**

RE: Relators' Request to Reconsideration

Relators' Request for Reconsideration, received on February 28, 2019, asked for reconsideration of the NorthMet flotation tailings basin (FTB) dam safety permit and the permit to mine issued to PolyMet for the NorthMet Project. Their Request for Reconsideration was reviewed and analyzed by Minnesota DNR Dam Safety staff ("Dam Safety") including the State Dam Safety Engineer and a geotechnical engineer. DNR's Dam Safety Staff reviewed the Request for Reconsideration submittal, which includes 16 exhibits. In addition, Dam Safety reviewed the materials submitted in response by PolyMet and other technical data on both the NorthMet FTB dam and the Brumadinho dam.

The Relators contend that new information has been revealed in the wake of the Corrego do Feijao tailings dam failure in Brumadinho, Brazil, and that this information "calls into question the method by which the PolyMet [NorthMet] FTB dam would be constructed and the methods used to evaluate its material strength characterization and its potential for liquefaction and failure".

The purpose of this memo is to document Dam Safety's consideration of whether or not the information from the Brumadinho failure, had it been available during review of the NorthMet FTB dam permit application, would have affected the permit decision such that the decision should be revisited and the permit amended or revoked. The focus of this memo is on the technical aspects raised in the relators' request for reconsideration.

The relators cite three main topics. First, they cite the recent ban on the upstream dam construction method in Brazil. Second, they claim that the Olson method, which was used in the design of the NorthMet FTB dam, predicted that the Brumadinho dam "would not be susceptible to liquefaction and failure". Finally, they contend that the existing LTV tailing dam has "risks posed by seepage collection and poor tailings drainage" that would relate to concerns about liquefaction.

Dam Safety spent many hours reviewing available information about the Brumadinho dam failure. It is Dam Safety's position that there are very few similarities between the Brumadinho dam and the NorthMet tailings dam. There are, however, numerous dissimilarities, including the following aspects of the Brumadinho dam: steep side slopes; constructed as a valley type dam; water management issues; close proximity to the ore body and mine blasting; blasting the morning of dam failure; and possibly others. See Bibliography for a list of some of the documents reviewed and developed in response to the Brumadinho dam failure.

The following sections are titled to correspond with and reply to the Relators' Request for Reconsideration arguments.

Argument I – A. Brazil banned upstream design

The upstream dam construction method is a commonly used construction method for tailings dams. In this method of dam construction, each "lift" of the perimeter dam construction is placed slightly offset from the previous lift toward the interior of the basin. As the dam is built, it projects further into the basin.

Selecting a tailings dam construction method is not a one-size-fits-all determination. The facts and circumstances of a particular project inform the design decisions for that project. Dam Safety is aware that there are several advantages and well as disadvantages with the upstream construction method. There are sites where upstream construction may not be an acceptable construction method, such as on a hillside, in a steep valley, in a seismically active area, or in an area with a large contributing watershed. Other aspects of a project may influence the design decisions, such as the amount of tailings produced and the rate of rise. Several of the dam failures cited by relators had rates of rise significantly greater than what is typically allowed in Minnesota. For example, the Fundao dam failure cited by the relators was preceded by a rate of rise on the order of 50 feet per year, much higher than the maximum 15 feet a year allowed for the NorthMet Project.

Ultimately, the safety of a dam is about more than just the construction method. To be safe, a dam must be designed for the site conditions (including topography, foundation materials, seismic zone, and climate), it must be constructed according to the plans and specifications that were developed by a competent engineer well versed in designing dams, and it must be operated and maintained according to a detailed operation and maintenance plan. It is Dam Safety's position that a carefully designed, constructed, operated, and maintained tailings dam using the upstream construction method can be safe.

As detailed in the DNR's findings of fact associated with the issuance of Dam Safety Permit 2016-1380 and the Permit to Mine, Dam Safety determined that the upstream construction method is acceptable for the NorthMet FTB dam. The basis for this determination has not changed. The site conditions in Minnesota vary greatly from those in Brazil, and the dam construction design proposed for the NorthMet FTB dam likewise differs from the Brumadinho dam. The NorthMet Project design has much flatter slopes than the Brumadinho dam, making it inherently more stable. The NorthMet FTB dam site is located in an area of flat topography, with little upstream drainage area, a low seismic zone, and far away from any mining or blasting activity. The Brumadinho dam is located on the side of a mountain, with a significant contributing drainage area, in an area of seismic activity, and relatively close to mining activity. Problems with water management were reported six weeks prior to the failure in Brumadinho.

Relators claim that for the Brumadinho dam "its upstream construction had contributed to its failure". To Dam Safety's knowledge, the cause of the failure of the Brumadinho dam has not been officially determined. As with most dam failures, there are likely multiple causes for the dam failure.

Argument I – B. Olson Method predicted that the Brumadinho dam would not be susceptible to failure

Relators call into question the Olson Method, which was used by PolyMet for the NorthMet Project, on the grounds that this method was applied in 2013 by Pirete and Gomes to show that the Brumadinho dam was not susceptible to failure. Relators claim that the Brumadinho dam failure demonstrates that the Olson Method of assessing dam stability is deficient.

Dr. Olson has stated that it appears that the Olson Method was applied incorrectly by Pirete and Gomes (2013), a paper cited by the relators. Notably, Dr. Olson did not review or comment on the Pirete and Gomes paper before it was published, as indicated on his written statement from March 11, 2019. His involvement in Brazil started in 2016, after the 2015 failure of the Fundao dam. Consistent with dam safety professionals more generally, Minnesota Dam Safety believes that the Olson Method is an established and accepted method for analyzing the stability of a tailings dam when applied correctly.

The 2012 Geotechnical Modeling Work Plan was developed by PolyMet and reviewed by the DNR and its consultant. The DNR did not write the work plan, and did not require use of the Olson Method in the design of the NorthMet FTB dam. Rather, PolyMet chose to use the Olson method. Part of the Olson Method utilizes site-specific field data to identify materials that are contractive and are susceptible to liquefaction. This method is especially useful when obtaining undisturbed materials samples for laboratory testing is unfeasible.

In addition to identifying potentially liquefiable materials, the Olson Method also involves an analysis to determine if liquefaction of the contractive material would be triggered. Finally, the method involves a post-triggering analysis to determine if the triggered liquefaction would result in a flow failure (failure of the dam).

Liquefiable (contractive) materials were identified as a potential safety issue for the NorthMet FTB dam.[1] A triggering analysis was performed to determine the impact of liquefaction on the dam segments along the slip surface where liquefaction would be triggered. For those segments of the slip surface of the dam shown to liquefy, liquefied shear strengths were applied. Determination of the liquefied strength of the contractive materials is detailed in the Geotechnical Data Package. Generally, liquefied shear strengths were determined using field techniques and laboratory analysis. Finally, a factor of safety was calculated for the cross section. The lowest factor of safety for this triggering analysis for the NorthMet FTB was greater than 1.7. The factor of safety is simply the ratio of the forces resisting movement divided by the forces initiating movement. A factor of safety of 1.7 indicates that the forces resisting movement are 1.7 times stronger than the forces trying to initiate movement. *See* Chapter 7.3.4 of the FTB Geotechnical Data Package and Memo from Tom Radue, P.E Barr Engineering to Christie Kearney Regarding "PolyMet NorthMet Project Flotation Tailings Basin Slope Stability Update for Erosion Case Triggering Analysis" (April 2, 2018). Among dam engineers this is considered a high factor of safety.

[1] If materials behind the dam becomes liquefied the probability of dam failure increases.

The Pirete and Gomes (2013) analysis applied the Olson method to their review of the stability of the Brumadihho Dam, identifying potentially liquefiable materials. However, their analysis of the critical failure surface did not include the lower depths of the tailings basin, where it appears they incorrectly identified the material as dilative. Their triggering analysis determined that no segments along the slip surface would liquefy. The lowest factor of safety calculated by Pirete and Gomes for the Brumadinho dam was 1.28, however, an analysis of the Pirete and Gomes work indicates that the Olson analysis was incorrectly applied and, therefore, the accuracy of this is questionable.

Dr. Olson, in his March 11, 2019 declaration, notes that Pirete and Gomes "inexplicably identified nearly all of the tailings below the depths of the in-situ test described in their paper as dilative and not susceptible to liquefaction", despite their earlier conclusion that Brumadinho tailings "liquefaction susceptibility is likely". Dr. Olson goes on to state that if Pirete and Gomes had correctly identified the tailings below the in-situ tests as contractive, that "they should have computed a critical failure surface that was consistent with the failure observed on January 25, 2019 with factors of safety only slightly greater than unity" for the existing conditions without any triggering mechanism. According to Dr. Olson, correctly applying the Olson Method would have determined that the Brumadinho dam was on the edge of instability. The conclusions of Pirete and Gomes were in error, but it appears to be due to their misapplication of the Olson Method, not the Olson Method itself.

Dr. Olson, in his capacity working with Vale and their consultants, notes that they "rarely considered liquefaction in the design and operation of their tailings dams". Indeed, the fully liquefied analysis did not appear to be completed for the Brumadinho dam referred to in Pirete and Gomes (2013). Dr. Olson states that he has recently been working with Vale to incorporate liquefaction analysis into the design of their tailings basins. In contrast, the design of the NorthMet FTB dam is based on a fully liquefied condition, which assumes all contractive materials liquefy. The PolyMet design for the NorthMet Project does not rely on whether or not liquefaction is triggered, it assumes that all saturated contractive materials are assigned their liquefied shear strength. Use of the Olson Method for the fully liquefied conditions dictated the relatively flat side slopes used in the NorthMet FTB design.

Argument I – C. Recent Inspection Reports undermine undrained assumption

Relators contend that the existing LTV tailings basin, upon which the NorthMet FTB will be constructed, has risks posed by poor tailings drainage. They contend that because a recent inspection report noted the dewatering of the southeast cell has not occurred, the tailings in the cell are saturated so they are not "drained", and therefore the long-term loading condition using drained strengths is incorrect.

Drained and undrained soil strengths are not the same as saturated and unsaturated soils. The "drained" strength means that there is no increase in pore water pressure due to an external loading. "Drained" does not necessarily mean "dry". As long as the material is free to dissipate pore water pressures, the material could be wet or dry and meet the definition of drained. For long-term loading conditions, it is assumed that excess pore water pressures are fully dissipated and the pore water pressure is in equilibrium, i.e. a "drained" condition. For short-term loading conditions, it is assumed that the pore water pressure increases due to the loading, i.e. an "undrained" condition. For short-term loading, both drained and

undrained conditions were assessed by PolyMet. It is appropriate to use drained strengths for long-term loading conditions. The NorthMet FTB dam meets required factors of safety for both short-term and long-term loading conditions.

Relators also contend that the seepage pump back system "could increase the potential for tailings liquefaction and dam failure". The NorthMet FTB stability models account for the seepage water in that the models are based on a certain height of water in the tailings basin. As long a water levels in the basin do not exceed the modeled height of water, the dam is expected to be stable. An automatic pond dewatering system was recently installed to lower basin water levels once they reach a specified threshold elevation.

Relators contend that, in the southern portion of the LTV tailings basin, the tailings have not dewatered, and they remain saturated. The stability model accounts for the material strengths of saturated tailings.

Summary of Dam Safety Review

Dam Safety has reviewed the "Relators' Request for Reconsideration." We find the request and supporting documents provide no new analysis or technical information that would justify a revocation or suspension of the previously issued NorthMet Dam Safety Permits, or the related Permit to Mine. The Minnesota DNR Dam Safety program is actively involved in the dam safety community and in discussions related to evolving knowledge and best practices for dam safety, including tailings basin dams. Dam Safety takes the safety of tailings dams and all dams very seriously. We maintain a rigorous permitting and inspection program to ensure that all projects are designed, constructed, and operated to be protective of human health and the environment. We always seek to learn from experience both within Minnesota and beyond. We will continue to learn all we can from the tailings dam failure in Brazil and use that information to help ensure long-term safety of all tailings dams in Minnesota.