memorandum

Project Name |	PolyMet Dam Safety Permit Application Review	**Date** |	05/15/17
To / Contact info |	Jason Boyle (DNR)		
Cc / Contact info |	Joe Henderson (DNR) and Mike Kunz (DNR)		
From / Contact info |	Dick Van Zyl, Steve Gale (Gale Tec Engineering, Inc.), Cecilio Olivier (EOR) and Stuart Grubb (EOR)		
Regarding |	Review Team Comments		

Background

PolyMet submitted two permit applications to the DNR for Dam Safety Permits for the NorthMet project. One application was for the Flotation Tailings Basin and the other was for the Hydrometallurgical Residue Facility (HRF).

To supplement the review process, the DNR requested that a team of top experts (EOR Review Team) be assembled to assess and comment on the proposed design, operation and maintenance of the facilities. The review approach focused on key elements similar to tailings basin review panels required by law in Montana and other western states. The review process included the following tasks:

- Documents Review – Including PolyMet's Dam Safety Permits applications, related technical documents, and comment tracking sheets.

- Site Visit and Discussion - Trip to Hoyt Lakes to develop observations and take field notes at the LTV/PolyMet tailings basin and proposed HRF sites. Meet with PolyMet and the tailings basin hydro designers to ask questions and discuss the different design elements.

- Review Meetings – Internal review meetings between EOR Review Team and DNR to discuss initial findings, need for additional information and develop final comments and recommendations. Meeting with PolyMet, DNR and the EOR Review Team to discuss final findings.

- Draft and Final Report - Present a Draft Report of findings to DNR and PolyMet. Prepare a Final Report including a response to comments on the Draft Report.

EOR Review Team

EOR assembled a Review Team of experienced experts in mining geotechnical engineering. The Review Team included:

- ***Dirk van Zyl, PhD, PE.*** Dirk is on the faculty of the University of British Columbia and consults with mining companies worldwide on tailings basin design. He was formerly on the faculty of the University of Nevada – Reno, and he has worked for several consulting companies. Dr. van Zyl has authored or co-authored over 120 papers on mining topics, including tailings basin management. He currently serves on several review panels in Montana and on the review panel that previously investigated the Mt. Polley dam failure.

- ***Steve Gale, PE.*** Steve is the President of Gale-Tec Engineering Inc. in Minneapolis, Minnesota. He has over 30 years of experience working as a geotechnical engineer. Mr. Gale and his company provide consulting services on all aspects of tailings basin design, management, and closure, including dam safety analysis and permitting. He has worked on many of the tailings basins on Minnesota's Iron Range.

Resumes are included in Attachment 1.

Review Process

The EOR Review Team went through the following documents:

- Technical Memorandum: NorthMet Geotechnical Data Package – Volume 1 (Flotation Tailings Basin) – Version 4 Modeling Outcomes Summary. Barr Engineering, April 2, 2013.
- NorthMet Dam Safety Permit Application: Flotation Tailings Basin. Barr Engineering, July, 2016.
- NorthMet Dam Safety Permit Application: Hydrometallurgical Residue Facility. Barr Engineering, July 2016.
- 2015 Tailings Basin Dam Safety Inspection Report. Barr Engineering, August 2016
- Technical Memorandum: DNR Review of PolyMet's Dam Safety Permit Application – Tailings Basin Comment 9 – LTVSMC Coarse Tailings Strength. Barr Engineering, December 30, 2016.
- Technical Memorandum: Tailings Basin Cell 2E North Dam – Modified Buttress as Alternative to Cement Deep Soil Mix Zone. Barr Engineering, December 30, 2016

The EOR Team (along with the DNR, PolyMet and Barr Engineering) conducted a site visit to the LTV tailings basin site and proposed HRF facility in September 29th, 2016. The EOR Review Team also met with PolyMet and Barr Engineering to discuss comments and questions on the proposed NorthMet project. A follow up meeting to discuss and review comments was held with the same participants at DNR headquarters on December 5th, 2016. The EOR Review Team and DNR met on several occasions to discuss the review's status .

Review Comments

The detailed EOR Review Team comments are presented in the review tables of Attachment 2. The columns on the tables include:

- *Comment/Concern* - These initial comments were written by the EOR Review Team, reviewed by DNR, and submitted to PolyMet in December, 2016.
- *PolyMet Response* - PolyMet provided these written and/or verbal responses to the initial comments.
- *Final Comments* - After considering PolyMet's response, the EOR Review Team prepared these comments contained in this column.
- *Recommendations* - The EOR Review Team recommends that the comments and issues be addressed as follows:
    - *Address Pre-Permit* - These issues will require additional information before a permit can be issued. This may require resubmittal of the complete permit application.

- *Address Post-Permit & Make Condition of Permit* - These issues require additional information, but they are not likely to have a bearing on the DNR's decision to grant or deny the permit. They may affect future construction and operation of the facilities. Some of these comments can only be addressed while the facilities are operating. PolyMet must address these comments if the permit is granted.
- *Address Pre-Construction* - These issues also require additional information, but they are not likely to have a bearing on the DNR's decision to grant or deny the permit. PolyMet must provide more information before beginning construction of the facility if the permit is granted.
- *Condition of Permit Recommendation* - The EOR Review Team provides elements and recommended language to be incorporated into the permit, either pre-permit or as a condition of the permit.

Comments on PolyMet's Design, Approach and Redevelopment of the LTV Tailings Basin

Observational Method (Comments #1, #4, #5 and #7 in Attachment 2)

The Observational Method is a well-documented and often-used approach to tailings dam construction and maintenance. The Observational Method steps are:

1) Predict behavior with detailed calculations,
2) Design with contingencies,
3) Construct with monitoring and
4) Compare measurements with predictions and redesign if necessary.

The EOR Review Team agrees that the Observational Method can and should be used during construction, but it is not a substitute for careful initial design. The EOR Team concluded that the permit application lacks the detail and description of contingencies for the Observational Method to be effective. If monitoring data indicate a potentially unsafe condition during construction, then the alternate construction methods and designs (contingencies) must be already in place so that they can be implemented immediately.

Peat Layers and Slimes Layers (Comments #3, #4 and #7 in Attachment 2)

The former LTV tailings basin was constructed over layers of peat in some areas. Layers of slimes (very fine-grained taconite tailings) were also included in the construction of the tailings basin dam. Both peat layers and slimes layers have very low shear strength, which could potentially contribute to a dam failure. The tailings basin can be designed to safely mitigate for these conditions, but the areas with peat and slimes must be well-defined and tested. The EOR Team commented that additional data should be gathered on the peat layers and slime layers, and that the design may need to be modified in the future in accordance with the Observational Method.

Cement Deep Soil Mixing (CDSM) & Dam Toe Buttressing (Comments #2 and #11 in Attachment 2)

In the permit application, PolyMet proposed constructing the dam with both CDSM and dam toe buttressing (reinforcement usually using waste rock). CDSM uses large-diameter drills to drill into the base of the tailings basin dam and mix Portland cement with the existing materials. Placing of these CDSM "pillars" close together in a line creates a kind of shear wall that increases the shear strength of the material. The construction needs to be carefully monitored in the subsurface to make

sure that the pillars are constructed as designed. CDSM is often used in the construction of embankments and dams, but to our knowledge has not been used in a tailings basin.

Dam toe buttressing places heavy materials at the toe of the tailings basin dam to prevent the toe of the dam from sliding and causing a dam failure. The required size and weight of the buttress increase as the height of the dam increases.

The EOR Review Team commented that additional monitoring would be required during CDSM construction and during operations and closure to assess the effectiveness of the CDSM. Since then, PolyMet has removed CDSM from the design plans in favor of using larger dam toe buttresses. The design plans with additional buttresses will have several advantages:

- The technology is better understood on tailings basin dams,
- Construction and maintenance are above ground, so critical observation and monitoring can be done with greater confidence, and
- The buttress can be constructed incrementally over an extended period of time, whereas the CDSM must be fully completed prior to placing the basin into service.

Peat deposits should be removed near the toe of the existing tailings basin dam so that the new buttress will have a solid footing. If peat deposits are not fully removed, the EOR Review Team commented that additional analysis should be required to evaluate the stability of the buttress toe that may be constructed over localized soft soils. PolyMet indicated that buttress construction will specify the complete removal of peat soils. The EOR Review Team also recommended performing additional analysis for other potential impacts due to additional wetland fill or the geochemistry of the buttress material.

Water Ponding (Comment #5 in Attachment 2)

As currently designed, a pond of water will be maintained on top of the tailings basin in perpetuity. During mining operations, the residue from the processing plant (tailings) is pumped to the pond as slurry, and water is returned to the plant after the tailings settle out. PolyMet developed stability analysis models that show the volume and location of the pond at various times during the operating life of the tailings basin. This stability analysis was based on maintaining a beach length of 625 feet between the inside crest of the dam and the edge of the water within the tailings basin. This would minimize the potential for the water to rise and cause erosion at the edge of the basin.

The EOR Review Team commented that some of the model runs did not seem to correctly account for a potential rise in water levels, the location of the beach around the pond, and the distance to the edge of the tailings basin. PolyMet indicated that the design included a 4 feet head increase while still keeping the water pond at a 625 feet distance from the crest of the perimeter dike. The EOR Review Team recommended that a water pocket distance of less than 625 feet (or in direct contact with the tailings dam) be analyzed as an event/condition of the Observational Method approach.

Existing Structures (Comment #6 in Attachment 2)

The EOR Review Team commented that some of the existing structures associated with the existing tailings basin had not been specifically addressed in the plan for future construction. The EOR Team

recommended that the permit includes language that requires all existing structures to be investigated and properly abandoned before construction to ensure that dike stability is maintained.

Bentonite Addition (Comment #8 in Attachment 2)

To minimize water seepage from the tailings basin, bentonite will be added to the soils at the top of the basin during the closure and reclamation process. The permit application only lists alternatives for placing the bentonite that will be pilot tested and field tested later. The EOR Review Team commented on specific elements that should be included in the field testing that would impact the permeability of the bentonite amended tailings. Once the preferred bentonite application method is selected, the EOR Review Team recommended developing material and installation specifications and a detailed protocol for both a laboratory and a field pilot study.

Statistical Analyses (Comment #9 in Attachment 2)

Geotechnical tests were performed to determine the shear strength of the tailings at hundreds of locations around the existing tailings basin. Statistical analyses are used to calculate the overall strength and stability of the basin. EOR Review Team commented that some of the geotechnical test results (i.e. low coarse tailings friction angles) were excluded from the statistical analyses. Because of their importance in the overall stability of the basin, the EOR Review Team recommended that coarse tailings friction angles be considered as a variable condition in the Observational Method process. This would also provide a consistent and proper procedure for future analyses.

It should be noted that including all the geotechnical results in the statistical analyses did not significantly reduce the global factor of safety. Nevertheless, the EOR Review Team recommended using the Observational Method to enhance instrumentation and monitoring at those discrete cross sections where lower friction angles could occur. If lower friction angles are observed, the statistical analysis must be rerun to verify that this localized factor of safety is still acceptable.

Wet Closure vs. Dry Closure (Comment #10 in Attachment 2)

Wet closure of the tailings basin is currently proposed, meaning that the top of the tailings basin will have a permanent pool of water on top of the basin. Wet closure has ongoing costs like; maintaining water levels to prevent flooding and drying out, erosion repair, treatment of discharged water and on-going monitoring. Dry closure (no water ponding) requires a greater initial investment, but has much lower ongoing maintenance costs and less long-term environmental risk.

The EOR Review Team did not proposed dry closure as a permit requirement at this time. The EOR Review Team recommended that if the wet closure is permitted, the DNR should require PolyMet to continually review the current state-of-the-practice for dry closure techniques prior to starting any tailings basin closure activities.

General Discussion of Issues – HydroMet Residue Facility

Stability of Underlying Soils (Comment #1 and #2 in Attachment 2)

The soft ground beneath the proposed residue facility consists of up to 30 feet of slimes, peat and tailings concentrate. This will not be an adequate foundation for the 80 foot high basin. Three potential remediation alternatives have been considered:

- Pre-loading the existing material with 50 feet of rock and soil to compress and consolidate the underlying material. This is the method currently proposed by PolyMet.
- Installing wick drains that will allow water to flow out of the existing material, thereby increasing its shear strength.
- Removing the existing material and any soft soils before constructing the basin.

The basin will have a geomembrane or geosynthetic liner. The liner could deform and fail if the existing underlying material cannot support the material added to the basin.

The EOR Review Team commented that the proposed pre-load design should be re-evaluated to determine if it will adequately surcharge and compress the existing material.

Geomembrane (Comment #3 in Attachment 2)

The EOR Review Team commented that more information was required in the permit application to evaluate the geomembrane liner system. Barr Engineering provided the information, so this issue has been closed.

Attachment 1 - Resumes

Dirk Jacobus Albertus van Zyl

CURRICULUM VITA

EDUCATION:

Executive Master of Business Administration, 1998, University of Colorado

Ph.D., 1979, Purdue University

M.S., Civil Engineering, 1976, Purdue University

B.Sc. (Honors), Civil Engineering, 1974, University of Pretoria, South Africa

B.Sc., Civil Engineering, 1972, University of Pretoria, South Africa

EXPERIENCE:

January 2010 to Present: **Professor and Chair of Mining and the Environment, Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Vancouver, BC.**

January 2008 to December 2010: **Professor of Mine Life Cycle Management, Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Vancouver, BC.**

September 1999 to December 2007: **Professor of Mining Engineering and Director of the Mining Life-Cycle Center, Mackay School of Mines (changed to Mackay School of Earth Sciences and Engineering on January 1, 2004), University of Nevada, Reno. Chair of Department of Mining Engineering from 2002 to 2007.**

April 1999 to present: **Tailings and Mine Rock Management Consultant Reno, Nevada and Vancouver, BC**

September 2001 to August 2008: **Chairman of Mining Engineering, Mackay School of Earth Sciences and Engineering, College of Science, University of Nevada, Reno**

1998 – 1999 **TRC Companies Inc.** **Denver, Colorado**
Vice President Mining Industry

1992 - 1998 **Golder Associates Inc.** **Denver, Colorado**
Principal, Vice President Mining

1990 - 1991 **EIC, Corporation** **Denver, Colorado**
President and Principal Engineer

1988 - 1990	**Welsh Engineering, Inc.** *Vice President (also member Board of Directors)*	**Denver, Colorado**
1987 - 1988	**CH2M HILL** *Geotechnical Engineer*	**Denver, Colorado**
1984 - 1987	**Colorado State University** *Associate Professor, Civil Engineering Department, Geotechnical Engineering Program*	**Fort Collins, Colorado**
1982 - 1984	**University of Arizona** *Assistant Professor, Department of Civil Engineering and Engineering Mechanics*	**Tucson, Arizona**
1979 - 1982	**Steffen Robertson & Kirsten,** *Senior Geotechnical Engineer, Project Manager and Office Manager*	**Johannesburg, South Africa, Denver, Colorado, Tucson, Arizona**
1975 - 1979	**Purdue University**	**West Lafayette, Indiana**
1974 - 1975	**Steffen Robertson and Kirsten** *Geotechnical Engineer*	**Johannesburg, South Africa**
1973 - 1974	**National Institute for Transportation and Road Research, Council for Scientific and Industrial Research** *Assistant Research Officer*	**Pretoria, South Africa**

PROFESSIONAL AFFILIATIONS:

Registered Professional Civil Engineer – California, Indiana

Registered Professional Engineering – British Columbia

Member, Canadian Institute of Mining, Metallurgy and Petroleum

Member, Society of Mining, Metallurgy and Exploration

AWARDS AND HONORS:

J.E. Jennings Award from South African Institute of Civil Engineers, 1981, Best Geotechnical Paper Published in the World by South African Authors for "The Piezometric Probe - A Useful Investigation Tool", In Proceedings of 10th Int. Conf. on Soil Mechanics and Foundation Engineering, Stockholm, Sweden.

Robert Peele Memorial Award, Society of Mining Engineers of the American Institute of Mining Metallurgical and Petroleum Engineers, 1986, best paper by young member "Construction Investigation of a Clay Heap Leach Pad" In Gold and Silver Heap and Dump Leaching Practice.

Society for Mining Metallurgy and Exploration Inc., 1992, Mining and Exploration Division, Distinguished Service Award

Society for Mining Metallurgy and Exploration Inc., 1998, President's Citation:
For continuous and consistent support of the Society's technology transfer and education through the creation and presentation of timely and industry relevant short courses, and the writing of applied engineering publications.

Society for Mining Metallurgy and Exploration Inc., 2003, Distinguished Member Award

Bureau of Land Management, 2005, Sustainable Development Award, Citation:
The award recognizes Dr. van Zyl's contributions over the last five years to a better understanding of mining and its contributions to sustainable development.

Adrian Smith International Environmental Mining Award, 2006.

Distinguished Lecturer, Environment and Social Responsibility Society, CIM Council. Topic: *Tailings Risk Management*. 2016 to 2017.

SPECIAL ASSIGNMENTS:

Dirk van Zyl was a member of the Independent Expert Investigation and Review Panel (Dr. Norbert Morgenstern, Chair and Steven Vick) appointed by the British Columbia Government as well as the Williams Lake and Soda Creek Indian Bands to investigate the Mount Polley tailings failure in 2014. The Panel was appointed on August 18, 2014 and provided their report on January 30, 2015. Full details of the report, the background information and field and laboratory investigations are available at https://www.mountpolleyreviewpanel.ca

Member of Expert Panel on Tailings Management, International Council for Mining and Metals, 2016

TECHNICAL PAPERS:

Huallanca, W., Reyes, A., Parra, D. and van Zyl, D. (2015). Determination of a tailings storage facility capacity via finite-element and finite-strain methods, Tailings 2015, Santiago, Chile: Gecamin, 9pp

Williams, D. Fowler, J. and van Zyl. D. (2015). Mine planning and acid rock management, 10th ICARD Conference, Santiago, Chile, 10pp

Boxill, L., Hockley, D., van Zyl, D., Thompson, J. and Olson, J (2014). Developing and approach to predict dewatering and material performance of polymer flocculated MFT, International Oil Sands Tailings Conference, Edmonton: University of Alberta

Xavier, A., Veiga, M.M., van Zyl, D. (2014). Introduction and Assessment of a Socio-Economic Mine Closure Framework. Submitted to *The Extractive Industries and Society Journal.*

Nichols, B, van Zyl, D, Veiga, M.M. (2014). Consolidation and Closure of Artisanal Mining Processing Plants in Portovelo, Ecuador, Mine Closure Solutions. Apr 28−30, 2014. Ouro Preto, Brazil. InfoMine, 14p

Charlebois, L., McPhail, G., Revington, A. and van Zyl, D. (2013). Observations of tailings flow and application of the McPhail beach profile model to oil sands and metal mine tailings, Tailings and Mine Waste 2013, Edmonton: University of Alberta, pp 169-180

Estepho, M., van Zyl, D., Znidarcic, D. and Revington, A. (2013). Seepage induced consolidation testing of mature fine tailings, Tailings and Mine Waste 2013, Edmonton: University of Alberta, pp 101-110

Van Zyl, D., Iannachione, A., Craynon, J. and Sarver, E. (2013). Mining and SD: Implementation of undergraduate and graduate courses at four universities, 6th International Conference on Sustainable Development in the Minerals Industry, Milos, Greece, 5pp

Pitzer, C. and van Zyl, D. (2013). Resilience –The new risk management, Proc. 35th International Conference on Safety in Mines Research Institutes, London: Institute of Materials, Minerals and Mining, 10pp

Fredlund, M, Thode, R., van Zyl, D., and Wilson, W. (2012). Back analysis of the Goat Hill North slope failure, Tailings and Mine Waste 2012, Colorado State University, pp 181 – 191

Fredlund, M., Zhang, J., van Zyl, D., and Wells, S. (2012). Multidimensional coupled sedimentation and consolidation theory, Tailings and Mine Waste 2012, Colorado State University, pp 313 – 324.

Wachtel, T. Quaranta, J.D., van Zyl, D. and Siriwardane, H. (2012). Seepage risk sensitivity for a potential failure mode analysis due to mining near bodies of water, Tailings and Mine Waste 2012, Colorado State University, pp 395 – 406.

Van Zyl, D. (2011). Questa rock-pile weathering study: geotechnical characterization, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 439 – 453.

Fredlund, M., Thode, R. and van Zyl, D. (2011). Slope stability model of the Questa rock pile – phase 1, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 467 – 478.

Priestley, D., Fredlund, M. and Van Zyl, D. (2011). Modeling consolidation of tailings impoundments in one and two dimensions, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 267 – 278.

Znidarcic, D., Miller, R., Van Zyl, D., Fredlund, M. and Wells, S. (2011). Consolidation testing of oil sand fine tailings, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 251 – 257.

Caldwell, J. and Van Zyl, D. (2011). Thirty years of tailings history from tailings and mine waste, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 79 – 91.

Van Zyl, D. and Caldwell, J. (2011). Brief history of the conference series, Tailings and Mine Waste 2011, Norman B. Keevil Institute of Mining Engineering, UBC, pp 1 – 4.

Mullard, Z. and Van Zyl, D. (2011). Enhancing access to information: social media applications and the mining industry, Proc. Social Responsibility in Mining, Santiago, Chile, Gecamin, 9 pp.

Zhou, J.W., Zhou, A.G., Van Zyl, D., Tang, Z.H. and Bu, J.W. (2011). Mine closure in China – problems, strategies and forecasts, In: Mine Closure 2011, Vol. 2, Fourie, A, Tibbett, M and Beersing, A (Eds.), Australian Centre for Geomechanics, pp 501-509.

Crossley, C., Russell, B., Van Zyl, D, and McKenna, G. (2011). Developing an operation, maintenance and surveillance manual for post-closure management, In: Mine Closure 2011, Vol. 2, Fourie, A, Tibbett, M and Beersing, A (Eds.), Australian Centre for Geomechanics, pp 219 -228.

Shandro, J.A., Ostry, A, Scoble, M. and Van Zyl, D. (2011). Reaching economic and social prosperity – a need to collaborate with communities through commodity cycles to post-closure, In: Mine Closure 2011, Vol. 2, Fourie, A, Tibbett, M and Beersing, A (Eds.), Australian Centre for Geomechanics, pp. 167 – 176.

Mullard, Z. and Van Zyl, D. (2011). The risks, challenges and benefits of using social media in the mining industry, Fifth Conference on Sustainable Development in the Minerals Industry, Institute of Mining Engineering I, RWTH Aachen University, June, pp 249 – 262.

Garcia-Vasquez, M. and Van Zyl, D. (2011). The role so employee capacity in reducing company-community conflicts in Peru, Fifth Conference on Sustainable Development in the Minerals Industry, Institute of Mining Engineering I, RWTH Aachen University, June, pp 407 – 414.

Sousa, R., Veiga, M., Van Zyl, D., Telmer, K., Spiegel, S. and Selder, J. (2011). Policies and regulations for Brazil's artisanal gold mining sector: analysis and recommendations, Journal of Cleaner Production, Vol. 19, pp 742-750.

Priestley, D, Fredlund, M. and Van Zyl, D. (2010). Benchmarking multi-dimensional large strain consolidation analyses, Uranium 2010 Proceedings, Saskatoon, CIM, pp 271-288.

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Galla, V., Van Zyl, D. and Morrow, S. (2009). Significance of measured and modeled unsaturated flow results in heap leach materials using large diameter column tests, SME Annual Meeting, Preprint, 13 pp.

Van Zyl, D. (2008). Life Cycle Assessment and Tailings Management Trade-Off Studies – Concepts, Tailings and Mine Waste 2008, Taylor and Francis Group, London, pp 355-358.

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Webb, G., Tyler, S., Collord, J., Van Zyl, D., Halihan, T., Turrentine, J. and Fenstemaker, T. (2008). Field-scale analysis of flow mechanisms in highly heterogeneous mining media. Vadose Zone Journal. 7: 899-908.

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Van Zyl, D., Lohry, J. and Reid, R. (2007). Evaluation of Resource Management Plans in Nevada Using Seven Questions to Sustainability, In: Proceedings of the 3rd International Conference on Sustainable Development Indicators in the Mineral Industries, Z. Agioutantis (ed), Milos Conference Center, pp 403-410.

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Van Zyl, Dirk J.A. (2005). Contributions of mining projects to sustainable development, Proceedings of 20th World Mining Congress, November 7 – 11, Teheran, Iran, 10 pp. (Invited keynote paper, written paper submitted but did not attend the meeting because of other travel commitments).

Van Zyl, Dirk (2005). Sustainable Development and Mining Communities, In: Mining in New Mexico: The Environment, Water, Economics, and Sustainable Development, Price, G.L., Bland, D., McLemore, V.T. and Barker, J.M. (Eds.), New Mexico Bureau of Geology and Mineral Resources, pp 133- 136.

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Shields, D.J., Wagner, L.A., Van Zyl, D. (2003). Indicators of Mineral Systems Contributions to Sustainability in the USA, In: Proceedings of International Conference on Sustainable Development Indicators in the Mineral Industries, Z. Agioutantis (ed), Milos Conference Center, pp 35 – 41.

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Hodge, R.A. and D.van Zyl (2002). Towards Change – The Work and Results of MMSD – North America, International Institute for Sustainable Development, Winnipeg.

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Van Zyl, Dirk J.A. and Glenn M. Eurick (2000). The Management of Mercury in the Modern Gold Mining Industry, EPA Conference on Mercury and Mining, San Francisco, November.

Van Zyl, Dirk J.A. and Straskraba, V. (1999). Mine Closure Considerations in Arid and Semi-Arid Areas, International Mine Water Association Conference, Seville, Spain.

Van Zyl, Dirk J.A. (1999). Technology, Management, Policy and Philosophy of Environmental Protection in the Mining Industry, Proc. of International Mining and Environment Congress, Colegio de Ingenieros del Peru, pp 771-784.

McGregor, Jock and Van Zyl, D. (1999). Parallels in the Development of Copper and Gold Heap Leaching Technology, In: Copper Leaching, Solvent Extraction, and Electrowinning Technology, Gerald V. Jergensen II (Ed.), SME, pp 155-166.

Cincilla, W. Cunning, J. and Van Zyl, D. (1998) Geotechnical Factors Affecting the Surface Placement of Process Tailings in Paste Form, for publication in Minefill '98, Brisbane, Australia, April.

Moss, A.E. and Van Zyl, D. (1997). The Mine of 2020, In: The Sustainable Development Agenda, Campden Publishers, London, pp 154 - 155.

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Conference on Cyanide and the Environment (1985), 2 volumes, Civil Engineering Dept., Colorado State University, Fort Collins, Colorado, 577 pp.

Stephan M. Gale

1995-Present President and Founder – Gale-Tec Engineering, Inc.
1976-1994 Project Engineer to Director of Engineering/Shareholder – STS Consultants, Ltd.

EDUCATION

M.S., Geotechnical Engineering, Ohio State University - 1976
B.S.C.E., Civil/Structural Engineering, Ohio State University – 1974

REGISTRATION

Professional Engineer: Minnesota, Illinois, Iowa, Wisconsin, Ohio and Nebraska

PROFESSIONAL ACTIVITIES

American Society of Civil Engineers
- 1973 - Present
- Elected Fellow in 1992 & Life Member in 2016
- Geotechnical Journal Reviewer

American Soc. of Testing and Materials
- 1995-Present
- Committee D-18-Soils
- Committee D-35-Geosynthetics

Engineers Club of Northern Minnesota
- 1985-Present

Society of Mining Engineers
- 1988-Present

University of Minnesota
- CE 4102 Capstone Design Mentor, 2003-2006

AWARDS/CERTIFICATIONS

Diplomate – Geotechnical Engineering by ASCE – GeoInstitute - 2013

Minnesota Senate and House Agricultural Committee Task Force, "Liquid Manure Storage in the Karst Region", 2000.

Young Engineer of the Year, American Society of Civil Engineers, 1988

Who's Who in Science and Engineering-Second Edition, 1993

EXPERIENCE

Mr. Gale has 40 years' experience in tailings, earth dam and embankment evaluation and design. He has been evaluating and designing tailings dams and preparing MDNR Dam Safety Submittals for over 30 years. He has presented lectures at conferences around the world ("Upstream Dam Construction: An Instrumented Test Fill Evaluation", presented in The Hague, Netherlands).

Dams and Levees

- Principal Engineer in-charge of construction and eventual closure of a 120-foot high, 4-mile perimeter Tailings Basin and Dike No. 1 for Eveleth Mines/United Taconite in Forbes, MN. Seepage and stability evaluations were required to be submitted to MnDNR over a 20 year period prior to closure in 1999. Work also included preparation of the closure/reclamation plan.
- Principal Geotechnical Engineer for Tailings Basin and Dike No. 2, also on the United Taconite property. Responsible for stability and seepage studies and the preparation of the yearly Dam Safety Report for the period 2000-Present.
- Principal Engineer in-charge of the design, including preparation of plans and specifications, for raises to the Hibbing Taconite Company Tailings Basin perimeter retention dam, including their Western Dam and Dams SD-2 and SD-3.
- Principal Geotechnical Engineer for the evaluation and preparation of the repair plans and specifications for 2-miles of a Mississippi River Flood Control Levee at Lock & Dam No. 3 in Welsh, MN. The work included evaluation of the existing earth levee and preparation of plans and specifications for reconstruction of the levee, repairing erosion and establishing riprap and dam bedding requirements.
- Mr. Gale, as a national geosynthetics expert, was retained by the U.S. Corps of Engineers in 2008 to assist them in the re-write of their Engineering Manual – "Engineering Use of Geotextiles" in Levees, UFC 3-220-08.
- Principal Geotechnical Engineer for the assessment of a large wetland complex and surrounding levees in Necedah, WI for the U.S. Fish & Wildlife Service. Mr. Gale participated in the design of a culvert to pass both fish and large flood flows and completed an evaluation and design for a roadway/levee protection system.
- Principal Geotechnical Engineer to evaluate and prepare repair plans and specifications for the Neill Lake Berm/Levee in Eden Prairie, MN. The project involved the inspection and evaluation of a 1000 ft long levee which maintained the water level in a recreational lake. Animal burrow holes, seepage and stability were assessed. Geophysical studies were performed to assess foundation conditions. Plans and Specifications was prepared for the repair.
- Principal Geotechnical Engineer for the field investigation and subsequent assessment of various berms/levees within the Kimmes-Tobin natural wildlife area for the Wisconsin DOT. The project involved the evaluation and repair design for levees that were subject to overflow, erosion and animal penetrations.
- Project Engineer for the evaluation of Golden Dam for the Arizona Water Commission. The dam was built to create a recreational lake,

however, large amounts of under-seepage prevented water impoundment. Studies included seepage and under-seepage analyses, uplift analyses and reconstruction recommendations including downstream buttress fills and upstream blankets.

- Project Engineer evaluating two 80-ft high flood retention earth dams and spillways built during the 1930's in Ohio for the Corps of Engineers - Huntington District. Mr. Gale supervised the exploration program and then prepared the evaluation report for the Bolivar and Beach City Dams. Finite element seepage analyses, evaluation of relief wells and slope stability evaluations using both computer and hand solutions were carried out.
- Principal Engineer in-charge of the dam inspection and performance evaluation of a perimeter dam system containing the Whitewater Reservoir, in Aurora, Minnesota. The reservoir is a water resource that provides make-up water for a Minnesota Power plant and LTV Steel Mining Company's iron-ore processing plant. The studies included instrumentation monitoring and evaluation. The studies pointed out deficiencies in embankment stability and detailed necessary corrections.
- Mr. Gale was retained as an expert to review the distress and assist in the repair of The Earth City levee near St. Louis, MO during a 1993 flood event. The Earth City levee is a three mile levee protecting an industrial park from the Missouri River. When the Chesterfield levee burst in 1993, Mr. Gale was called in to examine and make critical observations to the adjacent Earth City levee which was on the verge of failing. The levee protected over $1B worth of property including the Whirlpool Corporation and the United Parcel Service Midwest distribution warehouses. Five (5) ft. high sand boils were occurring landward of the levee. Soon into the evaluation, it was identified that sixty foot deep relief wells were not providing pressure relief and repairs were ordered. The levee survived the flood!
- Mr. Gale was retained as an expert to analyze and review the collapse of a 22-foot low-profile steel-arch culvert pipe for Inland Steel Mining Company (now Arcelor Mittal) during development of their new Laurencian pit. The arch collapse was attributed to inability of the granular backfill to resist high arch corner pressures caused by 240-ton mine trucks operating over the arch that had been placed at a skew with an embankment fill.
- Principal Engineer responsible for the evaluation and design over a 15 year span of Hibbing Taconite Company projects involving their Tailings Basin in Hibbing, MN including sheet pile walls for spillway channels, for erosion protection systems for open water areas and for the failure investigation of two 96–inch diameter water intake structures that had collapsed.
- Mr. Gale was the investigator of downstream scour of a 1911 constructed Amburson type concrete dam on the Blue Earth River in Rapidan, MN. Mr. Gale initiated a rock boring investigation in order to provide an assessment of rock slope deterioration. Mr. Gale provided an assessment of the potential for undermining of the downstream apron and prepared a filter/riprap design.

A SAMPLING OF PUBLICATIONS

"Reliability of Settlement Prediction-Case History", ASCE – Journal of Geotechnical and Geoenvironmental Engineering, Vol. 137, Number 4, April, 2011

"Embankment on Sludge: Predicted and Observed Performances", Canadian Geotechnical Journal, 2007

"Upstream Dam Construction: An Instrumented Test Fill Evaluation," Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products, The Hague, Netherlands, 1990.

"Geosynthetics Play Critical Role in Simultaneous Construction of a Storm Water Retention Pond and a Reinforced Roadway Embankment," Geotechnical Fabrics Report, March/April, 1989.

Attachment 2 – Comment Tables

Review of PolyMet's Tailings Basin Permit Application: <u>Tailings Basin Dam</u>

Reviewers: Dirk Van Zyl, Steve Gale/Nate Lichty - Gale Tec Engineering, Inc. and Stu Grubb/Cecilio Olivier - Emmons Olivier Resources, Inc.

#	Page	Section or Table Number	Comment/Concern	PolyMet Response	Final Comment	Recommendation			
						Address Pre-Permit	Address Post-Permit & Make Condition of Permit	Address Pre-constr.	Condition of Permit Recommendation
1	Geotech Report-page 123 Mgmt. Plan - page 5 Mgmt. Plan - page 34	Section 9 - Operat. & Mainten. Section 2.1-Flotation Tailings Charact. Section 6.3 - Adaptive Mgmt.	The Management Plan calls for the design and/or the operation to be modified based on operational experience using the Observational Method. We recommend that this approach be defined in the Permit similar to that included in a paper "Liquefaction of Tailings Dams" by Solseng, P.B. - Barr Engineering Company presented/published for a "Liquefaction of Mining Tailings" symposium in Cleveland, Ohio - 1997. The Barr paper details that the Observational Method concept design should include: 1) Predict behavior with detailed calculations, 2) design with contingencies, 3) construct with monitoring and 4) compare measurements with predictions and redesign if necessary. The Geotechnical Report Section 2.1-page 5 states that this method is used for all MDNR-Permitted Tailings Basins. If the Observational Method is to be permitted, we recommend that the plan include a design at the time of permitting and identify what instrumentation will be installed, where the instrumentation will be installed and what the instrumentation will monitor (e.g. excess pore water pressures and tailings dam deformations). If the Observational Method is permitted, we recommend that the permit require stability evaluations be submitted at least yearly with the annual Dam Safety Report. If a significant design change is required, we recommend that the company apply for a permit amendment.	Further clarification on the details of the Observational Methods were requested.	The Observational Method (Peck, R.B., Geotechnique, No. 2, 1969) is based on assessing potential geotechnical failure modes that may result during/post construction as well as conditions and events that could instigate instability. An example condition could be a previously undiscovered layer of soft soil beneath the dike alignment. An example event may be a large rainfall that causes increased seepage and slope toe erosion. After this assessment is complete and critical failure modes and conditions/events are identified and analyzed, contingency plans should be developed for each critical failure mode. We recommend this analysis be performed prior to construction. With the analysis results in mind, a monitoring system (geotechnical instrumentation, site reviews, etc.) should be developed and implemented during construction to monitor dike performance. The monitoring system would be used to confirm assumptions made during original design or to change operations/design if field observations and adverse measurements are recorded. We recommend that to adequately use this method for dike construction, that a geotechnical instrumentation and monitoring plan should be developed based on the results of the dike stability analysis that considers conditions/events that could result in localized or complete dike instability. Contingency plans should be developed for each critical condition. The instrumentation and monitoring plan should include 1) a list of geotechnical instruments that will be installed, where they will be installed and what they will be measuring, 2) how often the instrumentation readings be taken, 3) who will review the instrumentation readings, 4) what the typical values will be and what the thresholds will be that indicate “adverse conditions” that will require a change in operation or design. The contingency plan should include a list of potential adverse conditions that may occur and what would be observed if that condition occurred. The plan should include different operational/design options to address the adverse conditions.	X	X		The importance of a well defined Observational Method is paramount. It is the preference of the reviewers that this key issue be addressed as part of the permit application. Either as a pre-permit or as a condition of the permit, the following items need to be incorporated: 1) Adverse conditions/events that could lead to localized/global dike instability. 2) An instrumentation and monitoring plan that includes those items presented in "Final Comment" section. 3) A contingency plan that includes those items presented in "Final Comment" section.

Review of PolyMet's Tailings Basin Permit Application: <u>Tailings Basin Dam</u>

Reviewers: Dirk Van Zyl, Steve Gale/Nate Lichty - Gale Tec Engineering, Inc. and Stu Grubb/Cecilio Olivier - Emmons Olivier Resources, Inc.

#	Page	Section or Table Number	Comment/Concern	PolyMet Response	Final Comment	Recommendation			
						Address Pre-Permit	Address Post-Permit & Make Condition of Permit	Address Pre-constr.	Condition of Permit Recommendation
2	Mgmt. Plan - page 10 Geotech Report - page 75, Mgmt. Plan - page 10	Section 2.2.4 - Dam Construct. Section 6.3.2.4 - Cement Deep Soil Mixing Zone	Cement deep soil mixing (CDSM) shear walls are shown to be needed to satisfy stability of the north tailings dam as a result of liquefaction of buried slimes. The Geotechnical Report text states that a Construction Quality Assurance Plan will be developed. Since this CDSM structural feature is such a critical aspect of the plan, we recommend that the permit require bench-scale testing, test columns and field validation using such techniques as coring and wet sampling and geophysical testing (e.g. Ps logging and/or electromagnetic testing methods). The Federal Highway Administration (FHWA) has a design manual for Deep Mixing for Embankment and Foundation Support - October, 2013. This manual includes guidance for CDSM installation and integrity testing.	Post-permitting & pre-construct. bench scale testing and in-field validation testing is already incorporated in the construction specifications (FTMP, Attach. G, Section 313200). A Dec. 30, 2016 memo suggested that the CDSM be eliminated.	The Barr specifications included in the Basin Management Plan contain reasonable QA/QC procedures for CDSM construction.				This issue can be closed if a larger buttress will replace the CDSM.
3	Geotech Report - page 8 Geotech Report - page 41	Section 3.2 - Tailings Basin Develop. Section 5.2.3 - Shear Strength of LTVSMC Tailings and Table 5-10	The Report describes various peat layer thicknesses and various slime layer thicknesses beneath the Cell2E North perimeter dam. Sitka Corporation identified typical standard penetration resistance value (blow/foot) for the slimes was 5 or less and for the fine tailings was in the range of 15-20. We recommend that the layer thicknesses and the continuity of the layers be further investigated and a sensitivity analysis be performed based on the thickness, continuity and the liquefied shear strength values. A USSR liq=0.10 is included in Table 5-10 (page 41) for the LTVSMC fine tailings/slimes and further alludes to this value being a minimum to be used for design by the Engineering and Design Manual - Coal Refuse Disposal Facilities published by U.S. Department of Labor - MSHA. Further documentation should be provided for this value: and a sensitivity analysis should be performed in conjunction with the previously described parameters. Sitka Corporation found remolded vane shear strength values of the slimes to be in the range of 100 - 300 pounds per square foot. These low remolded vane shear strength values could indicate a USSR liq. less than 0.10. These lower values could result in a factor of safety of less than 1.1.	Slope stability sensitivity analyses to evaluate variation in material strength has been performed and reported in GDP Vol 1, Sections 6.6 and 7.3.8. Affirmation of selected strength parameters will be performed following acquisition of additional strength data during post-permit installation of instrumentation.	The additional subsurface exploration and instrumentation & monitoring plan should be developed based on the results of the analysis performed as part of the Observational Method process Part 1. The plan should include what instrument type is required, its location, depth and expected range of values that will be obtained during basin construction. This plan should be incorporated into the submittal discussed as part of Comment 1.	**X**	**X**		The additional subsurface exploration, performed post permit, and development of the Instrumentation and Monitoring Plan should be based on the analysis of critical failure modes as associated with Comment 1

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4	Geotech Report - page 8	Section 3.2 - Tailings Basin Develop.	The Report describes a layer of peat over a deposit of glacial till beneath the Cell 2E North perimeter dam. During the retreat of the glaciers approx. 10,000 years ago, depressions were formed in which lacustrine clay and peat were deposited. The Geotech. Report, however, does not reference any lacustrine clay layers, only peat over glacial till. Table 5-24 (page 64) identifies peat with a USSR yield = 0.23. This value may be appropriate for a fibrous peat but not for a decomposed amorphous peat or a high plasticity lacustrine clay. The soil types should be further investigated and sensitivity analysis performed for a range of shear strengths. Geotech. Report - page 49, Section 5.4.2.2, states that previous testing by Sitka resulted in higher permeability values for peat than that obtained from samples during the most recent 2014 investigation. This may indicate a different type of peat at various locations.	Same as Recommendation for Comment 3	The additional subsurface exploration and instrumentation & monitoring plan should be based on the results of the analysis performed as part of the Observational Method process Part 1. The results of this analysis should be used to develop the basin's instrumentation and monitoring plan. The plan should include what instrument type is required, its location, depth and expected range of values that will be obtained during basin's construction. This plan should be incorporated into the submittal discussed as part of Comment 1.	**X**	**X**		The additional subsurface exploration and instrumentation plan should be developed based on the analysis of critical failure modes as associated with Comment 1
5	Mgmt. Plan - page 22-24	Section 4.2 - Transport and Deposit. Plan	It appears that the stability analysis was based on maintaining a beach length of 625 feet between the inside crest of the dam and the edge of the water within the tailing basin. The water pocket could, at sometime during the operation, be closer to the dam than the 625 feet. Stability and exit seepage should be evaluated considering the water pocket closer or in contact with the tailings dam.	Addressed - have reviewed high pond conditions as shown in GDP Vol 1, Section 7.3.3.2 and supporting Sections	The analysis included a four foot head increase to the tailings basin water level while moving the water pond interface with the perimeter dike from 625 feet away to 150 feet away. Consistent with the Observational Method approach, a Contingency Plan should be prepared for instances when the water pocket is closer than 150 feet away from the inside crest of the dike. The April, 2017 Contingency Action Plan submitted by PolyMet/Barr should be updated to address this concern.	**X**	**X**		A Contingency Plan should be prepared as part of the Observational Method approach for circumstances when the water pocket is closer than 150 feet away from the inside crest of the dike
6	Mgmt. Plan - page 34	Section 7.3 - Structure Removals	The Management Plan is vague regarding abandonment of existing structures within the tailings basin and assumes that the previous owner properly abandoned all pipes within the basin which could be a conduit for water which could create erosion conditions which could then act as a trigger for liquefaction and induce a flow failure. Specifically, the 9 foot diameter drop inlet decant structure constructed in Basin 2W and the approximate 2000 lineal feet of 40 inch diameter spiral pipe extending into Basin 1E should be addressed.	This will be addressed post-permitting; prior to reactivation of the basin	If not investigated pre-permit, we recommend that the dam safety permit include language that requires all existing pipes/structures to be investigated and properly abandoned to ensure dike stability is maintained.			**X**	

Review of PolyMet's Tailings Basin Permit Application: <u>Tailings Basin Dam</u>

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7	Geotech Report - page 90	Section 6.6.1 - Range and Distrib. of Shear Strength Values	The Report identifies that sensitivity analyses were performed for the USSR properties for most of the soils using either a normal or log-normal distribution. However, a sensitivity analysis was apparently not performed for liquefied shear strength ratio (USSR) for the slimes. The Report identifies that based on previous geotechnical workshops, a single estimate of that particular strength was chosen. Apparently, the chosen ratio is 0.10. Using this ratio, 40 feet of overburden would result in a liquefied shear strength of 600 pounds per square foot. Residual vane shear testing has shown slime values as low as 100 - 300 pounds per square foot, which would result in a ratio of less than 0.10. We recommend that this issue be further explored.	Affirmation of selected strength parameters will be performed following acquisition of additional strength data during post-permit installation of instrumentation.	The additional subsurface exploration and instrumentation & monitoring plan should be based on the results of the analysis performed as part of the Observational Method process Part 1. The results of this analysis should be used to develop the basin instrumentation and monitoring plan. The plan should include what instrument type is required, its location, depth and expected range of values that will be obtained during basin construction. This plan should be incorporated into the submittal discussed as part of Comment 1.	**X**	**X**		The additional subsurface exploration and monitoring plan should be included and analyzed as part of the Observational Method and be as part of the submittal associated with Comment 1
8	Mgmt. Plan - page 37	Section 7.2 - Final Reclamat.	The Plan identifies approximately 3% bentonite by dry weight to be added to the fine tailings beach to a depth of 18 inches and then overlain by 30 additional inches of tailings and then vegetated. The 3% by dry weight addition should be further investigated based on field trials, not laboratory testing in which very controlled conditions exist. Closure of the pond bottom refers the Geotechnical Report reader to the Adaptive Water Management Plan - Version 7. The effectiveness of injecting bentonite through the pond water is subject to concern with regard to reliability of the infiltration reduction.	Pilot testing/field tests are already incorporated in closure construction specifications (FTMP, Attachment G, Section 03100)	A plan should be developed that requires test sections be constructed on both the pond bottom and tailings dike side slope to evaluate the chosen means for bentonite inclusion. The test section evaluation should consider: onsite water chemistry, potential for ice scour along the shoreline, oxidation of sulfide bearing rock within side slopes, and other concepts which may impact the permeability of the bentonite amended tailings. The Adaptive Water Management Plan, Section 5, states 3 methods on how the Tailing Pond bottom could be amended at the time of closure: 1) broadcasting granulated or pelletized bentonite on the pond surface and allowing it to settle to the pond bottom, 2) direct injection of bentonite into the pond bottom or 3) placing a GCL on the pond bottom. We understand that the PolyMet tailings are not available as yet for lab or field trials. But, if bentonite/tailing mixing (methods 1 or 2) is the preferred method of application, a preliminary material and installation specification should be developed and a protocol should be prepared for both a laboratory and a field pilot study as part of the permit application. The protocol (including the design calculations for 1 or 2) should include a degree of variability on which the acceptance criteria is based. The specification should also address how durability to ice heave on the side slopes and freeze-thaw degradation will be addressed.	**X**	**X**		Perform test sections for each bentonite application technology prior to tailings dike closure. A report should be submitted with test results and a QA/QC program demonstrating that the bentonite-tailings mixture has adequate permeability.

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9	Geotech Data Package, Vol. 1, Attach. C, page 19	Section 3.0 - Drained Shear Strength Paramet.	The shear strength data for the different materials was evaluated by considering laboratory shear strength data plus interpreted field shear strength data from various tests as appropriate. The 33rd percentile of the resulting data was then selected for the stability analyses. In the case of the drained shear strength of the LTVSMC coarse tailings, the shear strength ranges are: laboratory testing 28 to 47 degrees, SPT testing 26 to 50 degrees and CPT testing 39 to 46 degrees (outliers below 39 degrees, to as low as 32 degrees were excluded, Figure A-3). The resulting value selected for stability analysis from the statistical analysis is 38.5 degrees. This value seems on the high side as lab testing and SPT testing values in the high 20's are included in the evaluation while lower values of the CPT testing were excluded. Furthermore, the drained shear strength selected for the coarse tailings is higher than that selected for glacial till - typically a well graded material that is very dense. The angularity of the coarse tailings particles might have played a role in the selection of this higher value. It is recommended that the stability analysis should also be done with a lower shear strength value, say 36 degrees, for the coarse tailings as part of a sensitivity analysis. It is recognized that this may not change the outcome very much, however this sensitivity analysis is an important aspect of developing further confidence in the effective strength stability results.	A sensitivity analysis will be performed to review the effect of the lower friction angles on dike stability. Strength data will also be further investigated during instrumentation installation.	The Dec. 30, 2016 Barr Memorandum identified no substantial reduction in the tailings dike global factor of safety by lowering the coarse tailings friction angle from 38.5 deg. to 36 deg. We question why some of the data was excluded from the statistical analysis and recommend that the coarse tailings friction angle be considered as a variable condition in the Observation Method process. At cross sections where lower friction angles result in lower factors of safety, the Observational Method would suggest enhanced instrumentation and monitoring at these locations. This analysis should be incorporated into the submittal discussed as part of Comment 1.	**X**	**X**		The apparent variability of the coarse tailings friction angle should be analyzed as part of the Observational Method and be a part of the submittal associated with Comment 1
10		Section 7.2 - Final Reclamat.	PolyMet is proposing a 20 year mine life and "wet closure" for the tailings basin. The proposed design is permittable and if permitted, would need to be managed in compliance with all rules and regulations including financial assurance. If permitted, the DNR should also require PolyMet to continually review the current state-of-the-practice for design techniques prior to starting any tailings basin closure activities. Information should be reviewed so that the decision on the best closure design option, accounts for current technologies, for environmental protections and considers the long term cost of operation. Continued study of tailings basin closure designs should also be considered as a permit condition. If a closure design change is required in the future, it must meet all environmental review and permitting standards.	Polymet will continue to evaluate potential project improvements during operations and at closure, one of which may be revisiting the tailings closure approach.	The review team is not ready to commit to a dry closure requirement. Wet closure will be more difficult and costly to manage for the long-term and it must be determined if this commitment is acceptable.			**X**	

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11		Barr Memo Dec. 30, 2016 on Tailings Basin Cell 2E Buttress Design as Alternate to CDSM	The modified buttress design includes increasing the buttress height by 35 ft. to a total height of 84 ft above the surrounding grade. This increased height will require the buttress slope toe to extend approx. 100 ft more into the wetland than what was previously proposed (200-250 ft total). The stability analyses presented are limited to global failure planes through the entire tailings dike. The stability analyses indicate that the peat will be removed from beneath the buttress. Localized stability of the buttress toe with a failure plane extending out into the virgin peat soils does not seem to have been evaluated. This localized failure could be significant in that it could result in a progressive failure into the buttress. The results of the stability analysis should be used to determine the buttress toe design. Potential adverse environmental effects associated with the buttress fill (e.g. wetland fill and geochemistry of the Area 5 material) will also need to be addressed.			X			

Review of PolyMet's Tailings Basin Permit Application: HydroMet Facility

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1	Mgmt. Plan - page 10	Section 2.2.2.2	The 80 foot high residue storage facility will be constructed over potentially soft ground. The management plan addresses shear strength gain and settlement of the soft soils but does not commit to a construction plan stating that the Observational Method will be used to assess what type of construction needs to take place in the future. Since the soft foundation soils already exist in place, these soils should be further tested and further evaluated such that a design can be promulgated. The pre-load method should be evaluated and a determination made if the pre-load will induce shear strength gain of the soft deposit and whether external drainage, such as wick drains, would be required. It is our opinion that the Observational Method requires a design be presented at the time of permit application.	The need for wick drains is dictated by schedule; the time available for pre-load construction relative to required in-service date for the HRF. The wick drains are not necessary for dam stability.	The subsurface exploration indicates that the soft ground beneath the proposed residue facility consists of up to 30 ft. of slimes, peat and tailings concentrate. The geotechnical report states that this material was placed hydraulically and therefore is likely in a loose unconsolidated state. A preload to consolidate the soft ground has been proposed to reduce settlement and subsequent strains that may occur in the proposed HRF Geomembrane liner. Wick drains are listed as optional based on the amount of time that a preload can be placed. The preload is proposed to be about 50 ft. in height, constructed in 5 lifts each 10 ft. thick. The top of preload elevation is given as 1,620 ft. in the project Plans, approximately 50 ft. above the existing grade of the emergency overflow basin. The top of dam elevation and residue elevation is proposed to be 1,650 ft. Due to the preload, the over consolidation ratio is estimated = 1.37 of the unconsolidated material. The preload is proposed to remain in place until instrumentation has indicated that pore pressure dissipation has been completed and that minimal additional settlement will occur. A 2 year preload time has been estimated. The geotechnical report indicates that the soft material will reenter the normally consolidated state during the last few years of residue filling. The settlement modeling that was performed assumes that the soft soil is isotropic, consisting of a uniform material. The model also varies the depth of the soft soil, but the soft soil depths are only known at a few discreet points where borings were performed, so there is likely some variability that is not expressed in the model. Due to the likely variation of material type and depth of the soft material, it is likely that differential settlement will occur over the length of the liner system, especially after the material becomes normally consolidated again during HRF construction. This variability may cause an excessive amount of strain in the liner system. The liner system has been designed based on an analysis which considers uniform subsurface conditions. If deformation from the preload construction varies notably from the predictions from this analysis, then the preload height, wick drain type and extent and the liner and leachate collection system design, in part, will have to be modified, as required. In accordance with the Observational Method approach, variability of parameters should be predicted at this time and alternate designs included in the Permit application. This would be necessary in order to establish appropriate financial assurance.	X	X		Design of the preload shall be required to reduce the potential for differential settlement and excess strain in the liner due to the underlying soft soils considering variable soil properties and variable deposit depths. It is recommended that this design be evaluated and approved prior to Preload/HRF construction
2	Mgmt. Plan - page 8	Section 2.2.2.1 - Liner and Leakage Collection System Design	The HydroMet residue basin will consist of a double liner with an internal leakage collection system. Since this system is susceptible to rupture as a result of strains in the geomembrane or geosynthetic liner as a result of settlement or other localized conditions, we recommend that the pre-load/wick drain system be further evaluated and a design promulgated for review during permit.	Deformation and impacts on liner were presented in GDP Vol 2, Sections 5.4 and 6.1	See Comment No. 1.	X	X		See Comment 1.
3	Mgmt. Plan - page 33 and 34	Section 7.2.2	The management plan identifies that the HydroMet closure will include a 40 mil LLDPE membrane or a MPCA approved geomembrane and a geosynthetic clay liner (GCL) constructed over a working platform. As far as we know, the MPCA does not have an approved geomembrane list. They do have a guidance on their website. We recommend that the liner type be further investigated and the proposed liner be identified and detailed at permit.	The proposed 40 mil LLDPE liner is detailed in the RMP, Section 2.2 and Attachments A and G.	This issue can be closed.				