MEMORANDUM

To: Eric Scott

From: Tim Cazier, P.E. TC

Date: February 18, 2021

Re: **Morrison Quarry – Permit No. M-1973-021, Amendment 7 (AM-07); Geotechnical Slope Stability Preliminary Adequacy Review**

The Division of Reclamation, Mining and Safety engineering staff (DRMS) have reviewed the Seventh Amendment to Permit M-1973-021, Aggregate Industries (AI) Morrison Quarry, dated November 2020 and prepared by GEI Consultants, Inc.

The review consisted of comparing the application content with specific requirements of C.R.S 34-32.5-116(4)(i), Rule 6.5 of the Minerals Rules and Regulations of the Colorado Mined Land Reclamation Board for the Extraction of Construction Materials, and Policies of The Mined Land Reclamation Board, Section 30.0 – Factors of Safety for Slope Stability/Geotechnical Analyses (MLRB Policy 30). Any inadequacies are identified below along with suggested actions to correct them.

1. Seismic Stability – MLRB Policy 30 requires seismic evaluation be included in addition to static evaluations for geotechnical stability. No seismic analyses were found in the submittal. Please submit additional analyses factoring in earthquake loading.

2. Highwall Configuration – In the third paragraph on page 1, Section 1.1 General and in several other locations (e.g., Sections 6.3.5 & 6.3.6) in the text, and presumably the Slope-W and FLAC models, the interbench highwalls are either stated or appear to be vertical. However, section A-A′ (Figure 7) and section B-B′ (Figure 8) indicate a maximum highwall angle of 85°. The 5° difference may seem insignificant, but with a 70-foot high interbench highwall, the corresponding difference in the horizontal is just over 6 feet. As such, five benches will pull the overall highwall the equivalent of one bench width closer to the pit. Put another way the difference between 85° and 90° increases the overall slope from ~0.5H:1V to ~0.4H:1V. Please address the following:

   a. Clarify whether the intent is to mine at 85° or 90° and if the bench widths are drawn as 24 or 30 feet on Figures 7 and 8.
   b. Figures 7 and 8 should be revised to be consistent with the text and modeling efforts.
   c. If the intent is to mine at 85°, provide some discussion/rationale as to how the modeling at 90° is appropriate; conservative or not, given the steep dip angle of some of the formation to be mined.

3. <u>Groundwater</u> – Section 3.3 states groundwater is between elevation 6,450 and 6,600 and that that is below the base of the pit. However, Figure 7 shows the bottom of the pit at 6,200, and Figures 8 and 9 indicate the bottom of the pit is at either 6,190 or 6,230 (depending on whether the note or the elevation scale is correct in Figure 8). This indicates the stability analyses should incorporate saturation conditions below elevation 6,600. Please revise the analyses accordingly or provide a valid explanation as to why groundwater was not factored into the stability analyses.

4. <u>Laboratory Analyses</u> – The number of tests for each type of material were reviewed for compliance with Policy 30. There are some inconsistencies in rock material classifications between Tables 4.1 and 4.2 when compared to Rock unit in Appendix A.1 and/or the rock type in identified in Appendix A.2 (see **Attachment A** for a summary). There is also a test date discrepancy regarding sample 13 from boring M-3-18 (Appendix A.2, p. 105 of 114). The test document in Appendix A.2 dates the test as 7/19/2015, but the core was drilled in 2018.

   a. Please explain the rock material discrepancies such that the DRMS can be assured appropriate numbers of strength tests were performed for each rock material and applied to the pertinent material in the Slope-W and FLAC models.
   b. Please confirm the date error for sample no. 13.

5. <u>Table 5-1</u> – The first row in Table 5-1 (model parameters for Granitic and Biotitic Gneiss) states the selected 12.5 ksi value for unconfined compressive strength is based on the average value of seven tests performed in 2018. However, upon reviewing Table 4-3, there were only four samples (Nos. 4, 6, 8 & 9) for material categorized as Granitic or Biotitic Gneiss. Please explain why all seven values in Table 4-3 were used. [<u>*Note: Table 5-1 reflects those values found on p. 6 of 25 in Appendix C.1*</u>]

6. <u>Table 5-2</u> – The first row in Table 5-2 (model parameters for Sillimanitic Gneiss) states the selected 6.5 ksi value for unconfined compressive strength is based on the average value of three tests performed in 2018. However, upon reviewing Table 4-3, there were only two samples (Nos. 2 & 3) for material categorized as Sillimanitic Gneiss. Please provide the source of the third UCS value used in the average. [<u>*Note: Table 5-2 reflects those values found on p. 7 of 25 in Appendix C.1*</u>]

7. Rock Mass Characterization Summary – Table 5-4 appears to summarize the calculated parameters from Appendix C.1 for rock material not considered Sillimanitic Gneiss. The models in Appendices E and F appear to simplify the models to evaluate two potential conditions: 1) Assume no Sillimanitic Gneiss, and 2) assume certain regions of the model are primarily Sillimanitic Gneiss. There does not appear to be any summary of the Sillimanitic Gneiss parameters in Section 5.4. Assuming Sillimanitic Gneiss parameters are used in the pertinent analyses, please provide a similar summary for Sillimanitic Gneiss in Section 5.4.

8. Figure 6-2 – Both Sections 6.2.1 and 6.2.2 reference Figure 6-2 for primary highwall orientations evaluated as part of the kinematic analyses for the South and West Quarries, respectively. The DRMS could not find a Figure 6-2 in the submittal. Please correct the reference to Figure 6-1, if appropriate, or provide Figure 6-2.

9. Table 7-1 – This table provides percentage values for various types of failures and orientations in the South Quarry. Other than providing a ranking, what do these values mean in terms of geotechnical stability?

10. Table 7-2 – This table provides percentage values for various types of failures and orientations in the West Quarry. Other than providing a ranking, what do these values mean in terms of geotechnical stability?

11. 6,650 Intermediate Bench – The last sentence above Table 7-3 indicates a 60-foot bench width at elevation 6,650 results in a FOS of 1.26 or greater. It does not appear that a model was run specifically for a 60-foot bench, nor are results presented in Table 7-3 for a 60-foot bench. Based on the text in Section 7.2.1, it is also not entirely clear if a single 60-foot bench at elevation 6,650 is adequate or if all benches in the Sillimanitic Gneiss region need to have 60-foot wide benches.

    a. How was it determined a 60-foot bench would result in and adequate FOS?

    b. Clarify whether a single 60-foot wide bench at 6,650 is adequate or if all benches in the Sillimanitic Gneiss need to be 60 feet wide.

12. Table 7-3, Note 3 – There are two references in Table 7-3 to "Note 3" which states "A FOS was not able to be computed for this case as FOS by inspection is greater than 1.25". Please explain how an inspection can indicate a FOS is greater than 1.25.

13. Table 7-4, Note 4 – There is a references in Table 7-4 to "Note 4" which states "A FOS using FLAC was not computed for this case as FOS by inspection is less than 1.25". Please explain how an inspection can indicate a FOS is less than or greater than 1.25.

14. Kinematic Stability Recommendations – Section 8.1.2 provides a lengthy discussion on potential kinematic failures and how they might interfere with safe operations and failures

that could encompass several benches and a large rock mass. GEI provides the following recommendation: "Additional excavation should not occur until a site-specific geotechnical assessment and evaluation can be performed. The assessment must consider the orientation of the observed discontinuities and planned geometry of underlying bench, and a kinematic evaluation should be performed using discontinuity and geometric information specific to the observed bench conditions."

As stated in the title of Table 1 of MLRB Policy 30, our factor of safety minimums apply not to just operations, but to reclamation as well. The observed kinematic failures to date, as shown in Photo 8-1 of the submittal and an image from Appendix B (see **Attachment B**) suggest the currently proposed highwall configuration may not meet the criteria outlined in Section 30.2, Declaration of Purpose in Policy 30 to: i) Protect and promote the safety and general welfare of the people of Colorado, ii) Ensure reclamation of lands affected by mining to beneficial use, and iii) Aid in the protection of aquatic resources and wildlife. The DRMS is also concerned about how these kinematic failures might interfere with the reclamation plan proposed for the benches: either in preventing access for backfill or topsoil placement; or a significant failure subsequent to reclamation affecting significant reclaimed areas and/or failing to provide adequate safety to people or protect wildlife in a post-reclamation scenario.

A review of the 2019 Annual Report Geotechnical Addendum suggests benches 6950 and 6740 in the South Quarry may have portions reaching or exceeding bench capacity for rock fall. Please describe and commit to how the high potential for kinematic failures (including GEI's recommendation to perform a "detailed assessment and evaluation of discontinuity conditions") can or will be mitigated to prevent multiple bench failures raised by the GEI recommendations section. [*Note: DRMS has accepted adequate catch-bench capacity analyses for other projects, which is alluded to in Section 8.3, second paragraph.*]

15. Rock Cut Highwall Performance Monitoring Recommendations – In Section 8.2, GEI recommends supplementing the existing plan "with an annual program that includes quarry face monitoring by LiDAR (N, E and El.) scans of the rock face and 55-gallon drum monuments or other laser scanning method to detect changes in the highwall surface." The DRMS has several sites that have implemented a LiDAR system. Please commit in writing to including a LiDAR or equivalent monitoring system and including results in your Annual Report Geotechnical Addendum.

16. Figure 8 – Figure 8 presents inconsistent information with respect to the bottom of the pit: either 6,190 (according to the note), or 6,230 (according to the elevation scale). Please resubmit Figure 8 to clarify and/or correct the discrepancy.

17. Appendix B – At the top of p. 8 of GEI's Technical Memo is this statement: "A digital model with the sections included has been provided in 3D 4dim format with this project submittal". The DRMS has no record of receiving any digital submittals. Was this file

just submitted to Aggregate Industries for internal use? Please provide clarification as to whether specific software is required to read this file and if it was intended to be provided to the DRMS.

18. Appendix C.1 – The input parameters in the Hoek Brown Classification for Sillimanitic Gneiss-Global Bench Failures on p. 7 of 25 are identical to the input parameters in the Hoek Brown Classification for Sillimanitic Gneiss-Local Bench Failures above it on the same page, yet the values for mb and s in the Hoek Brown Criterion for Sillimanitic Gneiss-Global Bench Failures below it are different than those provided in the Hoek Brown Criterion for Sillimanitic Gneiss-Local Bench Failures. Furthermore, if D = 0, then the values for s and a are correct but not for mb. Please explain whether these are math errors or typos and if math errors, please provide corrected stability analyses as applicable.

19. Appendix E – There appear to be cases analyzed in Appendix E where an inadequate Factor of Safety was realized, but not reflected in the Tables in Section 7.2 (e.g., Case SQ_ 4-l_Local_lnt/Figure E.31 on p. 31). Please explain why these were not included in the summary tables in Section 7.2.

20. Appendix F – There appear to be cases analyzed in Appendix F where an inadequate Factor of Safety was realized, but not reflected in the Tables in Section 7.2 (e.g., Job Title: MQ_SQ_4_1b_Local/Figure F.29 on p. 29, and Job Title : MQ SQ 4 2b Local/Figure 30). Please explain why these were not included in the summary tables in Section 7.2.

If either you or the applicants have any questions regarding the comments above, please call me at (303) 328-5229 [mobile #].

ATTACHMENT A - Strength Testing Tracking

Permit No.	M-1973-021
Site Name:	Morrison Quarry
Permittee	Aggregate Industries
County:	Jefferson

Revision No.	AM-07
Source	Geotechnical Stability Exhibit
Specialist:	T. Cazier
Date:	2/2/2021

Direct Shear (ASTM D 5607) Test Results from Appendix A.2:

App A.2 Rock Type: Granitic Gneiss

App. A.1 Unit	*Granitic Gneiss*	*Biotite Gneiss*	*Biotite Gneiss*	*Biotite Gneiss*	*Biotite Gneiss*	*Biotite Gneiss*	*Biotite Gneiss*			
Table 4-1	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*			
Sample #	1	3	4	8	9	13	14			
Boring No	MQ-117	MQ-117	MQ-117	MQ-3-2017	MQ-3-2017	MQ-4-2017	MQ-4-2017			
Depth	72.5-73.0	336.7-337.5	428.4-429.0	161.0-162.5	246.5-248.0	169.0-169.8	223.5-224.2			
Date Tested	5/12/2017	5/12/2017	5/11/2017	5/17/2017	5/19/2017	5/19/2017	5/17/2017	Average	Minimum	Maximum
c (psi)	100.4	94.6	95.0	3.5	11.2	20.3	66.2	55.9	3.5	100.4
Phi (deg)	15.9	14.3	23.8	34.9	25.2	18.6	24.6	22.5	14.3	34.9

App A.2 Rock Type: Granitic Pegmatite

App. A.1 Unit	*Granitic Gneiss*	*Biotite Gneiss*			
Table 4-1	*Granitic Pegmatite*	*Granitic Pegmatite*			
Sample #	2	5			
Boring No	MQ-117	MQ-117			
Depth	173.5-174.2	505.0-506.5			
Date Tested	5/15/2017	5/12/2017	Average	Minimum	Maximum
c (psi)	60.4	151.5	106.0	60.4	151.5
Phi (deg)	21.8	26.5	24.2	21.8	26.5

App A.2 Rock Type: Blank/Unknown

App. A.1 Unit	*Biotite Gneiss*	*Sillimanitic Gneiss*	*Granitic Gneiss*	*Biotite Gneiss*	*Sillimanitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*
Table 4-1 / 4-2	*Granitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Biotite Gneiss*	*Sillimanitic Gneiss*	*Granitic Gneiss*	*Granitic Gneiss*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*
Sample #	6	7	1	5	7	9	11	12	13
Boring No	MQ-2-2017	MQ-2-2017	M-2-18	M-2-18	M-5-18	M-4-18	M-4-18	M-3-18	M-3-18
Depth	74.5-75	173.0-173.8	154.0-155.3	56.0-57.0	129.0-129.5	173.0-174.0	193.0-194.5	282.0-283.5	362.0-364.0
Date Tested	5/16/2017	5/17/2017	6/12/2018	6/12/2018	6/12/2018	6/12/2018	6/12/2018	6/12/2018	7/19/2015
c (psi)	0.0	24.2	8.9	0.0	25.4	44.0	31.1	119.7	139.6
Phi (deg)	29.8	17.3	33.9	30.8	19.6	21.3	28.1	15.9	25.8

App A.2 Rock Type: Sillimanitic Gneiss

App. A.1 Unit	*Granitic Pegmatite*	*Granitic Pegmatite*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*	*Granitic Gneiss*			
Table 4-1	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*	*Sillimanitic Gneiss*			
Sample #	10	11	12	15	16			
Boring No	MQ-4-2017	MQ-4-2017	MQ-4-2017	MQ-4-2017	MQ-3-2017			
Depth	80.1-80.8	81.0-81.6	123.0-124.0	323.3-323.7	81.5-82.5			
Date Tested	5/19/2017	5/17/2017	5/17/2017	5/17/2017	5/17/2017	Average	Minimum	Maximum
c (psi)	3.8	31.8	63.6	62.8	0.0	32.4	0.0	63.6
Phi (deg)	29.1	21.0	15.3	25.5	47.7	27.7	15.3	47.7

LEGEND:

MQ-2-2017	= 2017 data
M-5-18	= 2018 data
7/19/2015	= apparent date error

Granitic Gneiss	= Rock types consistent between Appenices A.1 & A.2
Granitic Gneiss	= Rock types inconsistent between Appenices A.1 & A.2
Granitic Gneiss	= Rock types consistent between Table 4.1 & Appenix A.2
Granitic Gneiss	= Rock types inconsistent between Table 4-1 & Appendix A.2

ATTACHMENT B - from p. 16 of Appendix B