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To:
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16 July 2024

Subject: Review: 19 April 2024 Supplemental Information:
Solid Waste Permit Application – GSL Landfill, Dalton and Bethlehem, New Hampshire

Dear Ms. Manzelli:

As per the agreement of service with BCM Environmental & Land Law, PLLC (BCM), I have reviewed the 19 April 2024 Supplemental Information regarding the Solid Waste Permit Application for the Granite State Landfill (GSL), proposed to be located in Dalton and Bethlehem, New Hampshire.

In this letter, I present my comments related to the adequacy of the Supplemental Information in addressing the comments by the New Hampshire Department of Environmental Services (NHDES), as well as the comments provided by BCM and its consultants. Specifically, comments related to engineering design are the focus of this review.

1. Geotechnical Report (Exhibit 7 of the Supplemental Information)

a. Slope Stability Calculations – Equipment Loading (starting on page 59 of pdf)

The purpose of this analysis is to demonstrate that the typical composite liner system on the side slopes can maintain integrity under both static and dynamic loading during all phases of landfill development pursuant to Env-Sw 805.06(i)(3). Specifically, the applicant has considered a case where a D6N LGP tractor dozer operates on a 3 horizontal (H): 1 Vertical (V) slope while spreading the soil components of the leachate collection and removal system (LCRS) or operations soil layer.

The applicant has used a minimum value of interface frictional angle (a) of 27 degrees and referenced "GCL/Drainage Geocomposite critical interface – See Appendix 2" [GCL = geosynthetic clay liner]. There is no Appendix 2 included in the Supplemental Information document from April, but the Supplemental Information document from February contains Appendix 2, where the results of interface direct shear tests were presented. A summary of the interface shear strength properties for the different soil and geosynthetic components was presented in Section VI, Attachment VI (3) Geotechnical Evaluation and Calculations under Volume 3 of the Permit Application submitted on 16 October 2023.

The choice of interface shear strength properties used in the analysis raises several questions:

a. What is the rationale for using the *peak* interface shear strength in the analysis to model a condition where a piece of equipment is operating on the slope? Why was *residual* interface shear strength (which is almost always smaller than the peak) not used? According to the results of direct shear tests presented by the applicant in Appendix 2, the *peak* shear strength is mobilized in a direct shear test at a displacement of approximately 0.5 inches. When displacement exceeds this value, the shear strength rapidly decreases to the *residual* value. It is possible for such small movements to occur while the liner is installed on the slope or when equipment operates on the 3H:1V (approximately 18 degrees or 33%) slope to place soil. It is reasonable to expect that the various interfaces on this slope will experience a small downslope movement during deployment and equipment operation. Thus, the *peak* shear strength would have already been mobilized, leaving only *residual* shear strength to resist any further movement.

The use of *residual* shear strength properties would represent a more critical condition and the applicant must demonstrate that the slopes would be considered stable under that scenario.

b. According to the information provided in Appendix 2, there are three more interfaces or materials that have shear strength properties that could likely be smaller than the one that the applicant has analyzed.
i. The *residual* shear strength of the Geocomposite/Textured Gemeombrane interface is represented by a cohesion of 115 psf and a friction angle of 10.3 degrees.
ii. The *residual* shear strength of the GCL/Textured Geomembrane interface is represented by a cohesion value of 255 psf and a friction angle of 12.7 degrees.

iii. The *residual* value of the internal shear strength of the GCL is represented by a cohesion of 193 psf and a friction angle of 2.3 degrees.

The applicant must demonstrate that these interfaces or materials do not represent a more critical condition than the one that was analyzed.

b. Slope Stability Calculations – GeoStudio output files (starting on page 61 of pdf)

Comparing the output files of GeoStudio with the interface shear strength properties, it can be found that the applicant has used peak shear strength properties in all stability analyses. Because the liner system would consist of several layers of materials (which have different shear strength properties), the shear strength of the material or interface with the lowest strength controls failure and is usually used in the analyses. In the specific case of GSL, the lower bound values of peak cohesion = 302 psf and peak internal friction angle = 24.5° were used in the stability analyses for the liner interface. The applicant also evaluated the liner interface stability using the internal shear strength of the GCL, using the peak strength properties (which are a peak cohesion = 3,100 psf and a peak friction angle = 12°).

The reviewer does not agree with the use of peak shear strength parameters for all the cases and believes it would be more appropriate to use the residual (post-peak) strength when dealing with liners on sloped surfaces. The peak shear strength of geosynthetic interfaces is mobilized at relatively small movements and only the residual strength is available for resisting further movements. The same is true for the internal strength of a GCL.

For example, according to the results of direct shear tests presented by the applicant, the peak shear strength is mobilized at a displacement of approximately 0.5 inches. When displacement exceeds this value, the shear strength rapidly decreases to the residual value. It is possible for such small movements to occur while the liner is installed on sloping surfaces or when waste material is first deposited and compacted in place immediately after the liner on a slope is constructed. For reference, the base of the subject landfill is inclined at a slope of approximately 10% in the cross-section AA' used in the stability analyses by the applicant. It is reasonable to expect that the liner on this sloping base will experience a small downslope movement during deployment and waste filling operation. Thus, the peak shear strength would have already been mobilized, leaving only residual shear strength to resist any further movement.

The two materials with the lowest shear strength values would be (a) the textured geomembrane liner versus the GCL and (b) the internal strength of the GCL. The applicant has cited the peak shear strength properties of the former as the lower bound value to be used in the analyses.

In fact, the residual shear strength of the same interface has significantly lower values and should have been used in the analyses. The residual value of cohesion is 255 psf and the friction angle is 12.7°, while the peak value of cohesion is 302 psf and the peak friction angle is 24°. The peak values were used in the analyses. Similarly, the residual value of internal shear strength of the GCL is much smaller than the peak value, which was used in the analyses.

The use of the residual values in stability analyses would significantly reduce the factor of safety. In order to meet the minimum acceptable factor of safety, the landfill configuration would have to be altered, making the slopes flatter and the heights of the landfill lower.

2. HELP Model Output (Exhibit 9 of the Supplemental Information)

The HELP model analysis was used to estimate the quantity of leachate generated in the landfill and determine whether the leachate collection and removal system would have sufficient capacity. The data in the HELP model shows that the slope of the leachate collection system was entered as 5% in the analyses. However, the bottom slopes in the slope stability analyses (cross sections AA' and BB') are at slopes of approximately 10% and the side slopes are at 3H:1V, i.e., at 33%.

The slopes used in the HELP model analyses should be consistent with the slopes shown in the cross sections. Generally, a steeper slope would result in a higher leachate flow rate, i.e., it is not conservative to use a flatter slope (such as 5%), when the actual slopes are steeper (10% or 33%).

Please let me know if you have questions about my comments and/or require further discussions.

Sincerely,

Anirban De

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