pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

May 5, 2016

Mr. Mark D. Reider, Environmental Manager
Lancaster County Solid Waste Management Authority
PO Box 4425
Lancaster, PA 17604

Re: Second Environmental Assessment Letter
Frey Farm Landfill Vertical Expansion
Permit No. 101389
Manor Township, Lancaster County

Dear Mr. Reider:

The Department of Environmental Protection (DEP) has reviewed your response to our initial environmental assessment review of your application and has the following comments:

1. The Lancaster Solid Waste Management Authority (LCSWMA) indicates that the incremental increase over time of the height of the expansion will not negatively impact the transient population. This is only partially correct. However, once the landfill reaches final grade, with the additional 50 feet, the visual impact will exist forever. LCSWMA states that the services of Kaufman Engineering, landscape architect, have been engaged to develop a landscape synthesis plan. It is stated that this plan will be submitted later. Without a visual concept plan at least, it is impossible to determine the full visual impact of the increased height of the landfill. In order for the Department to properly evaluate the final visual impact of the height of the landfill, a visual concept plan must be submitted including artist renderings of what the final landfill will look like after closure. It is understood that the final landscape synthesis plan will be submitted separately as a permit modification.

2. Please note that Frey Farm Landfill is particularly noticeable in the Long Level area of York County. This is confirmed by statements that placement of the wind turbines, right adjacent to the Frey Farm Landfill immediately calls the visual attention of everyone. Subsequently, people immediately notice the landfill as it is directly in back of the Wind Turbines. Additionally, the wind turbines are visible in other areas of Lancaster and York County thereby drawing attention to the landfill. With the artist renderings, the landfill profile will appear broader once the currently permitted elevations are reached, and elevations are increased as indicated by ARM Group with the proposed expansion.

   LCSWMA should take into account the importance of the visual aesthetics of the landfill with the increased additional attention of the landfill due to the immediately adjacent wind turbines. LCSWMA has currently a soil stockpile on top of the landfill. LCSWMA's placement and past operation of this soil stockpile did not promote positive visual aesthetics to the surrounding communities.

3. J. Dwight Yoder, Esq. indicates that ARM provided pictures in the line of sight study that appears to have used wide angle lenses, distorting the actual view of the individual locations. It is indicated that using a 55 mm lens depicts the actual view as seen by your eyes. Provide information on the type of camera lens that was used to take the pictures in the application and response to the first environmental assessment letter, and why that type of lens was chosen.

4. LCSWMA indicates that a radar-based messaging sign informing drivers of their speed will be purchased. It is our understanding that only a township can apply to PaDOT to obtain this device. Your response states "LCSWMA will make this resource available to Manor Township to promote speed enforcement along designated haul routes, particularly in areas of concern to the municipality." LCSWMA has approximately 87 miles of haul routes associated with your facility. Where will this sign be placed? In addition, for the Department to consider this an additional mitigation to the traffic harm, we must have a letter of commitment from the municipality or municipalities that an application will be submitted to PaDOT.

5. LCSWMA has indicated that a Safety Manager and designated staff will ensure proper use of designated haul routes and will monitor and enforce speed limits on the routes. It is indicated that there is only a "slight" increase of truck traffic associated with the vertical expansion. According to information provided by LCSWMA, at the maximum daily volume requested, 133 additional trucks will access the landfill. Additionally, the landfill's five haul routes comprise approximately 87.5 miles. Please explain the logistics of how the LCSWMA staff will monitor and enforce speed limits on all the haul routes. Please include your revised Transportation Plan as part of your response.

6. The Transportation Compliance Plan should explain how truck drivers are made aware of the compliance and safety considerations of the haul routes before they drive to the facility. If a truck driver would drive a truck to a LCSWMA facility and not be aware of the compliance and safety considerations of the haul route, the Transportation Compliance Plan should explain how the driver will be made aware of the compliance and safety considerations of the haul route.

7. In our November 17, 2015 environmental assessment review letter, DEP requested that a letter be sent to each school district indicating the increase in truck traffic to and from the landfill. LCSWMA has met with Penn Manor School District and received support. However, the purpose of the DEP's request for a letter was so that a record would exist showing that accurate information was provided to the school districts regarding your request. Was a letter initially sent? You also note that other school Districts will be engaged. What other school districts are involved? Proof of contact with all school Districts along the routes requested must be submitted as part of this application. In addition, the school bus stop location maps and information has not been submitted with your response. It is indicated that this information will be incorporated into the Transportation Compliance Plan. Again, the revised TCP must be submitted as part of this application.

8. **Appendix A – ARM Comprehensive Technical Response #7.a. – Pages 6 – 7:**

   a. In regards to PADEP's second opinion request, ARM elaborates on the numerous professionals employed at ARM, who are experts in the fields of geology and geotechnical engineering, and includes resumes in Attachment C of the March 7, 2016 ARM response document.

   b. PADEP Response:

      (1) PADEP's request for second opinions was not made with the intention to downplay ARM's expertise, but for a second party technical review due to the FFVE piggyback design being proposed in a geologically complex area. Please note, PADEP's geologist was aware of detailed design analyses in the Phase II documents; however, review of Phase II data will not begin until after the reviews pertaining to the Environmental Assessment (e.g. Form D) and Phase I are completed.

      (2) PADEP continues to request second party opinions from experts in the fields of geology/seismology and geotechnical engineering. Several reasons for the second opinion requests were pointed out in the November 17, 2015 PADEP Technical Review letter, during the December 9, 2015 meeting, and again below, because if the underlying/surrounding geology is not thoroughly understood and respected the vertical expansion may not withstand the test of time due to the cumulative effect of numerous atypical circumstances.

         (a) The complexly deformed/fractured/weathered Lower Paleozoic Wissahickon Formation beneath the landfill.

         (b) The closeness of the shallow groundwater and underlying unlithified rock (i.e. saprolite and weathered schist) and soil with varying amounts of clay/silt/sand/gravel in the vicinity of the proposed MSE Berm. As noted on a number of critical cross sections included on the Phase II Sheet 14 drawing (i.e. Section 25, Section 33, Section 38, Section 40, and Section 50), shallow groundwater is located in close proximity or within the MSE berm in several areas.

         (c) The magnitude 5.8 Mineral, Virginia earthquake, which occurred on August 23, 2011, not being included in the USGS 2008 Seismic-Hazard Map interpretation nor the USGS online software seismic risk/probability calculations submitted with the Permit Application (received by PADEP on April 21, 2015) and the March 7, 2016 ARM response, respectively.

(d) The need to look more closely at the seismic risk due to the FFVE being located in an area closer to the 0.10g value than what ARM was indicating in the Permit Application (0.091g). Now with the updated 2014 USGS Seismic-Hazard Map in-hand (based on an average shear wave velocity of 760 m/s in the top 30 meters), included in the December 15, 2015 email to Bill Tafuto from CG Sauls, the FFVE site is documented in an area with a seismicity coefficient >0.10g peak ground acceleration (PGA) and not less than nor equal to the 0.10g PGA contour as documented by ARM in the Permit Application and the March 7, 2016 response, respectively. The updated USGS 2014 Seismic-Hazard Map was used by PADEP to create the attached GIS maps, which indicate that the FFVE is located at a seismic coefficient >0.10g PGA (based on an average shear wave velocity of 760 m/s in the top 30 meters). Furthermore, the document titled *Expert Reports of Leis, Scharnberger, and Benson - 2016* provided additional information from several experts, noted below, related to the proposed FFVE. Review of this document indicates that the FFVE is located in an area which may require the analysis to be conducted with a PGA of approximately 0.20g, or twice that assumed in the current application, due to the need for more *"site specific"* analyses pertaining to seismicity and unlithified rock rather the use of *"generalized"* data. Review of these documents is included in subsequent comments.

- Section 1:
  Technical Review - Proposed Frey Farm Vertical Extension
  Walter M. Leis, PG (April 8, 2016)

- Section 2:
  Seismic Analysis
  Dr. Charles K. Scharnberger, PhD (2016)

- Section 3:
  Frey Farm Landfill Stability Under Seismic Loading
  Dr. Craig H. Benson, PhD, PE, NAE (April 11, 2016)

(3) Craig Benson, P.E. is recommending a PGA of .2 g for re-evaluation of the seismic analysis of the Frey Farm Landfill. Bensen references the Expert Report of Scharnberger evaluating the seismic analysis of the area of the Frey Farm Landfill. The global stability analysis should include an evaluation of saturated conditions of the landfill and underlying geology while applying the suggested .2g PGA (or value based on regional seismic data). Global stability analysis should include the MSE Berm and evaluate all represented sections of the landfill. Benson indicates the Global stability should evaluate the slope to the Susquehanna River.

(4) Additionally, the suggested .2g PGA (or value based on regional seismic data) should be applied to a sliding block analysis including saturated conditions for the landfill. The suggested .2g PGA (or value based on regional seismic data) should be applied to a veneer stability analysis of all liner and cap interfaces under saturated conditions.

9. **Appendix A – ARM Comprehensive Technical Response #7.a.2) – Page 8:**

a. ARM Response Paragraph, Last Sentence - ARM indicates that .... *"the analyses have used, to the maximum extent feasible, the most current data available in order to determine accurate and appropriate input parameters."*

b. PADEP Response:

(1) The updated USGS 2014 Seismic-Hazard Map, used by PADEP to create the attached GIS maps, indicates that the FFVE is located at a seismic coefficient >0.10g PGA (based on an average shear wave velocity of 760 m/s in the top 30 meters). As a result of this higher value and subsequent supporting documentation indicating an even higher PGA of 0.20g as suggested by Benson (2016), the FFVE design and cross-sections pertaining to the Phase II *Form 24* section of the Permit Application will need to be revised due to the original design calculations being based on the use of a lower seismic coefficient of 0.10g PGA. Additional discussion regarding PGA values is provided in subsequent comments, including the Benson (2016) and Scharnberger (2016) reports.

(2) The USGS 2014 Seismic-Hazard Map seismic coefficient contours have increased in the area of FFVE in comparison to the USGS 2008 Seismic-Hazard Map; however all of the online USGS software tools used by ARM in the March 7, 2016 response utilizes older data and does not include the magnitude 5.8 Mineral, Virginia earthquake. As a result, it is recommended that the seismic risk calculations be re-evaluated by a second party expert seismologist because the use of these USGS software tools may underestimate the risk/probability since they are based on the 2008 National Seismic-Hazard Map. (Note: more discussion in subsequent comments.)

(3) Additionally, the *Expert Reports of Leis, Scharnberger, and Benson - 2016* indicate that further *"site-specific"* study needs to be conducted in the area of the Frey Farm Landfill site. Note: additional information pertaining to these reports is included in subsequent comments.

10. **Appendix A – ARM Comprehensive Technical Response #7.a.4)b) – Page 10**

a. ARM indicates:

(1) Well FFMP016W has been pumped dry.

(2) *"This is not saturated and 'normally-consolidated' soil that would experience 'new stress' upon removal of buoyancy from the water table dropping and, thus, there is no concern related to dewatering-induced settlement."*

b. PADEP Response:

To PADEP's knowledge, Well FFMP016 has not been pumped dry. Did ARM intend to indicate Well FFMP025W (Total Depth = 39 Feet) and not Well FFMP016W (Total Depth = 150 Feet)? PADEP's concern is the affect the current/future pumping and/or nonpumping of Well FFMP016W could have on the shallow groundwater in the vicinity of the proposed MSE Berm near Soil Test Boring MSEB-12 and former Spring SP-01 (e.g. FFVE Permit Application Phase II Sheet 14, Critical Cross Section 33) and in the vicinity of Well FFMP025W (e.g. Phase II Sheet 14, Critical Cross Sections 38 and 40 and Phase II Sheet 22, Cross Section 39).

11. **Appendix A – ARM Comprehensive Technical Response #7.a.6) – Page 12**

a. ARM Response Paragraph, 2nd and 3rd Sentences – ARM indicates: *"It is unclear what purpose adding old springs that are no longer in existence would serve, as groundwater elevations at these springs would be estimated with low accuracy and, thus, not enhance any understanding of the groundwater conditions. Nonetheless, there are no additional springs/seeps that ARM and LCSWMA are aware of that haven't already been incorporated into the composite high groundwater surface."*

b. PADEP Response:

(1) PADEP requested former spring locations to be documented on the groundwater maps as they would provide additional monitoring points if flow would occasionally occur during seasonably high groundwater periods. PADEP did not intend for ARM to estimate groundwater elevations. Geology information in the original permit application (Giddings, 1985) documented two year-round flowing springs (i.e. Spring SP-01 and SP-02) which discharged to Manns Run and ultimately to the Susquehanna River. Former Spring SP-02 was located on the south side of Frey Farm Landfill in the vicinity of the Phase II Sheet 14, Critical Cross Section 50. These springs were present due to fractures, which could possibly provide a conduit for escaped leachate to flow. If a problem occurred with the landfill liners, former spring locations could provide monitoring points in addition to the perimeter groundwater monitoring wells. It is recommended that the locations of former springs be noted on the groundwater maps even though the overburden in the vicinity of these locations has been reworked.

(2) Additionally, the *Expert Reports of Leis, Scharnberger, and Benson – 2016*, in particular those by Leis (2016) and Benson (2016), indicate that seeps and/or springs are located on the west side of the Frey Farm Landfill. Note: additional information pertaining to these reports is included in subsequent comments.

12. **Appendix A – ARM Comprehensive Technical Response #7.a.7) – Pages 12 – 13:**

a. ARM Response Paragraph – ARM indicates: *"...LCSWMA's and ARM's opinions are that the geology and hydrogeologic conditions are sufficiently characterized and that additional studies are not needed. We cannot conceive of data that could be collected that would plausibly result in a change to any designed system for environmental protection in connection with the FFVE.....Moreover, this site and footprint had been previously characterized for the original solid waste permit (issued in 1989), and have been further characterized and monitored since the original permit issuance...."*

b. PADEP Response:

(1) One of PADEP's main concerns is the shallow groundwater system in the vicinity of the proposed MSE Berm as discussed under prior and subsequent comments/responses. It needs to be thoroughly evaluated in these areas so that a compromising situation, which could jeopardize the stability of the landfilled waste, does not occur in the future.

(2) Additionally, the *Expert Reports of Leis, Scharnberger, and Benson – 2016*, in particular those by Leis (2016) and Benson (2016), indicate that seeps and springs located on the west side of the Frey Farm Landfill and/or water-filled fractures have not been taken into consideration in the geologic/hydrogeologic/stability interpretations. These documents indicate a concern about weaknesses due to the toe-of-slope section of Turkey Hill being removed during the last century for the railroad. As a result, a potentially unstable situation may have been created due to the toe-of-slope removal. Additionally, the soil/colluvium creep along the flanks of Turkey Hill could jeopardize the stability of the landfill. More information pertaining to these reports is included in subsequent comments.

13. **Appendix A – ARM Comprehensive Technical Response #7.a.8) – Page 13:**

a. ARM Response:

ARM indicates that no additional cross-sections are needed in the vicinity of shallow groundwater and the tallest section of the proposed FFVE MSE Berm because the depth to groundwater has been modeled and accounted for in the MSE Berm design documentation included in Phase II, *Form 24*. Additionally, the groundwater is shown on geologic cross-sections included in the Phase II drawings, *Sheets 20-23* and additional documentation is included under Comment 7.a.4)b)2.

b. PADEP Response:

PADEP reviewed the cross-sections in the Phase II drawings, *Sheets 20-23 – MSE Berm Cross Sections 1, 2, 3 and 4* and under *Form 24*; however they do not provide detailed information as the Phase I drawings, *Sheets 11A and 11B – Hydrologic Cross Sections With Flow Nets - Cross-Sections A-A', B-B', C-C', D-D', and E-E'.* As a result, PADEP continues to request an additional hydrologic cross-section with flow net that includes the proposed vertical expansion, the area in the vicinity of FFMP001P (i.e. close to where Spring SP-01 was located), the proposed underdrain, and Soil Test Boring MSEB-12 which revealed groundwater at 10.5 feet below ground surface. Additionally, please include on the Phase II drawings, *Sheets 14, 17, 18, and 19:* the Section Lines for Cross-Sections A-A', B-B', C-C', D-D', and E-E' (documented on the Phase I drawing, *Sheet 10 – Composite Historic High Groundwater Contour Map*) and the locations of Spring SP-01, former Spring SP-02, the groundwater monitoring wells, and the seeps/springs documented by Leis (2016) in subsequent comments.

14. **Appendix A – ARM Comprehensive Technical Response #7.b. and #7.b.1 – Form D, Section A – Geologic – Pages 13 – 16:**

a. ARM Response indicated:

(1) PGA of 0.091g – Permit Application dated January 2015 - ARM used the USGS 2008 Seismic-Hazard Map and USGS online software tools for the value.

(2) PGA of ~0.10g – Environmental Assessment Response dated March 7, 2016: ARM indicates that the 2014 USGS Seismic-Hazard Map design coefficient for the FF Landfill site is similar to the one used in the original analyses (0.10g) and as a result, no additional analyses were completed.

(3) No additional analyses were completed because the 2014 USGS Seismic-Hazard Map is appropriate as noted below:

(a) The map is based on a 2% probability in 50 years which is equivalent to 10% probability in 250 years.

(b) The shear wave velocity (V_s^{30}) of 760 m/s was used by the USGS for the 2014 Seismic-Hazard Map contours, which is similar to the data gathered during the geophysical subsurface investigations for the Frey Farm Landfill Wind Energy Project in 2010.

(c) The Last Paragraph in ARM's response to this section indicated that "*...the Frey Farm Landfill is located on a line separating the 0.08g to 0.10g, and the 0.10g to 0.12g ranges. Therefore, using this map (which is recognized as the most up-to-date version of the Seismic Hazard Map produced by the USGS) there is a 2% probability that*

the FFLF will experience a PGA of 0.10g within the next 50 years, which is equal to a 10% probability of exceedance in 250 years (see USGS technical explanation in Attachment F). Note that this map assumes a V_s^{30} of 760 m/s for all locations, so it can be used as an accurate representation of the seismic hazard for the Frey Farm Landfill and no adjustment to the PGA is required. Therefore, since all of the analyses submitted as part of the FFVE Permit Application utilized a PGA of 0.10g, no further iterations of the analyses are required."

(4) Hard rock assumption used by USGS is based on International Building Code (IBC) and used to relate the subsurface materials in the upper 100 feet at a site to an average shear wave velocity (V_s^{30} m/s). ARM indicates that "*Assigning the proper V_s^{30} is important, since this parameter is used when calculating the seismic hazard for a location. The 'A' site class will return a lower PGA than the value determined for a 'B' site class.*" The following IBC Site Class Definitions *(Table 1613.5.2, Page 350)* was included in ARM's response:

Site Class	*Soil Profile Name*	*Average Property in top 100 feet Soil Shear Wave Velocity, V_s^{30} (m/s)*
A	*Hard Rock*	*$V_s^{30} > 1524$*
B	*Rock*	*$762 < V_s^{30} \leq 1524$*
C	*Very dense soil & soft rock*	*$366 < V_s^{30} \leq 762$*
D	*Stiff soil profile*	*$183 < V_s^{30} \leq 366$*
E	*Soft soil profile*	*$V_s^{30} < 183$*

(5) The March 7, 2016 response included calculations via the USGS Interactive Deaggregation online software used to help determine the design PGA that utilizes representative subsurface conditions at the site. The PGA results calculated by this software using a V_s^{30} of 760 m/s indicate that the peak horizontal ground acceleration for the FFVE is ≥0.09113g.

b. PADEP Response:

(1) On Page D(M)[1]-8 of the Permit Application, ARM documented that "*Seismic mapping indicates that the project site is subject to a possible seismic loading that has a peak ground acceleration (PGA) in the range of 0.08 to 0.10g with a 2% in 50-year probability of exceedance (refer to Attachment D(M)-3, Section B – Geology). As such, a seismic impact analysis, as defined by Federal Subtitle D regulations, is <u>not</u> required because expected PGAs are less than 0.10g.....there is a <u>less than 2% probability</u> that, over a <u>50-year period</u>, the PGA at the FFVE would exceed a magnitude that would cause damage to ordinary building structures ...Seismic conditions were evaluated as part of the mechanically stabilized earthen (MSE) berm stability analysis, utilizing a PGA of 0.10g. Internal*

stability and global stability of the six critical sections of the MSE berm were verified to have slope stability factors of safety of at least 1.0 for a PGA of 0.10g."

Additionally, on Page 6(1)-11 – Form 6 Narrative, Section 3.4.3 Seismic Risk Assessment, Third Paragraph of the Permit Application, it was noted that the average PGA was determined for the area in the vicinity of the FFVE and included on maps in Attachment 6-2. Please note that the Permit Application Attachment 6-2 PGA maps were based on V_s^{30} values for "Class A" lithified rocks ≥ 1524 m/s and not for *"site-specific"* lower shear wave velocities.

(2) During the December 9, 2015 meeting, PADEP pointed out that the 0.10g contour on the PGA map in *Attachment D(M)-3, Section B – Geology* was too close to the proposed FFVE site for ARM to indicate that it was located at a PGA value <0.10g and that a seismic impact study would not be required. Now with the 2014 USGS Seismic-Hazard Map in-hand (based on an average shear wave velocity of 760 m/s in the top 30 meters) and included as on overlay on the attached PADEP GIS maps, the <0.10g PGA value for the proposed FFVE area is no longer the case because the proposed FFVE is situated at a location >0.10g (i.e. within the 0.10g to 0.12g contours on the 2014 USGS Seismic-Hazard Map or even higher as suggested by Benson, 2016) and not on the 0.10g contour as documented by ARM in the March 7, 2016 response. As a result, a seismic impact study will be required. A 0.10g PGA seismic coefficient was used for the FFVE MSE Berm design, which is less than the >0.10g value documented for the FFVE location on the 2014 USGS Seismic-Hazard Map and as suggested by Benson (2016). As a result, the FFVE MSE design and cross-sections included in the Phase II *Form 24* section of the Permit Application will need to be revised due to the original MSE berm design calculations being based on the use of a 0.10g PGA seismic coefficient and not >0.10g. Additional discussion regarding PGA values is provided in subsequent comments, including the Benson (2016) and Scharnberger (2016) reports. As noted on PADEP *Form D*, Item A1, if the proposed facility is located within an area with a 10% or greater probability that a maximum horizontal acceleration will exceed 0.10g in 250 years *"....the applicant shall specify design measures necessary to withstand potential seismic events, and the Department will determine whether the proposed design measures provide adequate protection from earthquake damage."*

(3) The USGS Interactive Deaggregation plots (Attachment J of the March 7, 2016 response) created by ARM via the USGS online software is based on seismic data collected prior to the 2011 Mineral, Virginia earthquake.

(4) Please provide the V_s^{30} (e.g. 760 m/s) documentation from the 2010 Frey Farm Landfill Wind Energy Project Report pertaining to the geophysical subsurface investigation performed by ARM.

(5) Have actual V_s^{30} values been obtained for any of the underlying areas in the vicinity of the proposed FFVE MSE Berm, in order to verify similar 760 m/s shear wave velocity values used for the 2014 USGS seismic hazard map and the USGS online seismic software tool printouts included in the March 7, 2016 response?

(6) USEPA requirements per Code of Federal Regulations (CFR) 40 pertaining to Seismic Impact Zones are inserted below and can also be viewed at the following link:
http://www.ecfr.gov/cgi-bin/text-idx?SID=e1a813c99a7f9731327ad945ac9938ec&mc=true&node=se40.25.258_114&rgn=div8

40 CFR §258.14:

(a) New MSWLF units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the Director of an approved State/Tribe that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For the purposes of this section:

(1) Seismic impact zone means an area with a ten percent or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

(2) Maximum horizontal acceleration in lithified earth material means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

(3) Lithified earth material means all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by crystallization of magma or by induration of loose sediments. This term does not include man-made materials,

such as fill, concrete, and asphalt, or unconsolidated earth materials, soil, or regolith lying at or near the earth surface.

[56 FR 51016, Oct. 9, 1991; 57 FR 28627, June 26, 1992]

(7) USEPA document # EPA/600/R-95j051, April 1995, RCRA SUBTITLE D (258) SEISMIC DESIGN GUIDANCE FOR MUNICIPAL SOLID WASTE LANDFILL FACILITIES can be viewed at the following link.

http://nepis.epa.gov (Enter Simple Search Code: 600R95051)

As noted on Page 27 and 28:
Section 3.2 Interpretation of Peak Bedrock Accelerations, Paragraph 1: "The attenuation relationships used to establish the USGS seismic probability maps are based on ground motions recorded at bedrock sites. Bedrock is commonly defined in engineering practice as material having a shear wave velocity greater than 2,500 feet per second (750 meters per second). This is referred to as lithified earth within Subtitle D. Lithified earth is defined in Subtitle D as all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by induration of loose sediments. Lithified earth does not include man-made materials such as fill, concrete and asphalt, or unconsolidated earth materials, soil, or regolith (saprolites) lying at or near the ground surface. It is important to realize that the accelerations presented on the USGS maps are not the peak ground surface acceleration, unless bedrock is exposed at the ground surface. Section 4.1 of this guidance document reviews methods for calculating the peak ground surface acceleration based on the site specific subgrade profile that exists above the top of lithified earth (rock) and the peak bedrock acceleration from the USGS map."

(8) Attachment J of the March 7, 2016 response included the USGS documentation titled: *"Earthquake Hazards 101: The Basics"* and can be viewed at the following link:
http://earthquake.usgs.gov/hazards/about/basics.php#who

As noted under Step 5, Section - What data are used to make hazard maps? - Item 3. Geologic Site Condition:

"Earthquake ground motion waves travel rapidly in the earth's crust and mantle. That part of the earth's solid crust closest to the surface is called bed rock. The size of the ground motion experienced at the earth's surface is affected by the geology of the material between bed rock and the surface. Because the earthquake waves move more slowly in this material than in rock, the size of the ground motion increases.

This material, often called alluvium or "the soil column," increases the ground motion in such a way that "softer" soils, soils with less density, have lower seismic velocity, and hence experience larger increases in ground motion. It is necessary to know the geologic site condition in order to estimate the surface ground motion.

Maps are usually made for a common widespread site condition, and then rules are given for the user to adjust to other site conditions."

(9) As a result of bedrock not outcropping at the ground surface in the vicinity of the proposed MSE berm, but instead fill/clay/silt/sand/gravel/colluvium/ saprolite and weathered schist; a more *"site-specific"* evaluation per USGS and USEPA documentation inserted above accounting for local site conditions needs to be considered where lower V_s^{30} values may be required for the design calculations instead of the value used (i.e.760 m/s). Saprolite has been documented as deep as 80 and 90 feet below ground surface at former well locations FF-22 and FF-20, respectively.

(10) A seismic impact analysis, as defined by Federal Subtitle D regulations will be required because expected PGAs are >0.10g in the vicinity of the proposed FFVE and as a result, Form 24 will need to be revised.

(11) Reports provided by Scharnberger (2016) and Benson (2016), based on seismicity and/or landfill design, indicate that a more detailed *"site-specific"* seismic study needs to be conducted in the area of the Frey Farm Landfill. Note: additional information pertaining to these reports is included in subsequent comments.

15. **Appendix A – ARM Comprehensive Technical Response #7.b.2) – Pages 16 – 19:**

a. ARM Response documented:

(1) Paragraph 1, 3rd Sentence:

"Using the most current earthquake probability mapping online software provided by the USGS (http://geohazards.usgs.gov/eqprob/2009/index.php), there is a 6 to 8% probability that there will be an earthquake with a magnitude of 5.0 or greater within 50 miles of the site in the next 250 years; a map generated by the software for this scenario is included in Attachment I of this submission."

(2) Paragraph 1, Last Sentence:
"While ARM understands that this mapping software does not account for the Mineral, Virginia 2011 earthquake, or any earthquake data recorded after 2006, it is the only software currently available that will calculate probability for a certain earthquake magnitude."

(3) Paragraph 2, Last Sentence:
"As discussed herein, the maps and software provided by the USGS have been established as the most current source of information to be used for engineering design."

4) Paragraph 4, Last Sentence:
"....the analyses provided in the FFVE Permit Application are in accordance with the most up-to-date seismic hazard map, and do not require revision."

b. PADEP Response:

(1) ARM stands behind the 0.10g PGA value used for the FFVE MSE Berm design calculations in the Permit Application even though the 2014 USGS Seismic-Hazard Map indicates the FFVE site location to be situated in an area where the seismic coefficient is >0.10g PGA (based on an average shear wave velocity of 760 m/s in the top 30 meters), as noted on the attached PADEP GIS maps. Additionally, Benson (2016) suggests, the *"site specific"* PGA for the FFVE area is even higher *"due to amplification in the soils and waste between the bedrock and surface of the landfill."* As a result, PADEP continues to recommend that a second party expert seismologist provide a second opinion as to whether or not the 0.10g seismic coefficient utilized in the stability analyses is a sufficient value for the proposed FFVE and MSE Berm design.

(2) The earthquake map included in Attachment I of the March 7, 2016 submission is based on a magnitude 5.0 earthquake or greater within 50 kilometers, not 50 miles, which would be equivalent to 31 miles.

(3) The USGS earthquake probability tool website http://geohazards.usgs.gov/eqprob/2009 includes the following statements:

(a) *"This feature does not include potentially induced seismicity or any earthquake after the year 2006. A probability calculated for a location that is currently experiencing induced earthquakes will not be valid. This tool will underestimate the probability because it is based on the 2008 National Seismic Hazard Maps."*

(b) *"Although this information is a product of the USGS, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge."*

(4) Reports provided by Scharnberger (2016) and Benson (2016), based on seismicity and landfill design, indicate that a more detailed *"site-specific"* seismic study needs to be conducted in the area of the Frey Farm Landfill site. Note: additional information pertaining to these reports is included in subsequent comments.

16. **Additional information regarding Seismicity and Stability:**

a. **December 17, 2015 email from Bill Tafuto to CG Sauls** indicated that:

"...the seismic coefficient utilized in the stability analyses submitted with the Permit Application was 0.10g and the estimated PGA for the FFLF based on the 2014 GIS data is 0.101g. Therefore, the slope stability analyses are accurate relative to the most recent information provided by the USGS. Coefficients used in slope stability seismic analyses do not go beyond two decimal points, as such a portrayed accuracy would be misleading, which is why we use 0.10g. Additionally, solely out of curiosity, and not because such an analysis would be required, one of ARM's project engineers re-ran slope stability analyses for the MSE Berm cross section that had the lowest factor of safety (when using the 0.10g PGA), but instead of the actual 0.10g PGA, he used a seismic coefficient of 0.14g. This supplementary analyses returned a factor of safety of 1.13, which is still higher than the minimum acceptable factor of safety under seismic conditions. Therefore, even using a seismic coefficient 40% in excess of the actual design value would not create an unstable condition or unacceptable factor of safety for the proposed FFVE MSE Berm."

b. ***2016 - Expert Reports of Leis, Scharnberger, and Benson***
Section 1: Technical Review – Proposed Frey Farm Landfill Vertical Expansion
dated April 2016 by Walter M. Leis, PG summarized key points he presented during the July 28, 2015 public meeting and provided more backup information further supporting the need for additional study of the area as follows:

(1) *Soil and Rock Creep Analysis*: The following recommendations/comments were included:

(a) the need for additional borings to determine the rock fabric and colluvium, especially on the western slope of the Frey Farm Landfill Site, due to *"the potential for induced debris flow along this portion of the site."*

(b) *"geotechnical and soil physics evidence must be developed to determine the long term stability of the site with respect to the human intervention that has taken place to date and is further planned."* Several examples noted in the report that could promote structural failure due to past/present human activities include: *"addition of water seepage by design of diversion channels, loading of the top surface of the slope resulting in uniaxial compressive*

loading, and by bottom-of-slope removal such as had been done by the Pennsylvania Railroad."

(c) A concern/need for discussion pertaining to creep/downslope movement as a result of the historic *"toe-of-slope removal"* and *"top loading due to the FFVE."* He points out that these unaddressed concerns *"could be a causative element for increased creep and more rapid slope failure (known in geotechnical parlance as a 'trigger')."*

(d) Photos indicating rock gravity slide and soil creep on the flanks of Turkey Hill were included in the report (i.e. rotated trees, seeps, seepage channels at approximately 1 gpm, and colluvium/rock slides) in addition to labeled LIDAR maps showing these areas of concern.

e) *"Continued erosion of the site will certainly occur over several centuries. For this reason, a high degree of knowledge about this downslope movement of colluvium is necessary to consider overall safety, topographic structure, and whether this site can safely accommodate the proposed FFVE at all or whether additional design elements are needed to protect against the possibility of any catastrophic failure. This study should have been undertaken as part of the site planning process and not considered a mere 'design issue'."*

(2) <u>*Soil Water*</u> – LIDAR maps and photos showing the soil/colluvium/fractured bedrock and seasonal high water table (i.e. seeps, springs) in addition to the following recommendations/comments were included:

(a) The need for *"additional soil and hydrogeological analyses to determine the potential for significant ground water discharge along the western slope of the Frey Farm Landfill Site."*

(b) Several springs/seeps identified in earlier literature (i.e. 1913 photo posted along the Enola Low Grade Line and Giddings - 1985 initial Phase I report) were identified by Leis during a field reconnaissance on March 3, 2016.

(c) The Leis (2016) report mentions, *"Giddings (1985) and REWAI (1988) identified seasonal high water tables that would possibly intersect a liner base."*

(d) *"A non-transient stream appears just south of the parking area at the Enola Low Grade Trail."*

(3) Regional Ground Water – the following recommendations/comments were included:

The Giddings (1985) geostatistical model regional water table map and the 2005 ARM Creswell Landfill reuse plan groundwater map *"have produced what we believe are reasonably accurate map depictions of the water table surface."* In contrast, the Leis report indicates that *"ARM's* (Phase I) *Sheet 14, entitled 'The Ground and Surface Water Monitoring Plan' ARM presents an interpretation of the regional piezometric surface map (shown in Appendix D of this report). The incomplete interpretation of the regional water table as depicted in this map is due to a lack of sufficient monitoring points which result in an anomalous conclusion regarding the regional ground water flow....without a more accurate analysis of the ground water flow system, the monitoring network is unable to provide the necessary data to assure that the Susquehanna River remains unaffected by contaminants or landfill leachate."*

(4) Geophysical Analyses of the Frey Farm Landfill Site – *"a more detailed analysis based upon expected ground motion based upon these historical seismic events"* was recommended and included via the Scharnberger (2016) and Benson (2016) reports summarized in more detail below.

(5) The Leis (2016) report indicates that *"the following further assessment activities will be undertaken during the spring and early summer:*

(a) *Measurement of seep and stream discharges on the western boundary of the landfill site;*

(b) *Collection of mineralogical and rock fabric data in these same areas.*

- *Creep and colluvium movement assessments should be carried out in the field to determine long term stability of the hillside and the entire landfill site.*
- *Borings with oriented cores should be made to determine the continuity and makeup of regolith and weathered zones (reported in logs from other consultants).*
- *Structural geologic mapping should be conducted to assess secondary rock fabric, zones of weakness and lineaments that can control movement and ground water flow.*
- *Ground water characterization studies have not been done with a focus to assist in creating a design that is protective of the environment, specifically the Susquehanna River. Piezometric surfaces and flow nets need to be developed that can be incorporated into the design.*

- *Quantitative flow nets or pumping tests were avoided to assess horizontal and vertical ground water flow components.*
- *Springs, seeps and other surface discharge points need to be developed and incorporated into the design.*
- *Gravity effects for the closed facility (as designed) could result in a wide range of site problems that could affect the Susquehanna Basin. We question whether this design is neutral and beneficial and not harmful to the environment and public health within its operating life, then followed by an extremely long post closure period."*

c. ***2016 - Expert Reports of Leis, Scharnberger, and Benson***
***Section 2: Seismic Hazard Report* dated April 2016 by Charles K. Scharnberger, PhD** indicated that:

(1) The ARM seismic hazard assessment for the Frey Farm Landfill site *"significantly understates the level of seismic hazard."*

(2) An earthquake with a magnitude of 7, such as the 1886 Charleston, SC and the 1929 Grand Banks of Canada earthquakes, is conceivable for the Lancaster Seismic Zone (LSZ) area.

(3) Scharnberger's report included the following *"site-specific"* hazard analysis based on the Gutenberg-Richter equation. He noted that for the LSZ, in which the Frey Farm Landfill site is located, the Gutenberg-Richter equation is Log N = 2.8 – 0.65M (where M = magnitude). Scharnberger used a magnitude 6.0 (just above the magnitude 5.8 earthquake in Mineral VA in 2011) for the probability calculations below.

Probabilities that a Magnitude 6.0 or Greater Earthquake Will Occur in the LSZ

Years	*Probability (rounded to nearest whole %)*
50	*0.08 (8%)*
250	*0.33 (33%)*
500	*0.55 (55%)*
1000	*0.80 (80%)*

(4) Scharnberger indicated that his calculations differ from the standard seismic hazard maps because the USGS assesses earthquake hazards for the entire United States and do not include every seismically active zone such as the LSZ. As a result, he mentioned the USGS results are not as detailed due to smoothing/generalizing of the data (i.e. constructed via *"paint with a very broad brush");* and as a result suggested that *"A site-specific hazard analysis, such as the one presented here, should take precedence of the highly generalized standard hazard maps."*

(5) Scharnberger also conducted *"site-specific"* calculations for four epicenter clusters located within the LSZ and in close proximity of the Frey Farm Landfill site as noted in the table below. The following equation by Atkinson and Boore (1995) was used by Scharnberger to calculate the PGA values noted in the table. Scharnberger indicated that the calculated PGA values were based on a magnitude 6.0 earthquake and solid rock. On the other hand, he mentioned that a magnitude 5.0 and NEHRP Class B/C, which would be expected to amplify the ground acceleration, was used by ARM in the March 7, 2016 response. He also noted that *"the landfill structure itself is akin to a thick soil layer, which would be expected to amplify the shaking even more."* As documented below, all the PGA values were >10% g (i.e. >0.10g) for any distance, 10 to 50 km, away from the Frey Farm Landfill site.

$$\text{Log PGA} = 3.79 + 0.298\,(M - 6) - 0.0536\,(M-6)^2 - \text{Log R} - 0.00135\,R$$

Where: M = magnitude
R = distance from the earthquake origin to the site of interest

LSZ Epicenters (1972 – 2016)	*Distance* (R)	*Log PGA*	*PGA (cm/sec²)*	*PGA*
Marticville	*10 km*	*2.78*	*602*	*61% g*
Landisville	*18 km*	*2.51*	*324*	*33% g*
Dillsburg	*45 km*	*2.08*	*120*	*12% g*
Wyomissing	*50 km*	*2.02*	*105*	*11% g*

(6) Scharnberger indicated that based on his calculations, *"no matter where in the LSZ a magnitude 6.0 earthquake might occur, it would produce a PGA of at least 10% g in bedrock. And the probability of that earthquake occurring in 250 years is 33%, one chance in three."*

(7) Scharnberger states, *"it is my considered professional opinion that the level of seismic hazard at the Frey Farm site is unacceptably high for a vertically expanded landfill. The probability of an earthquake of sufficiently large magnitude to produce a PGA of at least 0.10 (10%) g at the site occurring within 50 km. of the site within 250 years is more than 0.33, far greater than the probability of 0.06 to 0.08 shown on the map in Attachment 1* (of the March 7, 2016 ARM response) *for an earthquake of only magnitude 5.0. (The Gutenberg-Richter law gives the probability of a magnitude 5.0 earthquake in 250 years within 50 km. of the site to be 83%.) It seems that the data on which the USGS map was based did not take into consideration the Lancaster Seismic Zone."*

d. ***2016 - Expert Reports of Leis, Scharnberger, and Benson***
Section 3: Frey Farm Landfill Stability Under Seismic Loading **dated April 11, 2016 by Craig H. Benson, PhD, PE, NAE** indicated that:

(1) USGS maps are based on regional interpretations using *"empirical methods"* which may lack resolution/accuracy in local areas; and as a result Benson suggested *"site-specific"* analysis to provide a more accurate peak bedrock acceleration (PBA), similar to the one provided by Scharnberger (2016).

(2) *"Landfills in seismic impact zones must be designed to withstand the peak ground acceleration (PGA) associated with the PBA. Based on Scharnberger's site-specific analysis, the landfill should be designed to withstand the peak ground acceleration (PGA) associated with a PBA = 0.1g. Due to amplification in the soils and waste between the bedrock and surface of the landfill (Kramer 1996), the PGA used for design and analysis is likely to be larger than the PBA, and larger than the PGA employed in the current analysis of the proposed Frey Farm expansion (PGA = 0.1g, ARM 2014)."*

(3) Benson included Figure 1 in his document which illustrates a soft soil/bedrock curve showing the *"Relationship between PGA and PBA as reported in USEPA guidance described in Richardson et al. (1995) with annotations added."* Based on this curve, Benson indicates *"the analysis should be conducted with a PGA of approximately 0.2g, or twice that assumed in the current application."* Benson also suggests *"more detailed analyses"* for determining the *"site-specific"* PGA and evaluating *"geosynthetic interfaces"* using *"residual shear strengths (Stark and Poeppel 1994).....commensurate with residual interface strengths reported in literature (e.g., Stark et al. 1996)."*

(4) *"Global stability analysis also needs to be conducted to evaluate stability under appropriate seismic loading."* Benson suggested these analyses account for:

a) *"...impacts of the weathered and fractured bedrock beneath the landfill and the significance of seismic loading on pore water pressures in the tight-filled fractures in the rock."*A picture of a water-filled fracture was included in the report (Figure 2).

b) *"...the loss of restraint at the toe as a result of rock removed to construct railway lines along the river during the last century (see cut toe in Fig. 3)."*

c) *"Impacts of seismically induced compression of soils beneath the landfill should also be evaluated."*

(5) *"...additional analysis needs to be conducted to evaluate physical stability of the Frey Farm Landfill with the proposed vertical expansion.....and should incorporate site-specific characteristics of seismic loading and consider stability within the landfill as well as stability of the foundation."*

e. PADEP Response:

(1) PADEP recommends that LCSWMA *err on the side of caution* with more certainty and less risk for the proposed FFVE due to numerous uncertainties related to seismicity and stability as follows:

(a) The 2014 USGS Seismic-Hazard Map indicating that the FFVE site is documented in an area with a seismicity coefficient >0.10g PGA and not less than nor equal to the 0.10g PGA contour as documented by ARM in the Permit Application and the March 7, 2016 response, respectively. As a result of expected PGAs >0.10g in the vicinity of the proposed FFVE, a seismic impact analysis as defined by Federal Subtitle D regulations will be required and Form 24 will need to be revised.

(b) The USGS Internet statements noted above documenting not to rely only on the USGS modeling tools, but also on *"technical subject-matter knowledge."*

(c) The *"site-specific"* hazard analysis conducted by Scharnberger (2016) indicating that *"the level of seismic hazard at the Frey Farm site is unacceptably high for a vertically expanded landfill. The probability of an earthquake of sufficiently large magnitude to produce a PGA of at least 0.10 (10%) g at the site occurring within 50 km. of the site within 250 years is more than 0.33, far greater than the probability of 0.06 to 0.08 shown on the map in Attachment I* (of the March 7, 2016 ARM response) *for an earthquake of only magnitude 5.0."*

(d) The recommendation by Benson (2016) for a more *"site-specific"* analysis, similar to the one conducted by Scharnberger (2016), which estimated PGAs >0.10g. He suggests "more detailed analyses" for calculating the FFVE PGA that reflect the amplification that will occur at the site. Based on the soft soil curve (Richardson et al. 1995), Benson recommends that the FFVE seismic analysis be conducted with a *"PGA of approximately 0.2g, or twice that assumed in the current application."* As previously noted, saprolite has been documented as deep as 80 and 90 feet below ground surface at former well locations FF-22 and FF-20, respectively.

(e) The need to further study the existing seeps/springs on the west side of the landfill as documented by Leis (2016) and Benson (2016) and incorporate them into the Phase I drawings, *Sheet 10 – Composite Historic High Groundwater Contour Map* and *Sheet 14 – Groundwater and Surface Water Monitoring Plan.* These springs could be used as groundwater monitoring points even if they do not flow year-round.

(f) The need for additional hydrogeological study due to unknowns that could affect the stability of the vertical expansion such as: springs/seeps/fractures on western flank of Turkey Hill; vertical/horizontal groundwater flow directions; and documentation by Giddings and REWAI in 1985 and 1988, respectively, identifying seasonal high water tables that would possibly intersect a liner base.

g) The need to further study the soil/colluvium creep and gravity slide issues due to stability concerns, especially on the west side of the landfill as documented by Leis (2016).

(h) The original landfill, structure beneath the proposed FFVE, not being based on a seismic impact area.

(i) The need to consider stability within the landfill as well as stability of the foundation in the design/planning.

(j) The Frey Farm Landfill being located immediately adjacent to the Susquehanna River which ultimately drains to the Chesapeake Bay.

(2) PADEP requests ARM to re-run the slope stability analyses for all of the MSE Berm cross sections, using a seismic coefficient of 0.2g as documented by Benson (2016), instead of 0.10g PGA which was used in the Permit Application calculations/design.

17. **Appendix A – ARM Comprehensive Technical Response #8.a. – Pages 19 – 21:**

a. ARM Response documented:

(1) Surface Water Quality and Sediment/Stormwater Runoff:

(a) The confusion in Stream W and Stream **F** was a mislabeling issue only in the text and did not affect the calculations.

(b) The harm of increased runoff/sedimentation to perennial streams will be prevented via E&S controls per PADEP Chapter 102 regulations such as: terraces, diversion interceptor channels and sedimentation basins.

(c) The impermeable FFVE landfill liner system and cap will protect the underlying groundwater.

(d) The FFVE groundwater and surface water monitoring program *"will ensure the prompt detection of any changes in water quality proximal to the waste disposal area."*

(2) Base Flow:

(a) ARM indicates "*the pre-project stream flow conditions will be maintained in both streams* (Stream **F** and Manns Run) *using discharge from the proposed stormwater basins.*"

b) The additional 9 acres of impermeable cap and liner for the FFVE will not adversely impact the quantity of stream baseflow due to:

- The total drainage areas for *Stream* **F** and Manns Run are approximately 90 acres and 595 acres, respectively.
- The FFVE *area* is only 1.5% of the Manns Run drainage area.
- The liner *will* be placed incrementally over the life of the FFVE.
- As the *new* FFVE liner is installed, other areas brought to intermediate or final cover grade will provide sustenance to both waterways.

b. PADEP Response:

(1) ARM does not indicate in the March 7, 2016 response if the additional 9 acres of impermeable cap and liner for the FFVE includes the additional capped/lined area for the MSE Berm if ash is used. How many additional acres will be affected if an impermeable cap and liner are required for an ash-filled MSE Berm?

(2) If Stream W is not affected by the FFVE, please indicate this in the response. If it will be affected by the FFVE (i.e. landfill and/or ash-filled MSE Berm), please also include this acreage in the response.

(3) If at any time, during the construction or life of the FFVE, the perennial streams (i.e. Manns Run or Stream **F**) indicate impact to baseflow via visual inspection or the annual benthic macroinvertebrate assessments, LCSWMA will be required to address immediately.

18. **Appendix A – ARM Comprehensive Technical Response #8.b. – Page 21**:

In regards to PADEP's request for a copy of the final Clean Water Act Section 404 State Programmatic General Permit (SPGP) pertaining to the Chapter 105 permit requirements and waiver letter, ARM documents on Page 16 of the March 7, 2016 response letter that *"LCSWMA will complete the 'PASPGP-4 Permit Compliance Self-Certification Form' upon completion of the work."*

Please note that the expert reports of Leis, Scharnberger, and Benson, as well as the aesthetic impact information provided by Dwight Yoder, Esq. were previously provided to you. Some of the Department's comments are based upon the review of the information in these reports. You may comment on these reports if you desire.

If you believe that any of the stated deficiencies is not significant, instead of submitting a response to that deficiency, you have the option of asking DEP to make a decision based on the information with regard to the subject matter of that deficiency that you have already made available. If you choose this option with regard to any deficiency, you should explain and justify how your current submission satisfies that deficiency. Please keep in mind that if you fail to respond, your application may be denied.

Should you have any questions regarding the identified deficiencies, please contact us to discuss your concerns or to schedule a meeting.

Sincerely,

John L. Oren

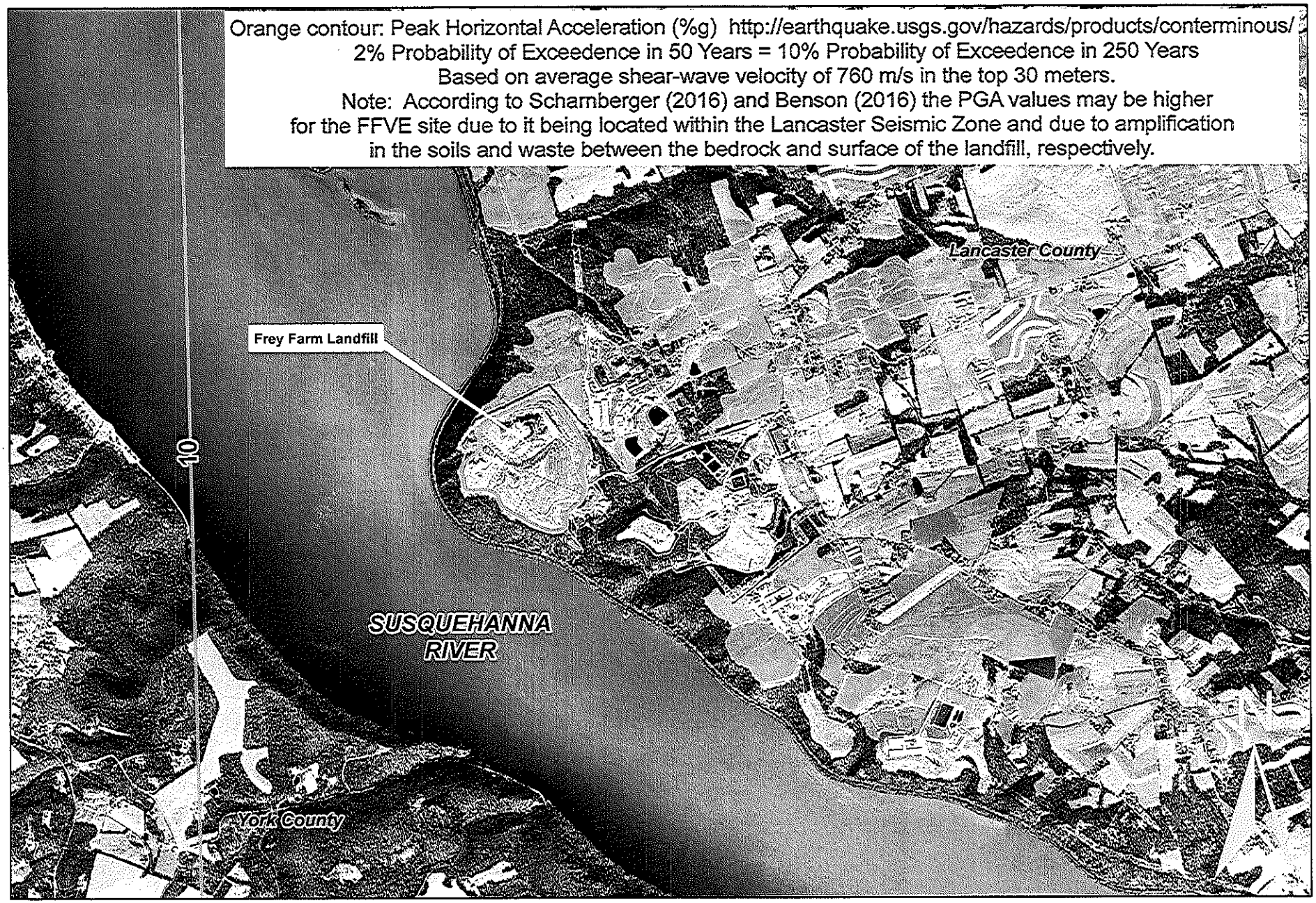
John Oren, P.E.
Permiting Section Chief
Waste Management Program

Enclosures

cc: Manor Township
Lancaster County Planning Commission
William Tafuto, P.E., ARM Group

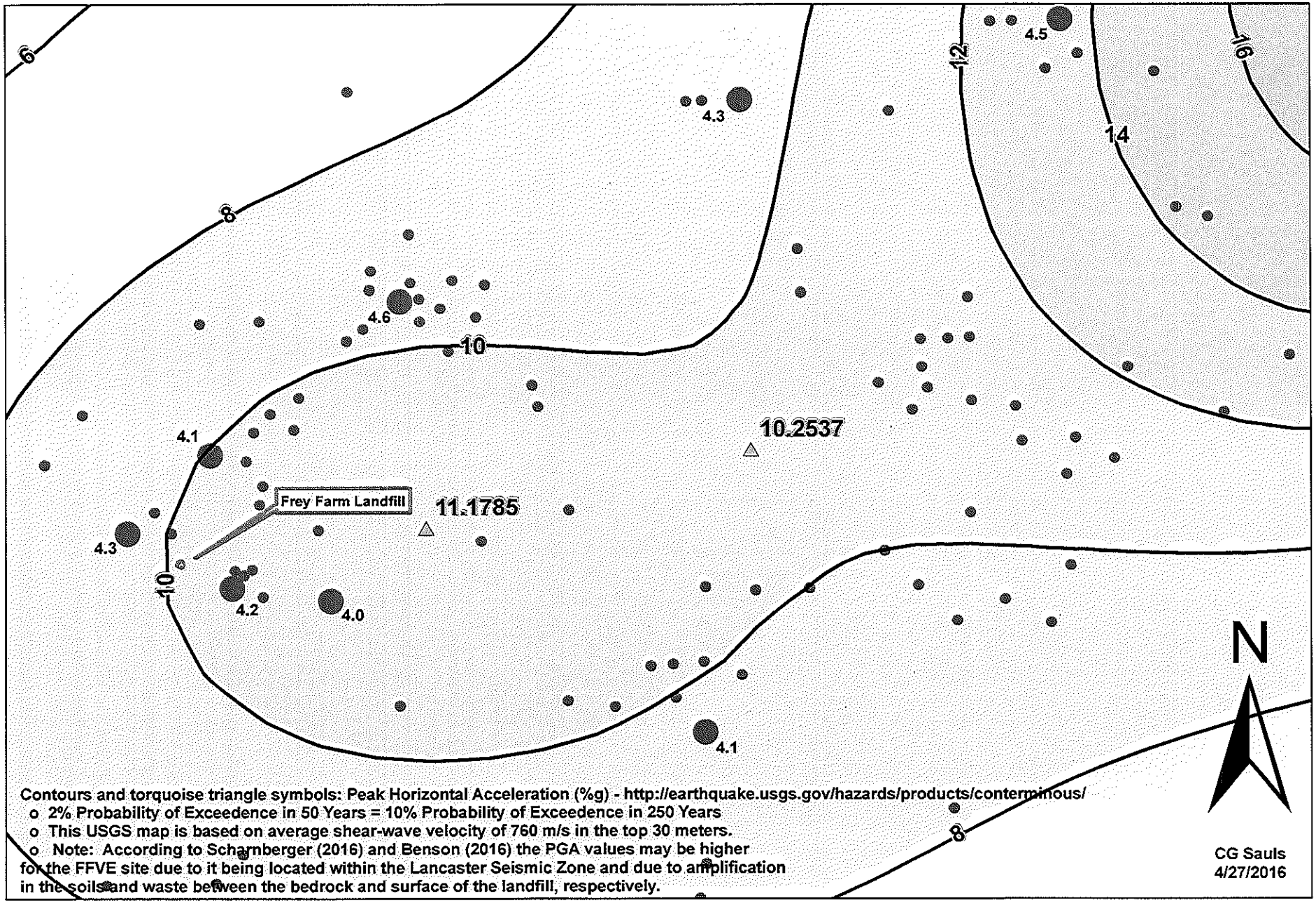
bcc: John Oren, PE
Ed Rawski, PE
Don Korzeniewski
Charlene Sauls, PG
Mark Embeck
Randy Weiss
Kip Portman
Beth Shuman
Tony Rathfon

LCSWMA - Frey Farm Landfill
USGS Seismic-Hazard Map Contours for the Conterminous United States, 2014



CG Sauls
4/28/2016

LCSWMA - Frey Farm Landfill
USGS Seismic-Hazard Map Contours for the Conterminous United States, 2014



Contours and torquoise triangle symbols: Peak Horizontal Acceleration (%g) - http://earthquake.usgs.gov/hazards/products/conterminous/
- 2% Probability of Exceedence in 50 Years = 10% Probability of Exceedence in 250 Years
- This USGS map is based on average shear-wave velocity of 760 m/s in the top 30 meters.
- Note: According to Scharnberger (2016) and Benson (2016) the PGA values may be higher for the FFVE site due to it being located within the Lancaster Seismic Zone and due to amplification in the soils and waste between the bedrock and surface of the landfill, respectively.

CG Sauls
4/27/2016

Red circles: Earthquake Magnitudes from 1724 to 2003, Rodger T. Faill, 2004
Larger circles indicate higher magnitudes.

0 5 10 20 30 40 Miles