

APPENDIX L

PEER REVIEW COMMENT AND RESOLUTION DOCUMENT

Peer Review – PA TENORM Study Report

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 1 Organization: Date: 1/7/15							
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
1	NA	Overall, I believe the study is very comprehensive and demonstrates that while there are areas of TENORM from the gas and oil industry, it does not present a significant radiological concern.		X			Noted.
2	NA	In the Study Implementation section, it states that gamma radiation exposure rates and gross gamma radioactivity surveys were performed at each facility using a Bicron Micro-Rem Meter or a Ludlum Model 19 Micro-R Meter, recorded in units of micro-Roentgen per hour (µR/hr). However, except for the Distribution and End Use sites, the exposure rates are based on measurements taken with a 2x2 NaI meter and a conversion factor of 800 cpm/µRh, based on Ra-226. While this will give an approximation of the exposure rate, it is not as accurate as measurements with a micro-rem meter since there are likely other radionuclides contributing to the gamma exposure.		X			The gross gamma radiation measurements performed over facility areas are included in Appendix E. The extensive scan data collected with 2x2 NaI detectors were presented in the text as a general approximation of exposure rate over these larger areas.

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3	NA	The reference to the conversion factor from cpm to µRh for the exposure rate measurements described above should read “Table 6.4” from NUREG-1507.		X			Reference changed to Table 6.4. The value of 800 was selected as a one significant figure estimate of the cpm per µR/h conversion for Ra-226 and progeny.
4	Section 9	Under the Recommendations for Future Actions section, it recommends that additional radiological sampling and analyses, radiological surveys, and additional study be performed for all the sites evaluated in this study. The Synopsis section only recommends further study of radiological environmental impacts from the use of brine for dust suppression and road stabilization. Based on the finding of this study, I question whether further sampling and study is warranted at any of the sites, from a cost-benefit perspective.				X	Section 9.0 includes facility type specific observations and recommendations. Additional actions are not recommended for all facility types.

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Reviewer: Number 2		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
1	3-16, Table3-2, Line 5 of data	Maximum value of .3 is clearly incorrect given a minimum of 7.44 and s.d. of 19.2		X			Data transposition error was corrected.
2(a)	4-2, para's 4.1.1.3 and 4.1.1.4	See detailed comment below table.				X	The text of Section 4.1.1.4 points out the difference between the maximum average and maximum values exposure rate values for all POTW-I's and references the tables where the values are further summarized as you state. The Section 4.1.6.1 external gamma exposure is a very conservative calculation based on the highest average value at any POTW-I and an exposure period of 2,000 hours/y. This assumes the worker is essentially outdoors within the site boundary the entire work year with 2 weeks off-site. The variables of exposure time and location by worker and task are

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							unreasonable and inaccurate to model beyond the simple conservative estimation presented. The only accurate study method is whole body dose monitoring of individuals to corroborate the actual exposure to workers.
2(b)	4-19 both tables	See detailed comment below table				X	See response to 2(a).
2(c)	4-26	See detailed comment below table				X	See response to 2(a).
2(d)	9-3, 9.1.2.1 2 nd bullet item	See detailed comment below table				X	See response to 2(a).
3	9-3, 9.1.2.1 last line	Apparent math error in calculation of ave. dose equivalent rate. 36.3 microR/hr times 2000 hrs should be 72.6 mrem/yr, not 62.6.				X	The exposure modeled is for dose above background. The maximum gamma radiation exposure rate is reduced in the calculation by the local background value of 5 µR/h. The conservative estimate is correct as calculated.

Review of *Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)* Study Report as requested by the Pennsylvania Department of Environmental Protection (PA DEP)

Overview of review

This review primarily consisted of a review of the observations in chapter 9.0 to determine if they were reasonable and if they were supported by the data presented in the earlier chapters. Detailed reviews of the other chapters were not possible due to lack of time, and lack of knowledge on my part.

Sections 2.0 (Study Implementation) and 8.0 (Quality Assurance and Quality Control) both appear to be adequate for this study based on my somewhat limited experience with environmental sampling.

Comments on Observations from Chapter 9.0:

9.1.1 Well Sites: Observations and the conclusions based on these observations all seem reasonable and justified.

9.1.2 Wastewater Treatment Plants

9.1.2.1 POTWs I have a concern with the second bullet item in this section. Besides the simple math error in the section, I believe that the conclusion may not be justified. The original concern that I had was based on the data presented in the two tables on page 4-19, which are referenced from sections 4.1.1.3, and 4.1.1.4 earlier in the report. In particular I noticed that the data for site 15 (and to a lesser extent site 17) had maximums far exceeding the other sites and a standard deviation that was larger than the average value. This site also had unusually high values on Table 4-13 (page 4-26).

When I received access to Appendix E, I reviewed the gamma scan maps for site 15, which clearly showed what I expected. Namely the distribution of elevated levels was not randomly distributed but was highly stratified, with the elevated readings primarily in the south west corner of the site. (Note that page numbers were not available in Appendix E but this comment is based on the image designated as WT-15-FS-031, WT-15-FS-032, and WT-FS-033 Gamma Scan)

The conclusion presented in the last paragraph of the 2nd bullet item in 9.1.2.1 on page 9-3 concludes that there is little potential for exceeding public dose limits from external gamma radiation based on the highest average which was for site 15. However this average is biased by the large number of samples taken outside the southwest corner of the site. A stratified survey of the site with average levels for each of the strata would be a better approach in my opinion and I suspect would show levels that might result in doses exceeding public dose limits for workers.

Given the low number of POTW-I's that are in the study, I am concerned that one of the sites has a relatively elevated concentration of radioactivity and believe that this needs to be studied to determine if the elevated readings could be associated to drilling in the area. I am not sure that a simple conclusion can be made from this study regarding public dose limits for POTW-I's, but I don't believe that the conclusion that there is little potential for exceeding limits is justified, particularly for workers

at the plants. This is especially going to be true if drilling is related to the observed readings at this site since levels may continue to climb with continued growth in the drilling industry.

9.1.2.2 and 9.1.2.3 Observations and the conclusions based on these observations all seem reasonable and justified. I looked up detailed definitions for CWT and ZLD facilities in order to better understand my concern with POTWs and believe that the relative number of these facilities in the State could also factor in the significance of the comments that I have made. It would be interesting to include in the report the total number of POTW, CWT, and ZLD facilities in the State and how many are impacted by drilling in order to better understand the completeness of coverage of the study.

9.1.3, 9.1.4, and 9.1.5 Observations and the conclusions based on these observations all seem reasonable and justified.

9.2 Recommendations for future Actions

I strongly endorse the 2nd bullet item in section 9.2.2 (conduct additional surveys at all WWTPs) especially if there is not a simple explanation for the elevated readings observed at site 15. The other recommendations also seem reasonable and justified based on the data presented in the report.

Other minor editorial comments are provided on the comment sheet.

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Reviewer: Number 3 Organization: Date:12/18/2014							
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
1	N/A	The document is generally well-done and I believe covers the most notable areas related to naturally occurring radioactivity and radiation associated with current oil and gas generation activities in Pennsylvania. I have no major issues or areas of disagreement with the report. I have not attempted to make any minor editorial comments. What few comments I have are included below.		X			Noted.
2	N/A	The document would benefit greatly from a strong and inclusive summary that presents the major findings of the study.		X			Synopsis added as Section 0.
3	N/A	Because Pennsylvania is one of the significant players in the area of fracking and new gas generation, and because the environmental issues surrounding this topic are and will likely continue to be controversial, I believe it would be appropriate to issue this report in draft form to a number of involved and interested groups, agencies and individuals in an attempt to gain some useful feedback.				X	The peer review process was undertaken to have a group of subject matter experts review and comment upon the report prior to release. This report is a discrete representation of the efforts associated with this study including the observations and recommendations for future actions that can be made based on the analytical results obtained.

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							Consequently, it isn't necessary to issue this as a draft for comment. This report is viewed as an initial major effort in the collection of information necessary to effectively manage TENORM from O&G operations. Any future regulatory actions that would result from any data or recommendations associated with this study will include an opportunity for public participation and comment.
4	N/A	I did not receive copies of any of the appendices and therefore have no comments regarding them.					Noted.
5	2.1.2.3/2-4/18	How were the samples preserved – acid addition or other means?	Oops – I see you refer to this in 3.6.2.	X			See Section 2.2.2, page 2-6, line 24.
6	2.2.1.3/2-6/2	When you say digested do you mean that the solid sample was completely dissolved, or was the digestion followed by filtration prior to coprecipitation with iron? Has the digestion process been demonstrated to be effective at removing all of the radionuclides of concern?			X		The solid sample was completely dissolved. The DEP BOL participates and successfully passes Proficiency Testing (PT) samples in mixed media which includes soil samples, purchased from an

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							accredited PT provider Environmental Resources Associates (ERA). The soil matrix is digested and completely dissolved prior to analysis. The solid samples for this study were prepared in the same manner as soil PT samples.
7	2.2.2/2-6/24-25	Does the nitric acid addition affect solubility of any suspended solids?	3.6.2 again	X			Addressed in Section 3.6.2.
8	2.2.2.2/2-7/12	Have you determined that the conversion to oxides via flaming the planchet did not volatilize significant Po-210, which might be a significant alpha emitter in Ra-226 containing samples.			X		No, the BOL has not determined how much if any Po-210 was volatilized during the conversion to oxides via flaming the planchet. Most of these samples contained very high levels of solids and were hygroscopic in nature. The sample matrix contributed significantly to the self-absorption of alpha and beta particles prior to reaching the detector. It was necessary to flame the planchet at high temperatures to convert nitrates to oxides even

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							though it is known, according to EPA research, that it is possible to lose some radionuclides such as polonium, lead, and cesium at high temperatures.
9	2.2.3/2-7/36	The statement is that a Ludlum Model 2200 Scaler-Ratemeter was sometimes used for counting scintillation cells. I assume this required use of a photomultiplier tube in conjunction with the scintillation cell and ratemeter. Perhaps this should be noted.		X			Section 2.2.3 line 34 was revised as "...collected at various locations using scintillation cells with photomultiplier tubes and..."
10	3.1.3/3-2/25-27	It would be helpful to convert the cited count rates to exposure rates, since the count rates alone are not instructive. I realize Table 3-3 has a footnote stating the conversion factor, but results in the text should be explanatory without the reader having to do the conversion.		X			Section 3.1.3 lines 26 and 27 have been revised as "...14,519 cpm (approximately 18 µR/h), and the maximum gamma radiation scan result measured was 30,823 cpm (approximately 39 µR/h).
11	Fig. 3-1/3-4/3-4	Do you have an explanation for why Ra-226 is so much higher than U-238 for WP-12-SL-052 compared to other samples?		X			The high Ra-226 activity was confirmed with a second analysis of the same sample. The high total U result using XRF was also confirmed with a second analysis of the same sample. We do not have an explanation for the

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							activity difference between the two isotopes.
12	3.2.2/3-5/9-11	In the usual application the null hypothesis is the hypothesis that presupposes that no statistically meaningful difference exists between the quantities being tested. Rejection of the null hypothesis normally implies acceptance of the alternative hypothesis. The hypothesis specified in the text is usually defined as the alternative hypothesis,				X	The test is still valid as used and stated.
13	Fig. 3-4/3-6	The WP-06-SL-037 point appears to show a greater Ra-U difference than is typical for most of the points. Any comment necessary?			X		For this sample, the Th-232 and U-238 activities are higher than the Ra-226 and Ra-228 activities. This is also the only sample collected in the Utica formation in a wet gas region. The difference may be impacted by the type of shale formation.
14	3.3.2/3-7/41-42	The levels are given in pCi/L with a wide range. I think a brief comment as to significance is appropriate – e.g., values compared to any reference values.					The Table 2-2 criteria for volumetric liquids were referenced in Section 3.3.2.
15	3.3.3/3-8/7-8 and 3.3.4/3-8/15-16	Same comment as 14.					The Table 2-2 criteria for volumetric liquids were referenced in Section 3.3.2.

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16	3.4.2/3-8/40-41	Again, a comment on significance of the radon levels would be appropriate.				X	The Rn in the samples described in Section 3.4.2 is from production gas that does not have either regulated criteria or project reference data for concentration comparison.
17	3.5.1/3-11/8	It is not clear what is meant by the “limiting local background gamma---”. Considering the Table 3-4 values, I don’t know how the 5 microR/hr “limiting” applies.		X			“Limiting” was removed from the sentence, since the value is for local background.
18	Table 3-1	It would be helpful to have a marker after the title refer the reader to the table up footnote so that the reason is specified for the same min and max values in many cases.		X			The title has been footnoted to direct the reader to the note at the end of Table 3-1.
19	Table 3-2	1) It would be helpful to have some indication in the title or elsewhere as to the media being assessed. 2) Putting a footnote marker in the Minimum, Maximum, and Standard Deviation columns would again be useful to the reader.			X		1) The title specifies surface and the specific location of the smear samples is located on site maps. There is no good way to specify the location in the table. A footnote has been added to generally describe the types of surfaces where samples were collected. 2) The title has been footnoted to direct the

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							reader to the note at the end of Table 3-2.
20	Table 3-3	Again, a specification of the type(s) of media being assessed would be helpful.		X			A footnote has been added to generally describe the types of surfaces where samples were collected.
21	Table 3-5	A footnote to explain the reason(s) for the “#N/A” entries as well as the significance of the “<” values in the table might be helpful. Also, the explanation of the use of ½ the MDC as the reported minimum would be appropriate. Similar comments apply to the subsequent tables.		X			All N/A values have been removed. Footnote explanations of the < values and 1/2 the MDC as reported minimum have been added.
22	Table 3-13	The “<565” and “<298” pCi/L values seem high if they represent the MDCs. Some explanation seems appropriate. A similar comment applies to some of the gross alpha values in Table 3-15 and Table 3-16.			X		The two Frac Phase liquid samples in question have elevated NORM activities. The Ra-226, Bi-214, and Pb-214 all have high activities. After reviewing the spectrum, the K-40 peak is present but has a high MDC because the overall background of the sample is also elevated. The gross alpha values for the Frac Phase liquids are elevated because a small aliquot of sample was analyzed in order to keep

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							the self-absorption factor low.
23	Table 3-18	Is there a reason why the median radon concentration is given at the bottom of the table, but no average value and standard deviation are given?		X			The average and standard deviation have been added.

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Reviewer: Number 4 Organization: Date:1/5/2015							
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
1	xiv	Under Condensate, define PSIA.		X			Change made as “pounds per square inch, absolute.”
2	xiv	Need better definition of flowback fluid. Second sentence, . . . fluid used to fracture the target formation, including any naturally occurring fluids contained within the rock (connate or interstitial fluids).				X	Pa DEP Code Definitions.
3	xv	Add word leachate and define it		X			Leachate added to the Glossary as “A solution resulting from water that has percolated through solid (e.g., waste in a landfill) and potentially leached out some of the soluble constituents.”
4	xvi	Define Proppant Sand by mentioning the sirf, i.e. 100 mesh (0.149 millimeters)				X	We did not find “sirf” as an acronym or term associated with proppant sand particle diameter, etc. The only mention of particle diameter (if the mesh size has to do with that) is that proppant sand of different particle size is selected for job specific requirements.
5	xvi	Servicing Fluids – “work over” should be hyphenated . . . “work-over”		X			Change has been made.

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6	xvi	Define Smear Sample: I imagine a round paper being forced to fit into a 10x10 cm square. Dumb I know, but that's the mental image.		X			Revised definition is: “A sample of removable alpha and beta surface radioactivity collected by pressing a 47-mm diameter filter paper over 100 cm ² of surface area to obtain an assumed fraction of removable material. The filter paper is counted for alpha and beta radioactivity without any preparation.”
7	xvi	Define Spent – maybe lubricants collected after use?		X			Revision made as “Oil and gas drilling and/or plug drilling lubricants that have exceeded their useful life.”
8	xvi	TENORM – last two lines should read: . . . or potential for human exposure have been increased BY HUMAN ACTIVITIES above levels concentrated . . . reads better.				X	Pa DEP Definition.
9	xvi	Add Sqular Equilitrium to definitions.		X			Definition for secular equilibrium has been added as: “A type of radioactive equilibrium in which the half-life of the precursor (parent) radioisotope is so much longer than that of the product (daughter) that the radioactivity of the daughter

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							becomes equal to that of the parent with time.”
10	Section 1.1, page 1-1	Line 12 & 13. Move “by human activities” to same place as shown in Comment No. 8 above.				X	See response to comment #8.
11	Section 1.2, page 1-3, line 2	Should “u” be “uranium (u)?”				X	No.
12	Section 1.3, page 1-4	Should the #'s beneath the symbols be defined? U-238 - half life? 4.5x10y		X			Year, day, hour, minute, and second have been defined in a footnote to Figures 1- 3 and 1-4.
13	Section 1.4, page 1-5, line 12	The 1 st use of the work “media” should be defined sooner. It does happen in end of line 14, but that is too late.			X		The 2 nd and 3 rd sentence in Section 1.4 have been revised as: “The product streams evaluated are natural gas and natural gas liquids, i.e., condensates. Other media evaluated includes solid...”, to connect the first and subsequent uses of “media”.
14	Section 1.4.1.2	Defines “drilling muds” as a liquid. Section 2.2.1, page 2-5 defines “drilling mud” as a solid. Need to reflect (early) that could be solid or liquid as a function of % solids % fluid.				X	Drilling muds are liquids by convention on well sites. Methods section includes explanation of when muds were analyzed as solids by gamma spec.

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15	Section 1.4.1.3, page 1-6, line 22	Many facilities are . . . Define facilities or reword. Tools, equipment, structures ? ? ?		X			First sentence rewritten as: “Many facilities, structures, and systems are utilized during...”
16	Section 2.1, page 2-1, line 5	Define “environmental media”		X			The term “environmental media” has been replaced with “solid and liquid waste, soils, ambient air, and gaseous emission products associated with O&G operations” to match the description in Section 1.4.
17	Section 2.1, page 2-1, line 9	Define “degree.” Do you mean the abundance?		X			Sentence revised to replace “degree” with “abundance.”
18	Section 2.1.2.1, page 2-3, line 24	“The media sampled during this study included.” Get rid of the work “following.” Poor grammar & redundant.		X			Change made as requested.
19	Section 2.1.2.2, page 2-4, line 5	Solids Sample Methods. Next line says “solid samples.” Should line 5 read, “sampling of solids methods” or “methods to sample solids?”			X		Section 2.1.2.2 title changed to “Solid Sample Methods” to match title for Section 2.1.2.3.

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20	Section 2.1.2.3, page 204, line 17	“ . . . they were preserved.” Define preserved. Lots of methods to preserve stuff. Preserve for its chemical characteristics or physical characteristics?		X			Sample preservation is the measure or measures taken to prevent reduction or loss of target analytes. Analyte loss can occur between sample collection and laboratory analysis because of physical, chemical, and biological processes that result in chemical precipitation, adsorption, oxidation, reduction, ion exchange, degassing, or degradation. Preservation stabilizes analyte concentrations for a limited period of time.
21	Section 2.1.2.4, page 2-4, lines 37 & 38	Rewrite. May be correct in lab jargon but sounds odd. Example – the natural gas was passed continuously through the cells for 10 minutes, thus purging the gas liners and the . . .				X	Standard method.
22	Section 2.2.1, page 2-5, line 5	If definition of drilling muds was changed to include both sand & liquid, this line now OK.					See response to comment #14.

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23	Section 2.2.1.1, page 2-5, line 12	Define “marinelli” somewhere		X			The term “Marinelli” has been added to the glossary with the definition of: “A lightweight polypropylene sample container with snap-on lid used for gamma spectroscopy analysis.”
24	Page 2-12 & 2-13	Table 2-2 extends over multiple pages. Each new page should say Table 2-2 (cont.). This comment applies throughout the document for multiple page tables.		X			The table titles have been applied across pages throughout the document.
25	Section 3.1, page 3-1, line 37	First line, I have seen phrase “Removable a/ B surface.” Please define.				X	The first use of “removable” is in the glossary definition of smear sample collection revised in comment #6. The first use in the text occurs in Section 2.1.1.3.3, which also references sample collection with smears. No change made.
26	Section 3.2.2, page 3-5, line 5	Define “student t-test” somewhere. 1 st mention of a specific statistical method.		X			Student t-test definition has been added to the glossary as “A test for determining whether or not an observed sample mean differs significantly from a

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							hypothetical normal population mean.”
27	Section 4.1.1.2, page 4-2, line 5	Add “ . . . and 10,000 dpm/100 cm ² , respectively. First time the grammatic forum is used.		X			Change made as stated.
28	Section 4.2.1.3, page 4-6, line 18	Either delete “(figures)” or define which ones.		X			Sentence revised to remove “(figures)”.
29	Section 4.2.2.3, page 4-7, line 7	Define “walkover surveys”		X			The term “gross gamma radiation scan” is used starting in Section 3.1. The acronym GWS is used in Tables 3-3 and 3-4 headers and not defined in the acronyms list. The use of “Gamma radiation walkover surveys” in Section 4.2.2.3 has been replaced with “Gross gamma radiation scans.” The rest of the document has been searched for consistent use of terms. The GWS acronym used in the headers for Tables 3-3 and 3-4 has been changed to “Scan.”

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30	Section 5.3, page 5-3, line 37	Nice job of providing definition within the context of sentence!		X			Noted.

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	Appendix A	It seems to me some explanatory information is necessary. I suggest modifications as follows . . .				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
1	Page A-1, line 10	Change “geology” to “geologic”				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
	Page A-1, line 12	Insert the 3 paragraphs (or some other similar introduction) to help the reader get the gist of where this section is going.				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
		Organic-rich, fine grained bodies of sediments have become the target of hydrocarbon production in Pennsylvania, and throughout the US, as a result of improved drilling and development methods, specifically horizontal drilling and hydraulic fracturing. As the chemical conditions which surrounded the deposition and subsequent diagenesis of these deposits have encouraged the deposition and concentration of naturally occurring radioactive materials, this section briefly describes some of the known, currently producing horizons, and likely to be explored/potentially produced that may result in the generation of technically enhanced NORM's. Although the focus of the TENORM Study is the solids and fluids resulting from hydrocarbon development, horizons rich in NORM occur at the surface, in areas where sediments outcrop as a result of natural features/events such as mountains, erosion, and manmade exposures such as mines, roadcuts, or foundation excavations.					

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Reviewer: Number 5 Organization: Date:1/5/2015							
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		The descriptions which follow are arranged in order from oldest to youngest age, geologically speaking. Although the expectation is the older horizons are deeply buried, geologic events (tectonics or “mountain-building”) have caused the horizons, in places, to occur at the surface as well as thousands of feet beneath the ground.					
2	Page A-1, lines 13 – 34	Move to Page A-3, line 28. Seems this belongs under the Lockatong Formation section.				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
3	Page A-3, lines 8 – 10	Confusing? Not sure what is being said. Since Marcellus and Onondaga fluids will be in contact, they “will” be similar? Or there will be very little statistical similarity?				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
4	Page A-3, line 12 & 13	What is the point of the sentence? Is this meant to say poorly collection samples will be biased by oxidation?				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
5	Page A-3, lines 18 – 26	Need a date (?? MA) for this Burket Member				X	This appendix was prepared by an external source and we chose not to edit that individual's work.
6	Page A-3, line 20	What does “inconspicuous” mean in this context? This, hard to find, not too limey?				X	This appendix was prepared by an external source and we chose not to edit that individual's work.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 5 Organization: Date:1/5/2015							
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
7	Page A-3, lines 23 & 24	“To date, no volcanic . . .” Not sure why this is included. Has no bearing on the project UNLESS the ash beds are suspected source of NORM. If yes, more explanation is required.				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
8	Page A-3, lines 42 – 44	Why is this mentioned? Seems out of context.				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
9	Page A-3, line 27	Need an age for the Lockatong in ?MA				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
10	Page A-4, line 2	Delete “obviously”				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
11	Page A-4, line 7	“substantial hydraulic head” assumes the reader has a lot of background in fluid mechanics. Should be translated. The “suggestion” that the hot fluids passed rapidly to the surface is good.				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
12	Page A-4, lines 21 & 22	“ . . . but is unlikely to be . . .” While true, it does not belong here.				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 5 Organization: Date:1/5/2015							
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
13	Page A-5, line 12	Define “. . . was wasted.” Discarded? Not included in sample?				X	This appendix was prepared by an external source and we chose not to edit that individual’s work.
14	Appendix A	A great read! Very informative.		X			Noted.

Peer Review – PA TENORM Study Report

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
Gen-A		This survey was well-designed, well-executed, and is very informative. It met the objectives stated in the plans. It is sufficiently broad in scope to capture the potential environmental insults. The results point to areas where more investigation and action is warranted.	Certain categories of facilities should be investigated further; despite being a very large survey, there is not enough statistical rigor in many instances to make actionable decisions.	X			Noted.
Gen-B		PA has a long history with radium contamination resulting from industrial activities. The PA DEP Bureau of Radiation Protection is one of the most experienced in the nation in dealing with these issues.		X			Noted.
Gen-C		The final report would have benefited from geospatial interpretation of the data, e.g., are the more radioactive residuals coming from one part of the play vs another or the wet gas side more than the dry side or visa versa. Are they evenly dispersed across the play?	The report would benefit from the use of more graphics.	X			Noted. Report will be issued as is. The figures presenting survey data are in Appendix E.
Gen-D		Consider parsing the data by facility in addition to study area.	All pertinent information for a facility would then be in one appendix or table.	X			Noted. The individual survey maps, by facility, are in Appendix E.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
Gen-E		Due to limited availability of some of the appendices and time constraints, this reviewer did not conduct full QC checks on any of the data sets. cursory reviews indicate good QA and QC with good reporting and record keeping.		X			Noted.
Gen-F		A review of the regulations and discharge permit parameters for facilities that handle, treat, and/or dispose of liquids from both conventional drilling and unconventional may be in order.		X			Noted. This is already identified as a recommendation for future action in Section 9.0 of the report.
Gen-G		It is suggested that the report be issued as a draft.	Due to the volume of data and various ways it can be parsed, and the lack of geospatial interpretation, along with some needed resampling, it may be better to issue the report as a draft, and then issue a final report after comment resolution.			X	The peer review process was undertaken to have a group of subject matter experts review and comment upon the report prior to release. This report is a discrete representation of the efforts associated with this study including the observations and recommendations for future actions that can be made based on the analytical results obtained. Consequently, it isn't necessary to issue this as a draft for comment. This report is viewed as an initial

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
							major effort in the collection of information necessary to effectively manage TENORM from O&G operations. Any future regulatory actions that would result from any data or recommendations associated with this study will include an opportunity for public participation and comment.
Gen-H		Consideration should be given to requiring Radiation Protection Plans, using a graded approach, as permit requirements for treatment facilities. These could include training requirements to address environmental and worker hazard, as well as required environmental and occupational monitoring. Facilities that generate high-activity radium wastes may be also candidates for a radioactive materials license.		X			Noted. Already included in recommendations for future actions in Section 9.0.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
Gen-I		It should be noted (perhaps in a footnote) that 100 mrem/y is the accepted annual public dose limit for members of the public (there are other levels cited elsewhere). Note that value is considered the total dose from all activities combined (except medical procedures), so that one practice or entity should not be giving the entire 100 mrem/y dose.	This metric was agreed to in the plans, so no change requested. Most estimates are very conservative and with few exceptions will any real workers receive a dose from TENORM that will approach the public dose limit.	X			Noted. The value is listed in Table 2-2 as a basis of comparison.
1	P4, s1.1	Typo Should be “Objectives”	TOC	X			Corrected.
2	P5, S3.7	Typo Should be “Environmental”	TOC	X			Corrected.
3	P5, S4.1	Typo Should be “Publicly”	TOC It seems that “Publically” is growing in popularity, but “Publicly” is what is used in RCRA.	X			Corrected.
4	P5, S4.27	Typo Should be “Environmental”	TOC	X			Corrected.
5	P12	Typo Should be ± plus or “minus”	Acronyms	X			Corrected.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
6	P12	Typo Should be POTW “Publicly” Owned Treatment Works	Acronyms	X			Corrected.
7	Introduction, P3, line1	Please List K-40	K-40 was analyzed in some samples, and is often the highest concentration in the sample.	X			K-40 and all reported results along with standard error and MDC are presented in Appendix C.
8	Introduction, P3, line 7	The equilibrium may be, and often is disrupted by natural weathering and geochemistry, and of course radon emanation. It is understood that in formation the uranium is not mobile, but that is not the case on the surface.	If it is not too much detail for this chapter, consider rephrasing the sentence to indicate that the radioactivity of surface soils is related to the natural radioactivity of the rocks the soil evolves from, as well as depletions of some isotopes due to weathering, chemical processes and emanation. .			X	Although correct, this level of detail is too much for this report.
9	Introduction, P3, line 10	Should be “ a Rn member”		X			Corrected.
10	Introduction, P1-3, line 10	While radon in gas may be an issue in some places as demonstrated in the report, the Pb-210 and Po-210 may be just as much of a concern.	Consider “Radon and its progeny are a concern ...uses.”	X			Added “ and progeny.”

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
11	P1-5. Line 20	It appears there is no direct mention of contaminated material and equipment, such as pipe, vessels, drill bits as a waste stream. If there were no measurements or evaluation of material and equipment, that should be noted.	These may be included in the facility evaluations, but hopefully can be mentioned in the introduction.			X	The study had limited access to pipe and equipment, specifically internal surfaces. This is already addressed in recommendations for future action in Section 9.0.
12	P1-5. Line 45	It is this reviewers understanding that POTWs can only accept waters from conventional drilling.	If so, perhaps a footnote with that clarification could be considered. The reader should be aware of what the data represent. This is important since there are indications of radium contamination from conventional, insults from unconventional would be likely more severe.	X			This is already identified in Section 4.0 of the report.
13	P1-6, Line 46.	Consider adding a sentence relative to the internals of the equipment can be contaminated with radon progeny.		X			Already addressed in Section 7.0

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
14	P2-9 Line 14	Uranium can be, and is soluble in water depending on its ionic state.	Consider rewriting this sentence to reflect that the +4 ion is insoluble (predominant in the formation), but the +6 ion (redox) is mobile. Are oxidizing agents used in making slickwater?			X	Although scientifically accurate, this was not observed in study.
15	P2-13, Table 2.2	In addition to Reg Guide 1.86, ANSI N13.12 has recently been updated and provides surface activity values that are more contemporary than 1.86 and are dose-based.	Consider listing ANSI N13.12 in addition to the 1974 Reg. Guide.			X	Criteria listed are for benchmarking measurement results and not for compliance or use in assessments.
16	P2-13, Table 2.2	ANSI N13.53 lists indoor, outdoor, occupational and residential exposure limits for radon	Consider adding ANSI N13.53 to the table			X	Criteria listed are for benchmarking measurement results and not for compliance or use in assessments.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
17	P3-1 Line 41 - and the other worker scenario sections.	Areas surveyed for surface activity well represent potential exposure to most workers, and the surveys were robust. However, a review of the data sheets in Appendix D indicate that internals of pipe and equipment (e.g., in boneyards or maintenance shops) were not surveyed. It is the internals of pipe and equipment that would be most highly contaminated. Surveys show that no significant contamination was found on exposed surfaces.	Please consider strengthening the text in these paragraphs noting the purpose of the survey, and that based on the radionuclide content of the waters and gas, elevated alpha and beta activity are likely present on the internals of equipment that could pose a hazard to maintenance workers and recyclers.	X			Report already includes this as a recommendation for future action in Section 9.0.
18	P 3-10 Line 9	Consider follow up sampling and analysis to resolve the question. See discussion in Appendix A.	It appears that the acidification of the unfiltered samples presents a potential issue. Since there is activity in both the filtered and unfiltered samples, the ratio between the two should be discerned somehow. Perhaps glass containers and no acidification until in the lab, if needed. Add	X			Noted. The report already addresses this in the text and in Appendix I.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
			this to the logistical challenges of sampling for Ra-224.				
19	Tables	If possible, measurement uncertainty should be reported, along with the MDC. Not reporting uncertainty makes some of the data less informative.	Would require landscape format. Can make a reference to the lab data in the Appendices for those parameters. For example, in many cases the gross alpha results are far below the Ra-226 results, which is unusual. Knowing the range of uncertainty on these measurements would be informative.			X	The standard errors (uncertainty) and the MDC values are already reported in Appendix C tables. This is noted in the report text.
20	Table 3-19	Without uncertainty being reported, it is difficult to fully appreciate these data.	See above			X	The standard errors (uncertainty) and the MDC values are already reported in Appendix C tables. This is noted in the report text.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
21	Page 4-2, Line 29	Were any other gamma emitters sampled? POTWs will often have man-made radioactivity in their influent from hospitals, etc.	I-131 can build up over time in POTWs and contribute to gamma exposure rates in the filter cake. Also exempt products such as smoke detectors can contribute to leachate concentrations. See the 2005 ISCORS reports.	X			An excellent point. Gamma spec reports for this study did not include anything but NORM radionuclides.
22	P 4-7 Line 33	Appendix I was not available for review.		X			Noted.
23	P 4-21 Table 4-6	Typo. Change “35,4” to “35.4”		X			Corrected.
24	Page 4-22 Table 4.8 – 4.15	The MDCs for Ra-226 on many samples are quite high.	Perhaps would have benefited from longer counting times? When combined with the acidification question, these data for filtered samples may be uncertain, and are suggested for further study.	X			Noted. High MDCs are usually associated with high solid content in the liquid samples and is already discussed in the report.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
25	Page 4-27 Tables 4-14 and 4-15	The radium results for influent at this non-impacted site seem high. If valid, historical industrial activities (e.g., mining) in the area should be evaluated to help determine why the influent is high.	The Ra-226 to gross alpha ratios for the filtered samples are seemingly incongruent. The unfiltered samples have too high a MDC to make a comparison.	X			Noted.
26	P 5-3 Sec. 5.3	This section is very informative.	Was ingrowth considered when evaluating the truck drivers or plant workers, or was that just based on Ra-226? Some facilities will accumulate these residuals for some period of time prior to disposal.	X			Noted. Worker assessments were based on measured exposure rates. The truck driver assessment assumed Ra-226 in equilibrium with progeny, i.e., conservative if ingrowth has not been achieved.
27	P 5-5. Figure 5-2	Figure is missing.				X	Figure 5-2, the sludge sample analytical results over time, is included.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
28	P 6-4 Line 1	Were there direct measurements made for alpha inside the housing or on the filter? Sampling the filter is representative of what remains in the stream of the gas, but may not represent what has plated out already on the internal surfaces.	The text only indicates that samples were collected and smears of the filter taken. Po-210 is an obvious concern...	X			Access to internal housing or pipes was not available during the study. Additional surveys/samples when access is available is already a recommended future action in Section 9.0.
29	Ch 7 Line 4	These applications are from conventional wells. Elsewhere in the report it is stated: "...The Ra-226 activity in unconventional well site produced water is approximately 20 times greater than that observed in conventional well site produced water." Therefore, this evaluation may not be representative of unauthorized discharges from unconventional well sites, nor should it be used as justification for using fluids from unconventional wells on roads.	Some of the background locations are elevated. There is no mention of what the NORM content of the gravel used in the roads may be.	X			Noted. Unconventional brine application is prohibited in Pennsylvania.
30	Page 8-11 Table 8-2 – Table 8.5	These data show the difficulty in getting representative data when sampling and analyzing field samples, particularly at low activity. While some of the isotopic data compare well, others fare less well. It is not clear why the samples are mixed well enough for some isotopes, but not others.	Samples blended in the field just won't be as well mixed compared to drying, mixing and splitting in the lab. Much better chance of more homogeneous splits, though never perfect.	X			Noted. Blending liquid samples in not problematic but splitting solid samples is. The split sample results reflect this. Solid samples have been sent out for analysis in duplicate by the QC laboratory. However, the results are not currently available.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
31	P 9-10 Line 11	Please note that maintenance workers at midstream facilities can also be exposed to Pb-210 and Po-210 when working on internals of pipe and equipment.	Progeny tend to plate out on surfaces where there is turbulence in the flow. That would include pumps, elbows, pig launchers/catchers, etc., in addition to the compressor stations themselves.	X			Noted. Section 7.0 already presents data and a recommendation for future action was made in Section 9.0.
32	P 9-10 Line 44	Other maintenance workers, such as workers in shop buildings are also at risk. Please expand the sentence to include all workers who could potentially be exposed.		X			Agree. The use of “worker” is generic, representing all workers including maintenance workers.
33	P 9-11 Line 28	Unfortunately, there are problems with these surveys and they should not be considered conclusive or representative.	See comment above and in conclusions section.	X			Noted.
34	P 9-12 Line 27	Agree All of these should be pursued, but with clarification: Drill cuttings may take on the characteristics of the formation, and since fluids are recycled, the potential for cuttings to be contaminated is not trivial. Only cuttings that are below authorized limits should be candidates for release and reuse.	In addition to adding the isotopes to the analyte list, radiation survey equipment should be available within reasonable time frames to conduct routine surveys as part of spill response. Operators should be trained on the use of these instruments.	X			Analysis for man-made radionuclides such as tracers used in O&G industry added as well as use of field survey instrumentation for areas impacted by spill.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
35	P 9-12 Line 34	Agree. All of these should be pursued.	Consideration should be given to requiring Radiation Protection Plans, using a graded approach, as permit requirements for certain treatment facilities. These could include training requirements to address environmental and worker hazard, as well as required environmental and occupational monitoring. Facilities that generate high-activity radium wastes may be candidates for a radioactive materials license.	X			Noted. Section 9.2.2 addresses.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
36	P 9-13 Line 1	Agree. All of these should be pursued.	May also need to consider gw monitoring at some landfills. Basic training requirements and record keeping should be part of D&O plans or CD. Sampling suite should also include common isotopes from industry and medical institutions that can contribute to gross alpha and beta. Baseline samples recommended where possible before acceptance of residuals as there may well already be radioactivity in the leachate from other sources.	X			Noted. Recommendations for future action is included in Section 9.0.
37	P 9-13 Line 14	Agree. There is no analysis or accounting of Po-210. This could significantly underestimate risks to workers where there is Pb-210 contamination.	This impacts the potential dose to some workers. Consider a statement about Po-210.	X			Noted. Recommendation is already made in Section 9.0.

COMMENTS BY REVIEWER				RESOLUTION			
Reviewer: Number 6		Date:					
Comment No.	Section / Page / Line No.	Comment	Other Details	Accepted	Accepted, but modified as follows	Rejected	Reason for modification/rejection
38		It is the opinion of this reviewer that the alpha and beta contamination potential (and hazard) on well sites and compressor stations, gas plants, et al., is underestimated because there was no access to equipment internals. Also, Po-210 does not appear to be considered, and that is an internal hazard.	Maintenance workers, on and off site (e.g., at repair shops) could be exposed to significant contamination based on years of experience in the industry.	X			Noted. Section 6.0 already discusses Po-210 and other alpha/beta emitting progeny of Rn and Section 9.0 recommends surveys of internal surfaces when accessible.
39	P 9-13 Line 21	Agree, as discussed elsewhere in the comments: Since these applications are from conventional wells. Elsewhere in the report it is stated: "...The Ra-226 activity in unconventional well site produced water is approximately 20 times greater than that observed in conventional well site produced water." Therefore, this evaluation may not be representative of unauthorized discharges from unconventional well sites, nor should it be used as justification for using fluids from unconventional wells on roads.	Some of the background locations are elevated. There is no mention of what the NORM content of the gravel used in the roads may be. Further study recommended. More sophisticated detectors (e.g., large area gas proportional or plastic scintillators, or much larger NaI crystals) will likely be required for analysis of these roads. Spectroscopy should also be used to strip out K-40, which will interfere with the measurements.	X			Noted. Only brine from conventional O&G production is permitted for application. Section 7.0 includes discussion of the high probability that reference background roads were also treated with brine, voiding true background measurements.